T. 28 N., RS. 9 AND 10 E.; T. 29 N., R. 10 E.

By C. F. Bowen.

STRATIGRAPHY.

EXPOSED ROCKS.

THICKNESS AND GENERAL CHARACTER.

The rocks exposed in T. 28 N., Rs. 9 and 10 E., and T. 29 N., R. 10 E. (see fig. 1), are illustrated graphically in figure 11. They have an aggregate thickness of about 650 feet and are of upper Pennsylvanian age. Above the Elgin sandstone there are numerous beds of limestone and some of sandstone interstratified with shale. Below the Elgin sandstone the rocks exposed consist mainly of sandstone and shale with only a few beds of limestone. In T. 28 N., R. 9 E., that part of the section above the base of the Wynona sandstone is exposed. In the other two townships the Elgin sandstone is the highest exposed formation. A detailed discussion of the stratigraphy and the grouping of formations will be given in the final report on the Pawhuska quadrangle. The present discussion is confined to the principal key beds used in mapping.

KEY BEDS.

The key beds of most value in working out the structure in this area are, in ascending order, the lower *Fusulina*-bearing limestone, the Labadie limestone, the middle bed of the Oread limestone, and the Lecompton, Plummer, Deer Creek, *Cryptozoon*-bearing, and upper *Fusulina*-bearing limestone members of the Pawhuska limestone. The outcrops of the lower *Fusulina*-bearing limestone, the Labadie limestone, the middle bed of the Oread limestone, and the Deer Creek limestone are shown on the map (Pl. VIII).

Other beds that may be used locally in studying the structure are a bed of ledge-making sandstone about the middle of the Elgin sandstone, the Wynona sandstone, and the two thin limestones below it, several sandstones between the Wynona sandstone and the Labadie limestone, and the top part of the sandstone between the Labadie limestone and the lower *Fusulina*-bearing limestone.

Lower Fusulina-bearing limestone.—The lower *Fusulina*-bearing limestone is a thin-bedded limestone 2 to 4 feet thick, containing an

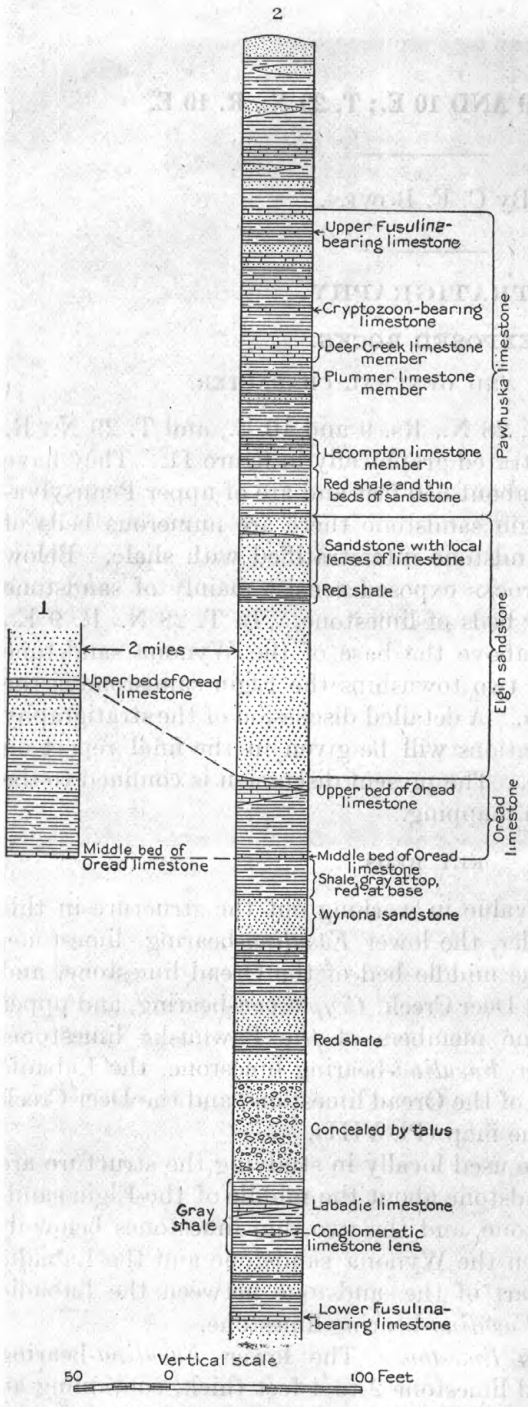


FIGURE 11.—Columnar sections of rocks exposed in T. 28 N., Rs. 9 and 10 E., and T. 29 N., R. 10 E. (See p. 45.)

abundance of long slender Fusulinas, which in places constitute most of the rock. In many places its weathered surface has a slightly reddish tinge that is apparently due to infiltration from the red shale immediately above it. Locally it becomes more or less sandy or grades into calcareous sandstone. In most places it rests directly on a thick bed of sandstone, whose outcrop is marked by a line of trees. Above the limestone there is commonly a thin bed of reddish shale, overlain by about 20 feet of sandstone with some interbedded shale. The outcrop of the limestone is not conspicuous and can not be seen from a distance. After its relation to the sandstones above and below it has been learned, it can usually be found by careful searching, even in places where it does not crop out continuously. It is exposed chiefly along the margins of the valleys of Pond Creek and Caney River and is well exhibited in the dugway of the wagon road near the top of the hill on the south side of Pond Creek near the southeast corner of sec. 2, T. 28 N., R. 10 E.

Labadie limestone.—The Labadie limestone is about 175 feet below the middle bed of the Oread limestone and 65 feet above the lower *Fusulina*-bearing limestone. It is 8 to 10 feet thick on the point south of Mission Creek in the NE. ¼ sec. 36, T. 28 N., R. 10 E., but a mile north of that place it is not more than 3 or 4 feet thick. Where best developed the Labadie is a crystalline limestone with a steel-gray color on the fresh surface; on the weathered surface the upper part is brownish and the lower part gray. It is not prolifically fossiliferous but contains some small, plump, rounded brachiopods. As shown on the map (Pl. VIII), this limestone crops out only in the southeast corner of T. 28 N., R. 10 E. Toward the north it thins so rapidly that it can not be recognized north of the east quarter corner of sec. 24, but a limestone about 2 inches thick at about the same horizon as the Labadie was seen at several places farther north in Tps. 28 and 29 N., R. 10 E.

Oread limestone.—In this area the Oread limestone is represented by the upper and middle limestones of the Oread of Kansas, the lower limestone of the Kansas section not being present. The middle limestone of the Oread is one of the best key beds in the area here described. It is a dense, fine-grained limestone about 18 inches thick, that has a steel-blue color on the fresh surface and weathers to a dirty yellow. It breaks into wedge-shaped joint blocks and is sparingly fossiliferous; the most distinctive fossil is a small species of *Fusulina*. In some places this characteristic part of the bed is overlain by a small amount of fine lyconglomeratic limestone. The limestone is remarkably constant in thickness and lithologic character throughout the area and is so characteristic that it can not be mistaken after having once been seen. The outcrop of this bed is shown on Plate VIII.

The upper bed of the Oread limestone ranges from a few feet to 16 feet in thickness. It is a thin-bedded ledge-making gray limestone, and where best developed the upper part (about 7 feet) weathers brown and the remainder white. The lower part contains in places an abundance of two species of corals, *Campophyllum torquium* and *Syringopora multilineata*. The former is a single coral, the individuals of which may be as much as an inch in diameter and several inches long. The latter grows in colonies, some of which are 6 inches or more in diameter, and in longitudinal section exhibits a mass of long, slender tubes resembling organ pipes. In addition to the corals there is a species of *Fusulina* larger than that found in the middle bed. The interval between this bed and the middle bed of the Oread ranges from 25 feet at Artillery Mountain, in the SE. ¼ sec. 21, T. 29 N., R. 10 E. (see column 2, fig. 11), to 90 feet at Tinker Hill, in the SW. ¼ sec. 30 (see column 1, fig. 11). This increase in interval between the two limestones is taken up in part by an increase in the

thickness of the shale between them but chiefly by the wedging in of sandstones that thicken to the south and west. As the sandstones thicken the upper bed of limestone thins somewhat and finally disappears rather abruptly between two beds of sandstone near the center of sec. 35, T. 29 N., R. 9 E. About 3 miles farther south, along the west side of Pond Creek, in secs. 14, 15, and 22, T. 28 N., R. 9 E., a lens of limestone, traceable for about 1 mile, having all the marks of the upper bed of the Oread and at about the same horizon, occurs between two beds of sandstone. The upper bed of the Oread has not been found south of Pond Creek.

Lecompton limestone.—The Lecompton limestone, the lowest limestone member of the Pawhuska limestone in this area, is about 190 feet above the middle bed of the Oread limestone and about 25 feet above the Elgin sandstone. The Lecompton consists of three beds of limestone separated by beds of shale, the whole about 12 feet thick. These limestones are gray and weather to a somewhat lighter color on the exposed surfaces, except that the upper part of the middle bed, and to some extent the lower bed, also weathers to a bright yellow. Fossils are abundant in some places and consist principally of large corals (*Campophyllum*) and ricelike *Fusulina*. This limestone generally crops out at the base of the slope above the Elgin sandstone and below the terrace formed by the Deer Creek limestone.

Plummer limestone.—The Plummer limestone member of the Pawhuska limestone consists of two thin beds, each about 1 foot thick, separated by about 5 feet of shale. The upper limestone, which makes the better key bed of the two, is about 35 feet above the top of the Lecompton limestone and consequently about 225 feet above the middle bed of the Oread limestone. The two beds of the Plummer are similar lithologically; the limestone is dense and fine-grained, has no apparent bedding planes, and is steel-gray to black on the fresh surface but slightly tinged with yellow on the weathered surface. It commonly crops out in the slope below the terrace formed by the Deer Creek limestone, from the base of which it is separated by about 5 feet of shale, and weathers out in large blocks which generally strew the slope. In places where the Deer Creek limestone has been eroded the upper bed of the Plummer may give rise to a more or less conspicuous terrace.

Deer Creek limestone.—The Deer Creek member of the Pawhuska limestone is 10 to 15 feet thick, and its upper surface is 15 to 20 feet above the Plummer limestone. The Deer Creek is a gray fossiliferous thin-bedded limestone, the lower part of which weathers white, is more resistant to erosion than the upper part, and commonly forms a rather prominent ledge bordering a broad sloping terrace, on the surface of which are many large white irregular slabs of the limestone. Above this white portion the limestone weathers gray with brown blotches,

which are especially prominent in a bed near the top containing an abundance of large *Fusulina*. This *Fusulina*-bearing bed makes one of the best key beds in the Deer Creek limestone. On the whole, however, this limestone is too thick to constitute a good key rock, and more accurate results can be obtained by using the Plummer limestone below. The Deer Creek limestone is the most prominent member of the Pawhuska limestone, and its outcrop is therefore shown on Plate VIII.

Cryptozoon-bearing limestone.—About 12 feet above the Deer Creek limestone is a limestone about 1 foot thick, characterized by fossil Cryptozoa. This limestone is dense and fine grained and has a black color, which becomes dirty gray on the weathered surface. Because of the fossils that it contains it is readily distinguished from any other limestone in the area where it is exposed and is therefore a valuable bed on which to obtain elevations on the terrace above the Deer Creek limestone.

Upper Fusulina-bearing limestone.—About 35 feet above the *Cryptozoon*-bearing limestone and therefore about 47 feet above the top of the Deer Creek member is a gray limestone less than 6 inches thick that contains an abundance of small, slender *Fusulina*. It is about 9 feet below the topmost member of the Pawhuska limestone and is of value chiefly in establishing the identity of this upper member, which is commonly referred to as the "red lime" because of its rusty-red to brownish-gray color.

UNEXPOSED ROCKS.

General character.—The character of the rocks not exposed at the surface and their relation to those that are exposed are shown in columns 1–5, Plate IX. The best key bed of the unexposed rocks of this area is the "Oswego lime" of the drillers (Fort Scott limestone). It ranges from 50 to 100 feet in thickness and it is broken into three members by two thin beds of black shale generally about 5 feet thick. (See column 3, Pl. IX.) These shales are reported in so many well logs that they seem to be constant and would probably be recognized by all drillers who made careful observations. From 250 to 350 feet below the base of the "Oswego" is the top of the "Mississippi lime." About 100 to 150 feet above the top of the "Oswego lime" is a limestone commonly called the Big lime. This is not so good a key bed as either the "Oswego lime" or the "Mississippi lime." In some parts of the area where drilling has been done the Big lime seems to consist of a single bed 50 to 100 feet thick; in other places there are two beds of limestone each 40 to 50 feet thick separated by about 50 feet of shale. Some drillers refer to these beds as the Big lime and second Big lime. In still other places there seem to be several beds of thin limestone between the

horizon of the top of the Big lime and the "Oswego lime." Another bed that seems to be rather constant throughout the area is a thick water-bearing sandstone (No. 4 of column 6, Pl. IX), which commonly contains some gas in its upper part. The top of this sandstone is approximately 700 feet above the "Oswego lime." The other unexposed rocks are sandstones, shales, and thin limestones having no distinctive characteristics.

Oil and gas bearing beds.—The beds in which oil and gas have been encountered in drilling are shown in column 6 of Plate IX. They include the Big lime, the "Oswego lime," and the "Mississippi lime"; two or three thin sands between the "Oswego lime" and the "Mississippi lime"; at least two sands between the "Oswego" and Big limes, either of which is called the Peru sand by the drillers; and several thin sands above the water-bearing sand described above. The Bartlesville sand is not generally recognized in this area. It may be represented in part by a thin sand that lies just above the the "Mississippi lime," and is referred to as the Bartlesville, Burgess, or Tucker sand by some drillers but is commonly not designated by any distinctive name.

The productive oil beds are the "Mississippi lime," two sands (Nos. 9 and 10) [1] between the "Oswego lime" and the second Big lime, a sand (No. 7) between the second Big lime and the Big lime, and probably the Big lime itself.

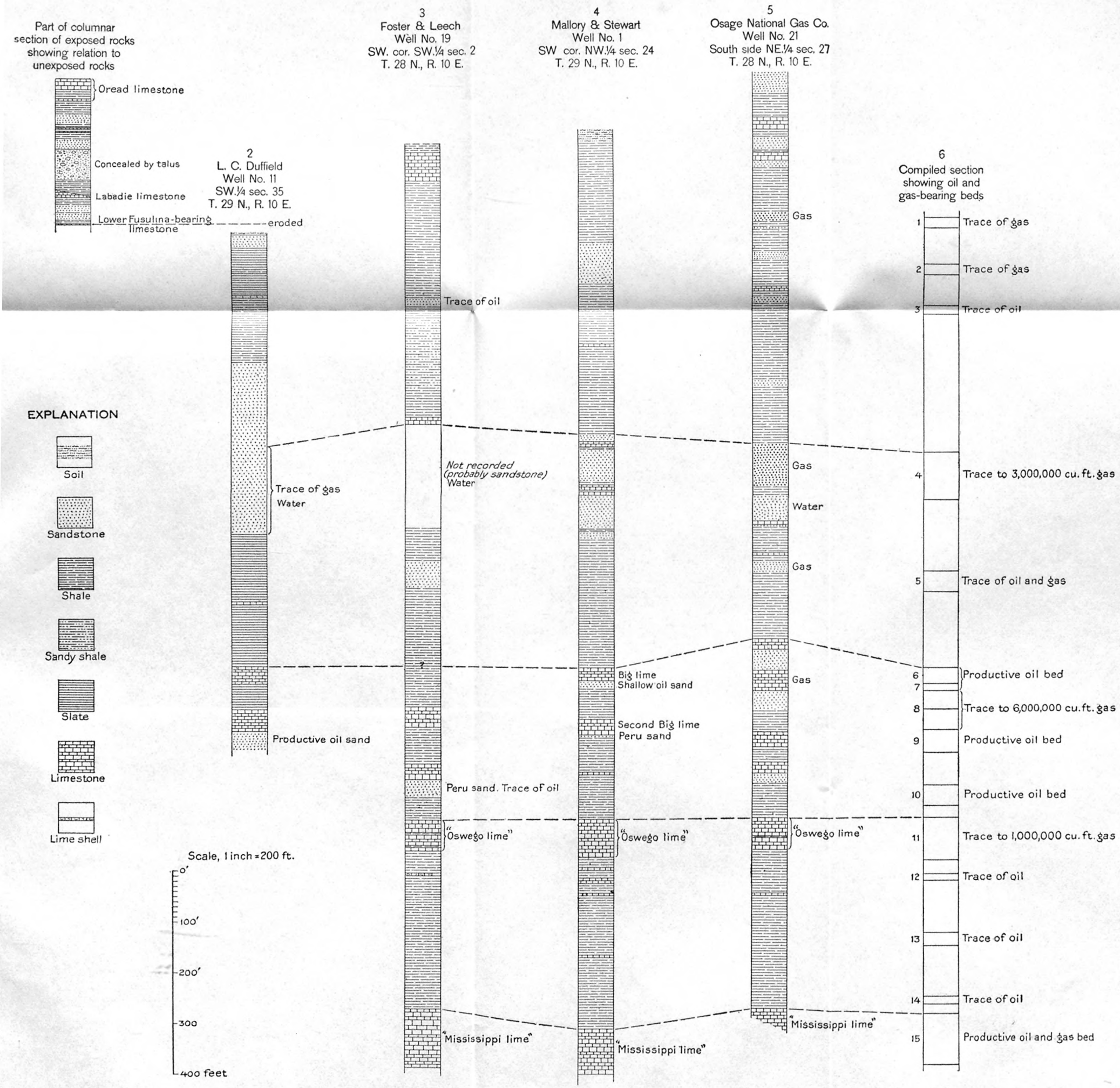
The "Mississippi lime" is the productive gas bed, but gas has also been found in quantities of as much as 6,000,000 cubic feet a day (initial production) in the "Oswego lime" and the second Big lime. A thin sand (No. 5) about 150 feet above the Big lime generally contains a small amount of gas. In one well a daily yield of 3,000,000 cubic feet of gas was reported from the top of the thick water-bearing sand (No. 4) 700 feet above the "Oswego lime," but so large a yield does not seem common at this horizon, most drillers simply reporting "gas" or "show of gas" from this sand. Two thin sands (Nos. 1 and 2) above the water-bearing sand contain traces of gas in some places.

STRUCTURE.

GENERAL ATTITUDE.

The rocks in this area show the low regional westward dip common to this part of Oklahoma. This dip is most pronounced in T. 28 N., R. 9 E. There are, however, many local exceptions to this general attitude in which the beds dip to the north, south, or east. These exceptions, especially those that involve a reversal or eastward dip in the rocks, are of particular importance to the oil geologist and driller, because they give rise to structural conditions favorable for oil and gas accumulation.

[1] These numbers refer to the corresponding beds in column 6, Pl. IX.



COMPARISON OF EXPOSED AND UNEXPOSED ROCKS AND STRATIGRAPHIC POSITIONS OF OIL AND GAS BEARING BEDS IN T. 28 N., RS. 9 AND 10 E., AND T. 29 N., R. 10 E.

The structure contours on Plate VIII, which depict the attitude of the rocks as seen at the surface, are drawn on a plane 20 feet below the middle bed of the Oread limestone.

ANTICLINES AND DOMES.

POND CREEK DOME.

In the following descriptions the anticlines and domes that have been drilled and developed are discussed first:

The Pond Creek dome covers an area of about 10 square miles lying mainly in the southeast quarter of T. 29 N., R. 10 E., and the northeast quarter of T. 28 N., R. 10 E. It is roughly circular in outline, with minor modifications on the west and southwest. It has a closure on the east of about 40 feet, and its crest lies near the center of sec. 3, T. 28 N., R. 10 E. It has long, gentle slopes on the north, south, and east but comparatively steep slopes on the west, especially in the lobe projecting up Pond Creek, where the slope amounts to 70 feet in about half a mile. The long uninterrupted slopes to the north, south, and west afford a large collecting area from which a supply of oil and gas might have accumulated. As indicated by the wells whose locations are shown on Plate VIII,[1] the central part of the dome, covering an area of about 3 square miles, has been extensively developed by the Roxana (formerly Belmont) Petroleum Co., L. C. Duffield, and Foster & Davis. Other scattering wells have been drilled over a considerably larger area, especially to the south and east.

On the top of the dome, in secs. 34 and 35, T. 29 N., R. 10 E., and the N. ½ sec. 3, T. 28 N., R. 10 E., the oil has been obtained chiefly from sands 9 and 10 (see footnote, p. 48) between the second Big lime and the "Oswego lime," but some wells are reported to have obtained their oil from the Big lime. In this same area the gas has been obtained chiefly from the "Mississippi lime," though some wells have obtained considerable quantities of gas from the Big lime and the "Oswego lime." On the lower slopes of the fold, as at the south side of sec. 2, in the NW. ¼ sec. 3, and in secs. 10 and 11, T. 28 N., R. 10 E., so far as drilling has progressed, the shallow sands are dry and oil is obtained from the "Mississippi lime," which is either barren of gas or contains only a small quantity near the top of the limestone. An exception to this condition seems to exist on the eastern slope of the dome, where the "Mississippi lime" carries gas to the very bottom of the syncline and shows only traces of oil. These conditions indicate that in the shallow sands which do not contain gas the oil has accumulated on the crest and upper slopes of the fold, but that in the

[1] Most of the wells shown on the map were located during the progress of the field work; those not so located have been taken from plats furnished by the Bureau of Mines and the Empire and Barnsdall oil companies.

"Mississippi lime," which carries both oil and gas, the gas has accumulated chiefly on the crest and upper slopes of the fold and the oil on the lower slopes. This distribution of oil and gas in the same bed should be kept in mind when other folds in this area are drilled, for it is quite probable that where gas is found at the top of a fold oil will be found in the same bed farther down the slope, but where oil is found at the crest the same bed is likely to contain less oil or be dry or carry water farther down the slope.

The initial daily production of oil from the shallow sands ranges from about 10 to 260 barrels. From the "Mississippi lime" the initial daily production of oil is from 10 to 30 barrels and that of gas from 1,000,000 to 11,000,000 cubic feet.

The limits of the productive area of the Pond Creek anticline have not yet been determined. On the north and south slopes no dry holes have yet been drilled. On the west slope one dry hole has been obtained in the SW. ¼ NE. ¼ sec. 5, T. 28 N., R. 10 E., below the belt of steep dips shown on Plate VIII. As no record has been obtained for this well it is not known whether or not it was drilled to the "Mississippi lime," which it is necessary to reach in order to insure a complete test in this area. Since the field work was completed a dry hole (not shown on Pl. VIII) has been drilled near the northwest corner of sec. 12, T. 28 N., R. 10 E., seeming to indicate that the limit of the productive area on the southeast has been reached. On the east slope gas has been obtained from the 'Mississippi lime" in the bottom of the small syncline at the east side of sec. 1, T. 28 N., R. 10 E., which indicates that the sands will probably be productive across this shallow depression to a small dome about half a mile farther east. To the north, in sec. 36, T. 29 N., R. 10 E., two dry holes and one yielding only a small quantity of gas have been drilled. These holes were all drilled to the "Mississippi lime" and therefore indicate that on the northeast the productive area does not extend into the depression at the east side of sec. 36.

Columns 2 and 3 of Plate IX are logs of two wells drilled near the crest of the Pond Creek dome. They show the productive beds and the depths at which they occur.

WEST TURKEY CREEK ANTICLINE.

The West Turkey Creek anticline is a narrow fold about 2 miles long from northwest to southeast, lying mainly in secs. 13 and 24, T. 29 N., R. 10 E. It is practically continuous on the west with the broad, low North Caney River anticline. The east limb of the fold is broken by a small fault that trends north. The contouring of this anticline is based entirely on elevations taken on massive sandstones, which over a part of the fold are covered by a heavy growth of tim-

ber. Most of the work was done by M. I. Goldman, who also mapped the township to the east.

The Roxana Oil Co. and Mallory & Stewart have drilled about 14 wells on the west slope of this anticline, chiefly in the E. ½ sec. 23 and the NW. ¼ sec. 24. All but two of the oil wells shown on Plate VIII obtained their oil from a shallow sand (No. 7) below the Big lime and had an initial daily production of 25 to 60 barrels. A well about 600 feet west of the east quarter corner of sec. 23 was drilled to the "Mississippi lime" in the expectation of finding gas but obtained instead a much larger supply of oil than is obtained from the shallow sand. Another well, near the southwest corner of the NW. ¼ sec. 24, a log of which is shown in column 4, Plate IX, obtained oil in the shallow sand and both oil and gas in the "Mississippi lime," but the quantity is not given in the well log. The depth to the shallow sand in these wells is about 1,080 feet and to the "Mississippi lime" about 1,770 feet. These two examples indicate the desirability of drilling to the "Mississippi lime" after the shallow sand has been exhausted or where it is found to be dry.

The limits of production on the northeast will probably not reach the depression in the NE. ¼ sec. 13, as two dry holes, at least one of which reached the "Mississippi lime," have been put down there and another in the northeast corner of sec. 24. On the southwest a dry hole in the Mississippi lime" was drilled in the northeast corner of sec. 26 and one in the shallow oil sand near the south quarter corner of sec. 23. About 4,000,000 cubic feet of gas (initial production) was obtained from the "Mississippi lime" in a well about the center of the SE. ¼ sec. 23.

NORTH CANEY RIVER ANTICLINE.

The North Caney River anticline crosses the Oklahoma-Kansas line at the north side of sec. 16, T. 29 N., R. 10 E., and continues southeastward into secs. 15, 14, and 23, where it merges with the West Turkey Creek anticline. From the point where it crosses the State line this fold continues on the Kansas side in a direction slightly north of west, probably to a point about north of the north quarter corner of sec. 18, and therefore within a mile of the town of Elgin, Kans. So far as could be determined, the fold has no easterly dip and is therefore in the nature of a "nose" pitching to the northwest. Its relation to the structure on the north was not determined, but on the southwest there is a large gathering ground from which oil and gas may have been obtained.

The greatest development in this fold has been in the N. ½ secs. 15 and 16 and northward across the Kansas line. With one exception the wells on the Oklahoma side have all been gassers that obtained

their supply from the "Mississippi lime," which was reached at a depth of 1,700 to 1,775 feet, the depth depending on the topographic location of the well. In several of the gas wells a show of oil was also obtained from the "Mississippi lime." A well drilled about 900 feet west and 500 feet south from the north quarter corner of sec. 16, and therefore somewhat farther down the slope than the other wells shown on Plate IX, obtained an initial production of 25 barrels of oil and 100,000 cubic feet of gas from the "Mississippi lime." The gas-producing area extends southeastward probably without interruption to the Turkey Creek anticline. Dry holes in the valley of Caney River in sec. 21, one of which is known to have reached the "Mississippi lime," indicate that the productive area will probably not extend as far south as the shallow syncline lying just north of the river. If the conditions are the same in this fold as in the Pond Creek dome, oil should be found in the "Mississippi lime" between the area of gas production along the crest of the anticline and the bottom of the syncline to the south.

WEST MISSION CREEK DOME.

The West Mission Creek dome lies in secs. 26, 27, and 34, T. 28 N., R. 10 E. It is oval in outline, and its major axis has a northeast-southwest extent of about 2 miles. The crest of the dome lies near the east side of sec. 27, and it has a closure on the east of about 40 feet. The slopes to the south and west are steep, especially in their lower parts; that to the north is gentle, merging with a broad terrace. The fold is limited on the southeast by a deep syncline that separates it from the East Mission Creek dome, on the southwest by a narrow saddle that separates it from a large anticline in T. 27 N., R. 10 E., and on the west by a shallow depression that separates it from the Rattlesnake anticline. The chief area from which oil and gas may have been gathered for the West Mission Creek dome is therefore the broad, flat terrace to the north, and smaller quantities may have accumulated from the territory near by on the west.

The dome has been partly developed by the Osage Natural Gas Co., whose wells are mainly on the crest and north slope of the fold. No oil has been obtained; the initial daily production of gas ranges from 750,000 to 4,500,000 cubic feet and is obtained from the "Mississippi lime" at an average depth of about 1,900 feet. Traces of oil from sands 7, 10, and 14 and also from the "Mississippi lime" have been reported in the logs of some of the wells. A log of one of these wells is shown in column 5, Plate IX.

Dry holes which reached the "Mississippi lime" have been put down in the syncline to the south, in secs. 25 and 35. It is probable, therefore, that the productive area will not extend to the base of the

steep slope on the south. The dry hole near the south quarter corner of sec. 27, which seems to have reached the "Mississippi lime," is difficult to explain, as it is located practically on the crest of the fold. At least one other hole should be drilled on the west end of the dome before it is abandoned. The dry hole a little northeast of the west quarter corner of sec. 26 has no significance, as the tools were lost, and the hole was abandoned at a depth of 695 feet. The other two dry holes on the north slope of the dome, in secs. 26 and 27, reached the "Mississippi lime" and therefore seem to be fair tests. From the evidence at hand it seems that the prospects of obtaining oil in the "Mississippi lime" on the lower slopes of this dome are not so good as in the other folds thus far discussed. Should other tests be made, especially on the north and west slopes, there is reasonable hope of finding oil.

EAST MISSION CREEK DOME.

The East Mission Creek dome occupies the SE. ¼ sec. 25 and most of sec. 36, T. 28 N., R. 10 E., and extends eastward into secs. 30 and 31, T. 28 N., R. 11 E., a report on which is given in another chapter of this bulletin. The crest of the dome lies about 1,000 feet west-northwest of the east quarter corner of sec. 36; the closure on the east amounts to 20 or 30 feet. The dome has a fairly good gathering ground to the north but very little to the west and south. It has not been developed, but the conditions here are probably somewhat similar to those on the West Mission Creek dome. The depth to the "Mississippi lime" at the crest of the dome is probably about 1,750 or 1,800 feet.

RATTLESNAKE ANTICLINE.

The Rattlesnake anticline lies northwest of Rattlesnake Spring and occupies parts of secs. 19, 20, 21, 29, and 30, T. 28 N., R. 10 E., and secs. 25 and 36, T. 28 N., R. 9 E. Its longest axis trends northeast, is about 4 miles long, and pitches to the southwest at an average rate of about 25 feet to the mile, but at the extreme southwest end the pitch is 80 feet to the mile. The fold is chiefly of the plunging anticlinal nose type, but seems to have a closure of about 10 feet at its extreme northeast end, in sec. 21. It has a large gathering ground to the northwest, west, and southwest.

Evidence regarding the amount of development on this fold is somewhat conflicting. The plats obtained from the Empire Oil Co. and the Bureau of Mines show four dry holes, all fairly well placed in the fold, at the southwest corner of sec. 20, the northwest corner of sec. 28, the southeast corner of the SW. ¼ sec. 21, and the southeast corner of the NW. ¼ sec. 21. The plat obtained from the Barnsdall Oil Co. shows but two of these holes, one in the northwest corner of

sec. 28, which is recorded as a gas well, and a dry hole in the southeast corner of the SW. ¼ sec. 21. In the field the writer succeeded in finding but one of these four holes, that in the southwest corner of sec. 20. The hole is dry, and from the log filed at the Indian Office it evidently reached the "Mississippi lime." If the four holes shown on Plate VIII have all been drilled and all reached the "Mississippi lime," it would seem that the anticline has been fairly well tested, and that if any further drilling is done it should be farther down the slopes of the fold or on its extreme southwest end. On the other hand, if only the hole in the southwest corner of sec. 20 has been drilled, at least one other test should be made on the highest part of the fold, about the center of the SW. ¼ sec. 21. There is some room for doubt whether the three holes referred to above not found by the writer were actually drilled. No record of any of them has ever been filed at the Indian office at Pawhuska. An abandoned oil well in the southwest corner of sec. 28 is reported by two of the authorities given above, but on visiting this locality the writer found the remains of a derrick but no evidence of a hole nor any indication (such as a sludge pile) that any drilling had ever been done here. Inquiry among ranchers near by disclosed the fact that a derrick had been built there but that no drilling had ever been done and that the derrick was finally blown down. The occurrence of a 10-barrel oil well on the Spring Creek dome, about three-quarters of a mile north of the crest of the Rattlesnake dome, is at least suggestive that some oil should be found in the latter.

SPRING CREEK DOME.

The Spring Creek dome lies on a tributary of Spring Creek in the SW. ¼ sec. 16, T. 28 N., R. 10 E. It is a small dome having a closure of only 10 feet. A 10-barrel well on the southwest end of this fold, which obtained oil at a depth of 1,820 feet, probably from the "Mississippi lime" or a thin sand immediately above it, is the only one thus far drilled. A 30-barrel well in the northeast corner of sec. 16 is more closely related to the Pond Creek dome than to the Spring Creek dome. It suggests, however, that the entire saddle between the two folds may contain oil.

BIRCH CREEK TERRACE.

A broad terrace on which there are a few minor protuberances occupies the area in T. 28 N., R. 10 E., bounded on the north and northeast by the Pond Creek dome and the syncline lying southeast of it, on the south by the West Mission Creek dome, and on the west by the Spring Creek dome. The outline of this terrace, which may be called the Birch Creek terrace, is based on elevations taken on

various beds of a thick sandstone series, for the most part covered with timber. Some allowance should therefore be made as to details.

One dry hole has been drilled on the terrace near the west quarter corner of sec. 24. No record is available to show the depth of the hole, and its value as a test is therefore not known. It seems probable that if oil and gas were originally present in this terrace they would have migrated for the most part to the domes surrounding it, and that it is therefore not a promising place in which to obtain oil or gas. It may be, however, that small local pools have accumulated in the minor protuberances on the surface of the terrace.

DIVIDE DOME.

The Divide dome occupies parts of secs. 12 and 13, T. 28 N., R. 9 E., and secs. 7 and 18, T. 28 N., R. 10 E. Its crest is on top of the high timbered divide which trends northeast through this part of the area, and it has a closure of only 10 feet. The outline of the dome is based mainly on elevations taken on the middle bed of the Oread limestone. In addition to the main dome there seems to be a long, narrow southward-trending spur extending across sec. 13 and into sec. 24, T. 28 N., R. 9 E. The outline of this spur is based partly on elevations on the Oread limestone and partly on beds in the Elgin sandstone. The dome has a large gathering ground to the west. No wells have been drilled on it. Its crest is capped by the Elgin sandstone (partly eroded), and the "Mississippi lime" should therefore lie at a depth of about 2,150 feet beneath it. A test hole placed about the center of the SW. ¼ sec. 7 would be on about the highest part of the dome, but considerable advantage in drilling could be obtained by choosing a location farther west, near the west side of the section and below the rim of Elgin sandstone.

RICEROCK ANTICLINE.[1]

The Ricerock anticline lies in secs. 7 and 18, T. 28 N., R. 9 E., and secs. 12 and 13, T. 28 N., R. 8 E. The axis trends a little north of west from the south quarter corner of sec. 7, T. 28 N., R. 9 E., to the east quarter corner of sec. 11, T. 28 N., R. 8 E. From this axis the beds dip northwest and southwest. To the east the fold dies out in a flat terrace almost a mile broad, which on the east merges with the regional dip. The steepest dip on the fold is on its tip, where the beds incline to the west about 80 feet to the mile. On the flanks the dips probably average about 60 feet to the mile. The formation capping this anticline is a sandstone about 20 feet above the "red lime" in the stratigraphic column. A thin bed of lime-

[1] The descriptions of the Ricerock anticline, Upper Pond Creek dome, and Limestone Flat terrace were supplied by K. C. Heald.

stone, thickly filled with tests of *Fusulina*, was of great assistance in mapping the structure, as it furnished an easily identified, thoroughly reliable horizon on which to determine the relative elevations of different parts of the fold.

The doming of this fold is so slight that it is in effect more of a terrace than an anticline, and the chance that it has induced the formation of a large pool of oil is comparatively slight. If there is such an accumulation it is probably confined to the west flank of the fold. Accordingly a good location for drilling would be about the center of the SE. ¼ SE. ¼ sec. 12, T. 28 N., R. 8 E. The depth to the "Mississippi lime" at this point should be about 2,200 feet.

UPPER POND CREEK DOME.[1]

The Upper Pond Creek dome lies in sec. 19, T. 28 N., R. 9 E. It is a low, almost imperceptible bulge, bounded on the northeast by a small fault with a throw of 10 feet or less. Dips on the other flanks average about 60 feet to the mile. A cross section of this fold from northwest to southeast would show a very low, flat arch. One from southwest to northeast would show half such an arch abruptly terminated by a vertical fault scarp.

The shape and outline of this dome were determined by elevations on several of the resistant limestone beds of the Pawhuska formation. The bed that caps the fold is the first heavy limestone below the "red lime."

This anticline is so low that its effect in arresting the migration of oil has probably been slight. The most promising place for a pool is on the west flank of the fold, where the beds dip westward at a fair rate. Accordingly the center of the SW. ¼ SW. ¼ sec. 19 is suggested as a good location for drilling a test well. At this place the "Mississippi lime" should lie about 2,100 feet below the surface.

LIMESTONE FLAT TERRACE.[1]

In sec. 32, T. 29 N., R. 9 E., and secs. 5 and 8, T. 28 N., R. 9 E., there is a marked change in the rate of the regional westward dip, the rocks flattening out toward the west, making a terrace about 1 mile broad and 3 miles long. At the south end of this terrace is the Ricerock anticline described above. The terrace is not absolutely horizontal but slopes to the west at a rate of about 10 feet to the mile. On its surface there are two very small anticlines and at least one correspondingly small syncline, but these features are relatively minor parts of the terrace as a whole. The rock that caps the terrace is the highest bed of the Pawhuska lime-

[1] The descriptions of the Ricerock anticline, Upper Pond Creek dome, and Limestone Flat terrace were supplied by K. C. Heald.

stone, and the elevations that proved the existence of the terrace were taken on the limestone ledges that make up the Pawhuska limestone. At its west edge the rocks forming this terrace pitch to the west at a rate of about 60 feet to the mile, and at the east edge they rise to the east with a somewhat gentler slope.

The structure of this terrace is not such as to influence any great accumulation of gas or oil, and any wells that may be found on it will probably have a small initial production. The most promising part of the terrace is the region of moderately steep dips west of the flat top of the flexure. Accordingly the center of the NW. ¼ sec. 7, T. 28 N., R. 9 E., is suggested as a good location for drilling a test well. The depth to the "Mississippi lime" here should be about 2,150 feet.

MINOR FOLDS AND TERRACES.

There are several minor anticlines in this area, most of them without any closure on the east, and some terraces in which there is a possibility of finding oil or gas. Most of these minor features are wholly undeveloped. Attention is called to them here in the belief that they are the most favorable places to test after the areas described above have been drilled.

One of these small anticlines occurs in the S. ½ sec. 29, T. 29 N., R. 10 E., and another in sec. 31, extending west into sec. 36, T. 29 N., R. 9 E. The latter has well-defined south and west dips but very little dip to the north. The "Mississippi lime" should be reached on these folds at 1,900 to 2,000 feet.

A small dome is shown near the center of sec. 4, T. 28 N., R. 10 E., with a nose extending southwestward into sec. 5. The chief evidence for the existence of this dome consists in pronounced reverse dips in the sandstones on opposite sides of Spring Creek. On the northwest side of the creek the sandstone dips northwest at an angle of about 15° for a distance of about 1,000 feet. Dips of this magnitude in the Pawhuska quadrangle usually indicate faulting, but no definite evidence of a fault could be found here. On the southeast side of the creek near the center of the section the sandstone dips to the southeast at a low angle. The sandstones are badly broken and difficult to trace with certainty in this part of the area, so that the evidence of reverse dips is not strongly supported by elevations on the beds. In this dome the "Mississippi lime" lies at a depth of about 1,800 feet in the valley of Spring Creek.

A small anticline that shows dips on the north, south, and west but merges into a flat or terrace on the east occurs in sec. 3, T. 28 N., R. 9 E. It has not been drilled, but the "Mississippi lime" is estimated to lie at a depth of 2,200 feet below it.

Four holes have been drilled in the northwest corner of sec. 22 and the northeast corner of sec. 21, T. 28 N., R. 9 E., in a narrow belt of steep westward dips with a flat or terrace above and below. One of the wells obtained a little oil and gas and would probably yield enough to pay for pumping if there were any other wells in the vicinity; the other three holes are dry. These wells were drilled several years ago, and as no record of them seems to have been kept it is not now possible to ascertain even the depth to which they were drilled. If they penetrated the "Mississippi lime" there would be little inducement for further drilling at this place. On the other hand, if they did not reach the "Mississippi lime" it would be very desirable to continue one of them down into that formation, which should be reached at a depth of about 2,000 feet in the well where the show of oil and gas was obtained. It is probable that the holes were not drilled deeper than the "Oswego lime," because at the time of drilling oil was being obtained from the "Oswego" or a sand about 400 feet above it in the Elgin field, about 7 miles farther north. The occurrence of even a small quantity of oil here is interesting, because it seems to bear out what has been observed in at least two other places [1] in the Pawhuska quadrangle—in sec. 20, T. 29 N., R. 9 E., and sec. 22, T. 24 N., R. 10 E.—namely, that there is a tendency for oil to accumulate in belts of steep westward dip bordered above and below by terraces.

A terraced area similar to the one just described but much more pronounced, having a westward dip of 60 feet in half a mile and bordered above and below by a broad flat, occurs in secs. 29 and 32, T. 28 N., R. 9 E. If future experience demonstrates that structural features of this character are likely to contain oil or gas, this one would certainly be worth testing.

[1] Heald, K. C., Geologic structure of the northwestern part of the Pawhuska quadrangle, Okla.: U. S. Geol. Survey Bull. 691, pp. 88–89, 1918 (Bull. 691–C).
Bowen, C. F., report on T. 24 N., R. 10 E., in this volume (Bull. 686–D).