T. 24 N., R. 10 E.

By C. F. Bowen.

STRATIGRAPHY.

EXPOSED ROCKS.

General character.—The rocks exposed in T. 24 N., R. 10 E. (see fig. 1) are illustrated graphically in figure 5. They have an aggregate thickness of about 550 feet and belong stratigraphically in the upper part of the Pennsylvanian series. They consist mainly of alternate beds of sandstone and shale, with two well-defined limestones near the base of the section, two thin limestones about 100 feet below the top, and local lenses of limestone at other horizons.

The sandstones are for the most part medium-grained quartzose rocks but vary in composition and physical features and are irregular and inconstant in thickness and extent. The shales are prevailingly red, but, as shown in the columnar section, there are two well-marked intervals of gray shale which are valuable guides in tracing the sandstones above them. A detailed discussion of the stratigraphy and the grouping of formations will be given in the final report on the Pawhuska quadrangle. In this report the description is confined to the principal key beds used in mapping.

Key beds.—The exposed rocks include three more or less well-defined key beds, the outcrops of which are shown on the accompanying map (Pl. V). They are, in ascending order, the Birch Creek limestone, the Bigheart sandstone, and the Fourmile sandstone. At the top of the section is another sandstone, 15 to 20 feet thick, named by K. C. Heald [1] the Wynona sandstone, from exposures at and near the town of Wynona, in T. 24 N., R. 9 E.

Birch Creek limestone.—The Birch Creek limestone, named from its excellent exposure in the bluffs on the north side of Birch Creek, near the east edge of the SE. ¼ sec. 25, is well exposed also on the south side of Birch Creek to a point within about a quarter of a mile of the west side of sec. 36, where it passes beneath the surface. Another good exposure occurs in the railroad cut about 1½ miles south of Bigheart, in sec. 19, T. 24 N., R. 11 E. It is a hard light-gray crystalline, somewhat dolomitic limestone and is sparingly fos-

[1] Report on T. 24 N., R. 9 E., in preparation to form a part of Bulletin 686.

siliferous. It contains a considerable percentage of iron, which gives it an unusually high specific gravity and produces a deep rusty-brown color on the weathered surface. Laterally it grades into limy sandstone.

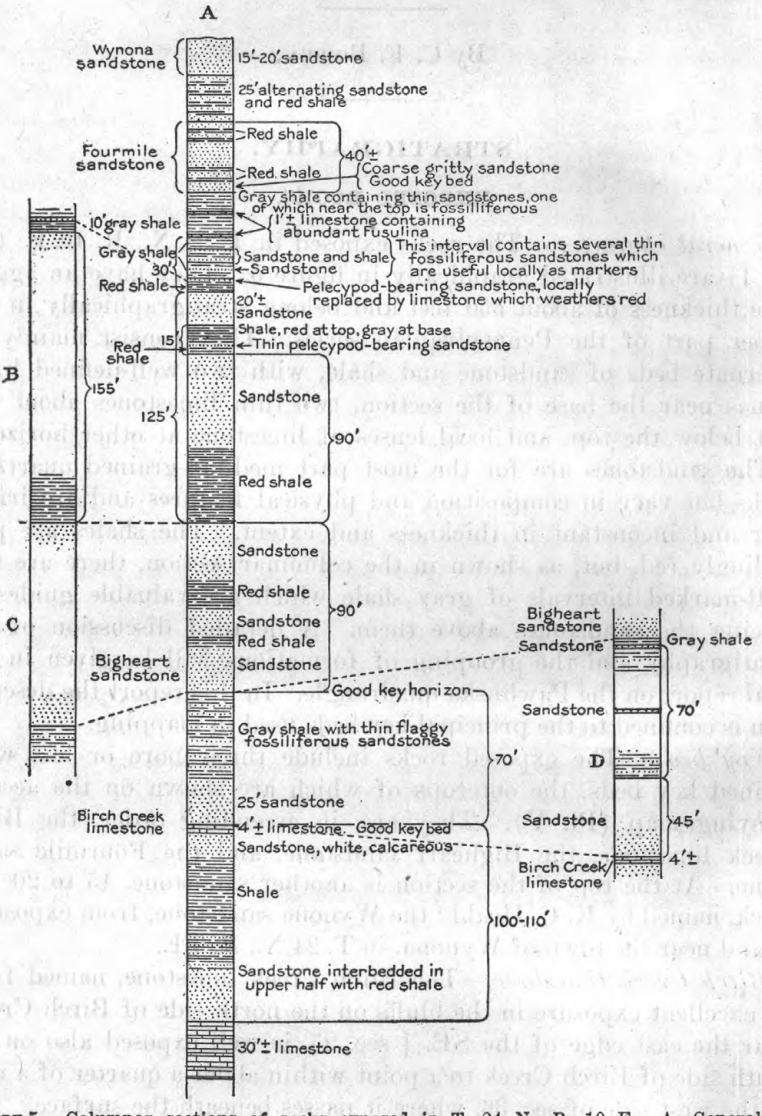


FIGURE 5.—Columnar sections of rocks exposed in T. 24 N., R. 10 E. A, Generalized section; B, section at north side of sec. 24, showing convergence of the beds indicated between that point and the east quarter corner of sec. 22; C, section near the south quarter corner of sec. 14, showing convergence of the beds indicated between that point and the SW. ¼ NW. ¼ sec. 11; D, section in the NW. ¼ sec. 19, T. 24 N., R. 11 E., showing convergence of the Bigheart sandstone and Birch Creek limestone between that point and the SW. ¼ sec. 36, T. 24 N., R. 10 E.

The Birch Creek limestone seems to be at approximately the same horizon as a limestone at Bartlesville believed, but not definitely proved, to be the Stanton limestone. According to O. B. Hopkins,[1] however, the Birch Creek may be as much as 15 feet below the limestone at Bartlesville.

Bigheart sandstone.—From 70 to 115 feet above the Birch Creek limestone is a massive ledge-making sandstone, 25 to 50 feet thick, here called the Bigheart sandstone[2] because it is well exposed at Bigheart, forming the main ledge in the bluffs west of the road between Bigheart and Quawpaw. It is a massive, cross-bedded ledge-making sandstone 25 to 50 feet thick. In some places it consists of a single bed; in others it is separated into two members by a bed of red shale 4 feet or more thick. At its base the sandstone is slightly conglomeratic, and for several feet above this basal part it is very coarse grained or gritty. In this gritty portion the coarse grains of white, red, and black quartz stand out in relief on the weathered surface, in marked contrast to the other sandstones in this part of the section. The conglomeratic portion is rarely exposed, because it disintegrates readily and is also commonly covered by talus or wash. The gritty character of the basal part of this sandstone, together with the fact that it rests on gray shale, whereas the shales higher up in the section are red, make the contact of the shale and sandstone a valuable key horizon. In some places, however, there is a small amount of red shale between the sandstone and the gray shale, but in such places the gray shale can usually be found and there is little difficulty in establishing the horizon. The conglomeratic character of the sandstone is most pronounced in the southern part of the township.

Fourmile sandstone.—About 40 feet below the top of the section and about 350 feet above the Birch Creek limestone is a group of beds consisting predominantly of sandstone, with some interbedded shales near the top and base. These beds, here called the Fourmile sandstone, are well exposed on the point south of Fourmile Creek in the SW. ¼ sec. 30, extending eastward about three-quarters of a mile from the small oil field at the west side of the section. They consist of a massive sandstone about 25 feet thick, overlain and underlain by some thinner sandstones and interbedded red shales, the whole having a thickness of about 40 feet, but this varies considerably from place to place. The basal bed of this sandstone is distinguished from other sandstones in this part of the section by being coarse and gritty, resembling the basal part of the Bigheart sandstone, but it

[1] Report on T. 25 N., Rs. 11 and 12 E., in preparation to form a part of Bulletin 686.

[2] The name Bigheart sandstone was used by L. C. Snider (Oklahoma Geol. Survey Bull. 7, p. 221, 1911) for 175 feet of sandstones and shales supposedly exposed at and near Bigheart, but the term is here restricted to the basal massive sandstone of that series of beds, which is a useful horizon marker over a considerable area.

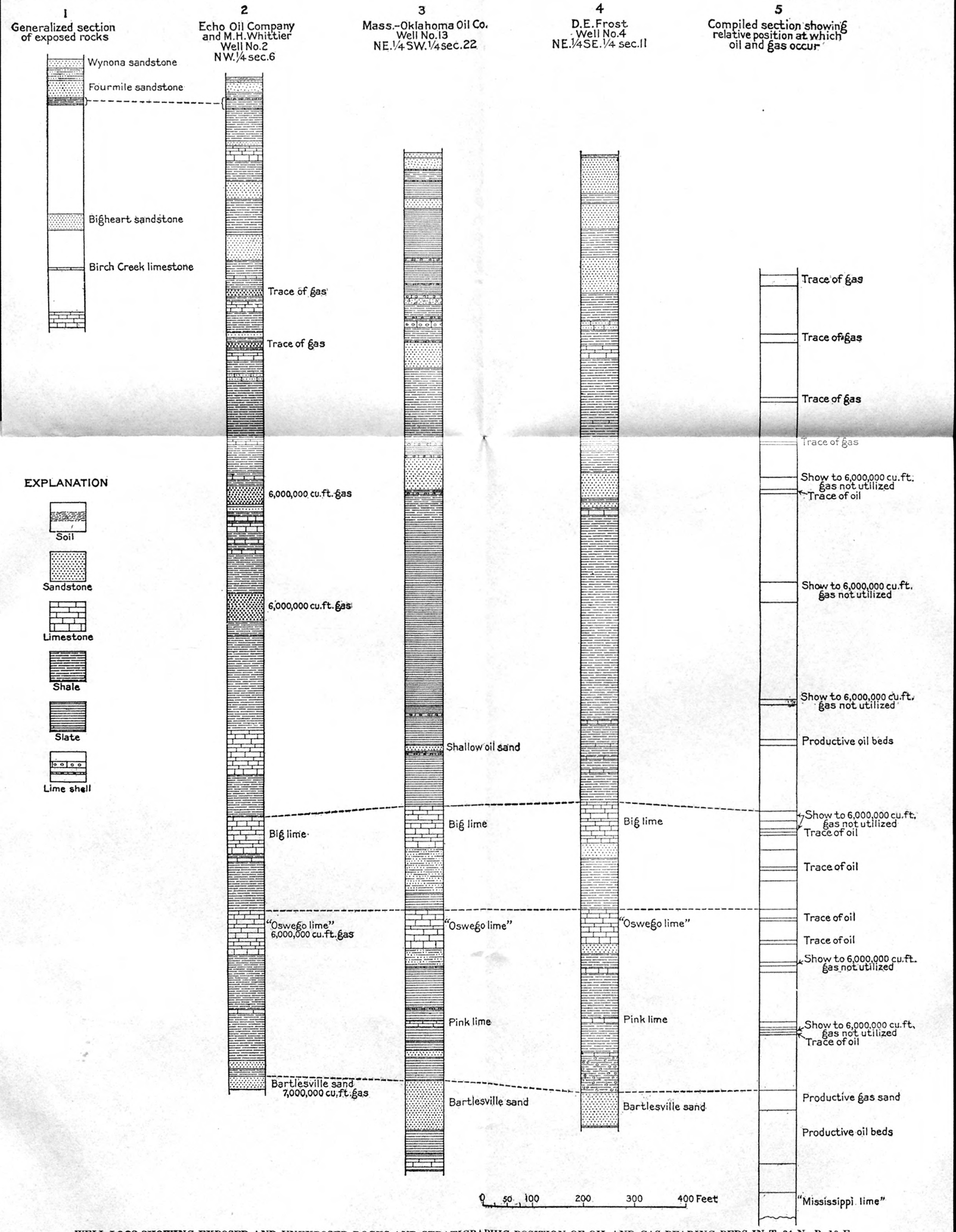
differs from the Bigheart in not being conglomeratic. It is also immediately underlain by gray shale, whereas the other shales in this part of the section are prevailingly red. The distinctive character of the sandstone, together with the gray shale below, render this basal bed the most distinctive traceable key bed in the western part of the township. It is however, less distinctive and valuable in the northern part of the area than in the southern part. The tracing and identification of the bed are further facilitated by the presence of two thin limestones and a thin fossiliferous sandstone in the shale below it. The limestones are 8 to 10 feet apart, and the upper one is 10 to 15 feet below the base of the Fourmile sandstone. These limestones are commonly a foot or less in thickness and are similar in composition, being characterized by an abundance of small *Fusulina*, with few other fossils. In places they grade into calcareous sandstones characterized by a smooth white weathered surface. Exposures of these limestones are rare. They are commonly concealed by talus and hill wash from the sandstone above but can be found in a sufficient number of places to render them valuable as checks on the sandstone. A good exposure of the lower limestone occurs in the bed of Fourmile Creek about 400 feet west of the west boundary of sec. 30.

Between the upper limestone and the base of the Fourmile sandstone there is a thin fossiliferous sandstone which in the northern part of the township contains an abundance of *Fusulina*, but farther south these are replaced largely by pelecypods and brachiopods. The brachiopods serve to distinguish this sandstone from other fossiliferous sandstones lower in the section.

UNEXPOSED ROCKS.

The unexposed rocks and their relation to those exposed at the surface are shown graphically in columns 1 to 4, Plate VI. To a depth of about 1,200 feet below the Birch Creek limestone they are very similar in character to the surface rocks. Between this depth and the "Mississippi lime" limestones become more abundant, two beds of which, the Big lime and the "Oswego lime" (Fort Scott limestone), are commonly recognized by drillers. The position of the oil and gas bearing sandstones with relation to these limestones is shown in column 5, Plate VI.

The principal oil-producing sandstone in this area is generally known as the Bartlesville sand, although it may include more than the Bartlesville sand at Bartlesville. It is 70 to 150 feet thick and in many of the wells is broken in the lower part into several thin beds, to some of which the drillers have given distinctive names, such as Tucker sand and Burgess sand. Gas is commonly found in the upper part of the Bartlesville, the oil in some of the wells not



WELL LOGS SHOWING EXPOSED AND UNEXPOSED ROCKS AND STRATIGRAPHIC POSITION OF OIL AND GAS BEARING BEDS IN T. 24 N., R. 16 E.

being encountered until the sand has been penetrated to a depth of 50 feet or more.

About 650 to 675 feet above the Bartlesville and about 275 feet above the "Oswego lime" (Fort Scott limestone) is a thin sand 10 to 12 feet thick which is the source of the oil obtained in sec. 22.

Between the Big lime and the Fort Scott ("Oswego") limestone occur one or more sands or sandy shales. To one or another of these the name Peru sand is commonly applied. In some places this sand contains traces of oil, but it has not been a source of oil in this township. Traces of oil also occur in some places in the "Oswego lime" and the Big lime and in one or more shallow sands 600 feet or more above the Big lime.

The chief source of gas in the township is the upper part of the Bartlesville sand, commonly referred to as gas sand by the drillers. In some places a considerable supply of gas has also been encountered in the "Oswego lime" and in the Big lime. Traces of gas have been found in thin sands between the Bartlesville sand and the "Oswego lime," and also at various horizons from 350 to 1,000 feet above the Big lime. In only one place, however (the North Cochahee dome), are these shallow sands reported to have yielded more than 1,000,000 cubic feet of gas a day.

STRUCTURE.

The rocks in this township have a somewhat steeper westward inclination than is common in other parts of the Pawhuska quadrangle. A belt of especially steep dips crosses the central part of the area in an almost due north direction. The largest anticlines or domes lie east of this belt. The structure contours shown in Plate V are drawn on an assumed datum plane 220 feet below the Fourmile sandstone. The anticlines and domes will be described from east to west, beginning at the southeast corner of the township and progressing westward by tiers of sections.

BIRCH CREEK AND BIGHEART DOMES.

The Birch Creek dome, in secs. 25 and 36, and the Bigheart dome, in the southeast corner of sec. 12 and the northeast corner of sec. 13, lie mainly in the next township to the east. As they are fully described in the report on that township, they will receive only brief mention here.

The Birch Creek dome covers an area of more than 4 square miles and has a closure on the east of about 125 feet. It is therefore one of the largest structural features in the Pawhuska quadrangle. Its crest lies about 1½ miles northeast of the southeast corner of this township. A part of the fold has been well tested in T. 24 N.,

R. 11 E., where the most oil has been obtained on the north slope of the dome and gas has been obtained in several wells drilled near its crest. Along the north side of sec. 25 and in the southwest corner of sec. 26 of the township here discussed dry holes have been obtained well down toward the base of the fold. A hole in the SW. ¼ sec. 25, however, in about the same structural position, obtained some oil, but no record is available of the quantity. In view of previous development the SW. ¼ sec. 25 and all but the west tier of forties in sec. 36 of this township appears to be very promising oil territory.

REDEAGLE ANTICLINE.

The Redeagle anticline lies mainly in secs. 1, 2, 11, and 12 of this township but extends into the SW. ¼ sec. 6 and the NW. ¼ sec. 7, T. 24 N., R. 11 E. The major axis of the anticline is about 2½ miles long and trends somewhat north of east. The maximum width of the fold from north to south is about 1 mile. Near its west end, in sec. 12, there is a slight constriction which gives the anticline a compound structure. The shape and extent of that part of the anticline lying in T. 24 N., R. 11 E., are uncertain because it occupies an alluvial flat in which no key beds are exposed. The crest of the fold lies in that township, and the amount of east dip is apparently slight, not more than one contour closing around the fold. The beds have a gentle westward dip from the highest part of the fold to about the center of sec. 11, from which they drop about 50 feet in the next half mile.

About one-half of that part of the anticline lying in T. 24 N., R. 10 E., has been developed by the Pen Mar, Barnsdall, and Nicaragua oil companies. (See Pl. V.[1]) Out of 45 productive oil wells for which records are available, 5 are reported to have had an initial production of 300 to 1,500 barrels, 11 to have ranged between 100 and 250 barrels, and 28 to have produced less than 100 barrels. The largest yield was obtained from wells near the crest of the anticline, extending from the southeast corner of sec. 11 to the NE. ¼ NW. ¼ sec. 12. About 200 feet north of the south quarter corner of sec. 1, at about the highest point stratigraphically on the anticline that has yet been drilled, a dry hole was obtained. This well did not penetrate the "Mississippi lime," however, and is therefore not a conclusive test. It is logical to assume that either oil or gas will be found in the crest of this fold.

The oil obtained has all come from the Bartlesville sand, though in some of the wells showings of oil are reported in the "Oswego" and Big limes. Gas is reported from the top of the Bartlesville sand, from

[1] Locations of wells not seen during the field work were taken from plats furnished by the Bureau of Mines and the Empire and Barnsdall oil companies.

the "Oswego" and Big limes, and from thin sands below the "Oswego lime" and above the Big lime.

The anticline has a large gathering ground to the north and west, but a relatively small one to the south and east, owing to the rather deep depressions in these directions.

PENCRESDALL ANTICLINE.

The Pencresdall anticline lies mainly north of Birch Creek in sec. 23 but occupies also the southwest corner of sec. 13, the SE. ¼ sec. 14, the northwest corner of sec. 24, and the north-central part of sec. 26. In outline it is somewhat pear-shaped, with the large end to the northeast. Its maximum extent from northeast to southwest is about 2 miles and its maximum width about 1 mile. The greater dips are to the north, west, south, and southeast and amount to about 50 feet within the first half mile. The drop to the east is less than 20 feet.

The northern part of this anticline has been developed by the Pen Mar, Crescent, and Barnsdall oil companies, and the extreme south end by the Barnsdall Oil Co. and the Prairie Oil & Gas Co. (See Pl. V.) The oil and gas thus far obtained come from the Bartlesville sand, though traces of both oil and gas are found at higher horizons. The initial production of the wells ranged from 5 to 700 barrels a day, but only three of them exceeded 200 barrels. As may be seen from Plate V, most of the wells are on the sides of the anticline. Two wells in the northwest corner of sec. 23, on top of the anticline, obtained about 1,000,000 cubic feet of gas a day from the Bartlesville sand but no oil. This suggests that gas rather than oil may be found in the top of the anticline. If future development should prove this to be the condition, drilling should be continued well down into the "Mississippi lime" in order to determine whether or not an adequate commercial supply of gas or possibly of oil may be obtained. The wells referred to above apparently did not penetrate the "Mississippi lime." Dry holes have been obtained well down toward the base of the fold in several places, indicating that oil will probably not be found in the adjacent synclines.

SOUTH COCHAHEE DOME.

The South Cochahee dome includes the SE. ¼ sec. 4, nearly all of sec. 5, the southeast corner of sec. 6, and the northeast corner of sec. 7. In sec. 6 it connects by a narrow saddle with the North Cochahee dome, lying to the northeast, mainly in T. 25 N., R. 10 E. The South Cochahee dome is somewhat oblong, having an east-west length of about 1½ miles and a north-south width of nearly 1 mile. The highest point of the dome lies about 800 feet north-northwest of the south quarter corner of sec. 5. The eastward dip is very gentle, amounting to less than

20 feet in about three-quarters of a mile. The north and south slopes are also gentle, that to the north being somewhat the steeper. The slope to the west is relatively steep, amounting to 60 feet in about half a mile. It is probable from the present development that the low saddle which connects this dome with the North Cochahee dome will prove to be productive oil or gas territory.

This dome is practically undeveloped. A well drilled in the southwest corner of the NE. ¼ sec. 6 (see Pl. V) had an initial production of about 50 barrels. A well a few hundred feet west of this one, drilled since the mapping was completed, is reported to have been brought in with an initial production of about 500 barrels. Another well about the same distance south of the one shown on the map is said to have come in with a production of about 50 barrels. The oil probably comes from the Bartlesville sand, though no complete log is yet available.

The existing developments indicate that the crest of this fold, like that of the North Cochahee dome, will probably yield gas and that oil will be found on the slopes. The dome has a fairly good gathering ground.

NORTH COCHAHEE DOME.

The North Cochahee dome lies mainly in T. 25 N., R. 10 E., and will be described in the report on that township. A few gas wells have been obtained on that part of the dome lying in this township. A log of one of these wells, showing the quantity of gas and the horizons at which it was obtained, is given in column 2, Plate VI.

EAST BIRDSEYE ANTICLINE.

The East Birdseye anticline occupies the SW. ¼ sec. 18 and the NW. ¼ sec. 19, with a narrow southeastward-projecting nose extending diagonally across the NE. ¼ sec. 19. It is separated from the main Birdseye anticline, to the west, by a low saddle. The highest point on the anticline seems to lie about on the line between secs. 18 and 19, at a point about 1,800 feet from the west side of the township. This small fold has an east closure of about 25 feet over an area of about half a square mile. It has not been developed, but conditions will probably be about the same here as in the main Birdseye anticline in T. 24 N., R. 9 E., except that this anticline is probably somewhat less favorably situated for oil and gas than the one to the west, because that one would trap the oil migrating up the westward slope. There is, however, considerable gathering ground to the north and south from which oil and gas might have been accumulated. It seems, therefore, that the East Birdseye anticline is well worth testing.

FOURMILE DOME.

The main part of the Fourmile dome lies in T. 24 N., R. 9 E., and is more fully described in the report on that township. The part of the dome lying in this township occupies the SW. ¼ sec. 30. The dome is somewhat larger from east to west than from north to south and occupies less than 1 square mile. It has an east closure of about 30 feet, and its crest is about 1,500 feet west and a little north of the southwest corner of sec. 30. The developments on that part of the anticline lying in this township are mainly on its north slope, where seven wells have been drilled. Each of these wells obtained oil in the Bartlesville sand, and their initial daily production ranged from 5 to 75 barrels. A dry hole was obtained on the east slope of the fold near the south quarter corner of sec. 30, limiting the probable productive area in this township to the SW. ¼ sec. 30. The dome has a large gathering ground to the north, south, and west.

TERRACES.

In the N. ½ sec. 22 the Massachusetts-Oklahoma (formerly Pen Mar) Oil Co. has several productive oil wells on what seems to be a terrace having a belt of steep dips about half a mile wide with a flat or terrace both above and below. The production is obtained chiefly in the zone of steep dips and at the inner edge of the lower terrace. Dry holes have been obtained on the flat above the steep dips, and also in a small synclinal reentrant north of the main producing area. The wells are small, the initial production after shooting ranging from 5 to 75 barrels. At present they yield only a few barrels each per day. The oil comes from a shallow sand 125 to 150 feet above the Big lime and about 650 feet above the Bartlesville sand. A log of one of these walls is shown in column 3, Plate VI.

The occurrence of oil at this place, away from any anticline or dome, may be the result of the terrace structure or it may be due to a lenticular sand or some other unknown factor. It simply illustrates the possibility of finding small pools of oil independent of anticlines or domes.

Terraces very similar to that in sec. 22 occur in the W. ½ sec. 3 and the W. ½ sec. 25. The terrace in sec. 3 is more pronounced structurally than that in sec. 22, being characterized by broader flats both above and below the belt of steep dips. However, notwithstanding this more favorable structural condition, the chances for oil accumulation are probably less in sec. 3 than in sec. 22, because the South Cochahee dome, immediately west of sec. 3, would trap the oil that otherwise might have migrated up the slope from the west.

The terrace in sec. 35 has a broad upper flat in which three dry holes have already been drilled. The lower flat is less well marked

but may be sufficient to have produced the same effect as that in sec. 22, providing there was an available source of oil. It should be recognized, however, that the chances for obtaining oil in these terraces is considerably less than in well-defined anticlines or domes.

SYNCLINES.

In secs. 12 and 13 there is a deep syncline which, in view of the number of dry holes obtained around its margin, is exceedingly unpromising oil and gas territory. A similar syncline occurs in the NW. ¼ sec. 25 and extends southward across sec. 26. Other synclines in which oil will probably not be obtained occur in parts of secs. 17, 18, and 19.