THE OIL AND GAS GEOLOGY OF THE FORAKER QUADRANGLE, OSAGE COUNTY, OKLAHOMA.

By K. C. Heald.

INTRODUCTION.

Scope of paper.—The aim of this paper is to describe and portray those features of the Foraker quadrangle which may be of interest and assistance in the discovery and development of accumulations of oil and gas. In the first part of the paper the character of the surface and the accessibility of different parts of the quadrangle are discussed. Under the heading "Stratigraphy" those strata which are valuable as key horizons in mapping structure are described in detail, and the probable positions of oil sands are given. Under the heading "Structure" the geologic structure is portrayed by map and stereogram, and the anticlines which the writer believes favorable for the accumulation of oil and gas are described in detail. In conclusion specific recommendations for prospecting are given, and the writer's belief concerning the probability of the occurrence of oil and gas accumulations is set forth.

Location.—The Foraker quadrangle lies in the extreme northwest corner of Osage County, Okla., between meridians 96° 31′ and 96° 45′ and parallels 36° 45′ and 37°. Its north boundary is just north of the Kansas-Oklahoma line. (See fig. 1 and Pl. II.)

Field work.—The field work that furnished the data for this report was done during the summer and fall of 1915. Headquarters were made in the towns of Grainola and Foraker, where good hotel accommodations were obtained, and in Foraker very good livery service was available. Reconnaissance trips were first made over the area, after which the detailed work necessary for mapping the geology was done. Several recognizable beds of limestone were traced through the region, and elevations were taken at many points along the outcrops. These elevations were obtained by plane-table work, supplemented by a few hand-level observations close to established bench marks. The work was much facilitated by the excellent base map prepared by the Geological Survey in 1914, on which the surface

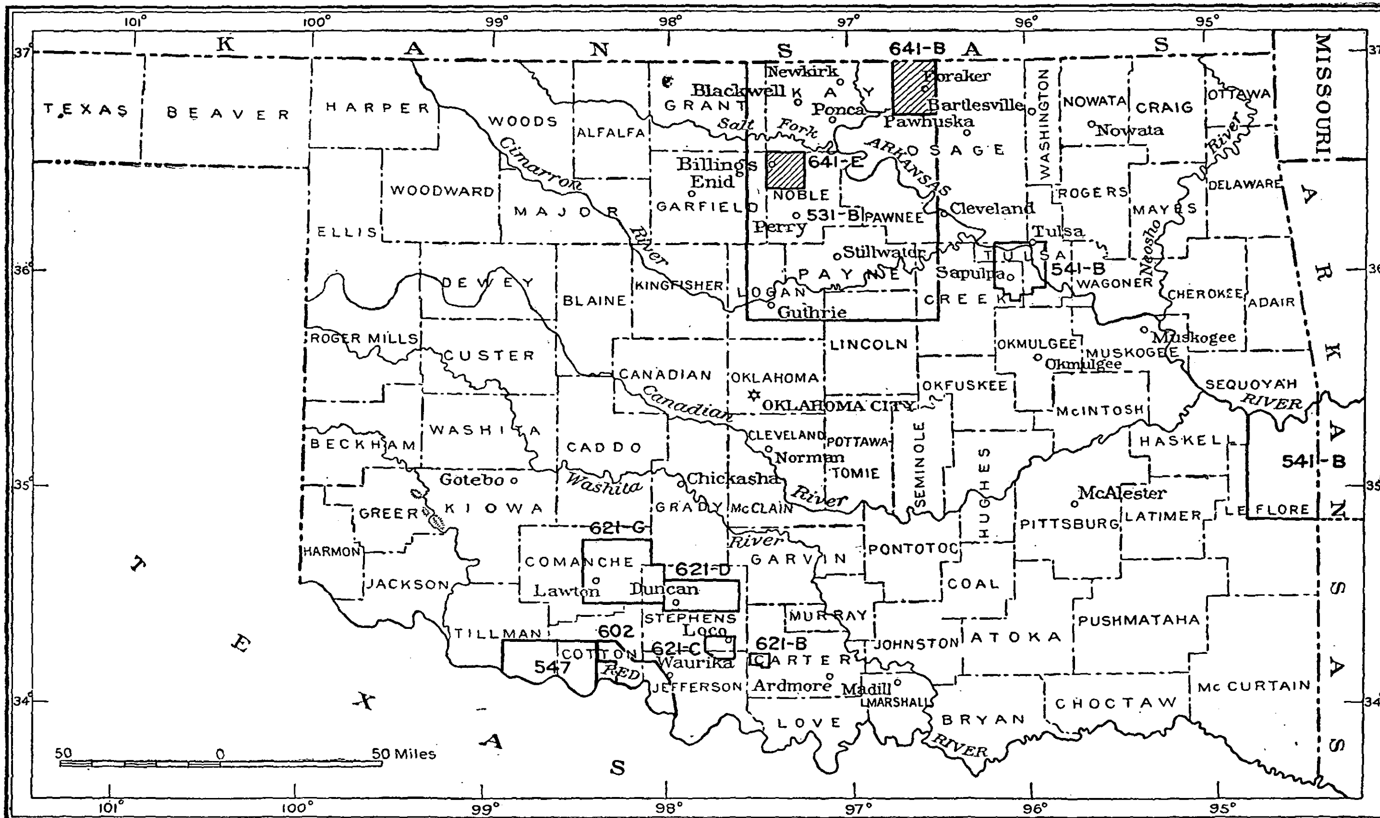


FIGURE 1.—Index map of Oklahoma showing location of Foraker quadrangle (marked "641-B"). The districts indicated by heavy lines have been described in separate papers, the number of which appear in black type.

features are represented by contour lines with a 20-foot interval. (See Pl. II.) Bench marks are established at most of the section corners and quarter corners.

GEOGRAPHY.

Relief.—A view westward from the rim of the scarp west of North Bird Creek, near the east side of the Foraker quadrangle, gives the general impression of a great plain with almost no relief. This plain seems to slope gently for some 15 miles to the steep bluffs west of Beaver Creek, which are the southern extension of the Flint Hills of Kansas. In places there are scars, which evidently mark steep-sided valleys, and a few low hills modify the regularity of the surface, but they are not prominent. This smooth-appearing plain, however, is cut by numerous valleys. Erosion is active, and gulches and valleys are being vigorously excavated. The resultant débris is carried away by the streams before it has a chance to accumulate in any great quantity, and consequently the valley sides are steep, although the many beds of soft shale prevent the development of prominent cliff faces. The more resistant rocks form conspicuous outcrops, whereas the softer, less resistant shales and thin limestones are carried away faster, and because of this difference the resultant slope has the appearance of a series of steps or terraces, such as are shown in figure 2.

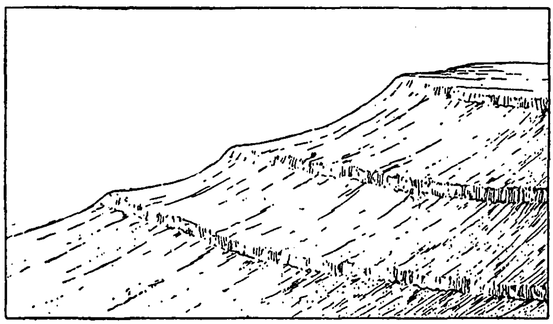


FIGURE 2.—Hill slope showing alternating hard and soft strata.

The most striking topographic features in the quadrangle are the bluffs west of Beaver Creek, in the northwest corner, and those which rim the valleys of Buck Creek, Sand Creek, North Bird and Middle Bird creeks, at the eastern margin. These scarps show the same general feature of alternating gentle and steep slopes as is shown in the valley sides, except that the slope, taken as a whole, is more abrupt—in fact, the scarps are so abrupt and so continuous that they form considerable obstacles to travel by vehicle. Both lines of bluffs vary locally in trend, having reentrants and projections in response to the locations of stream courses and consequent erosional activity, but they maintain a constant general direction of a little east of north.

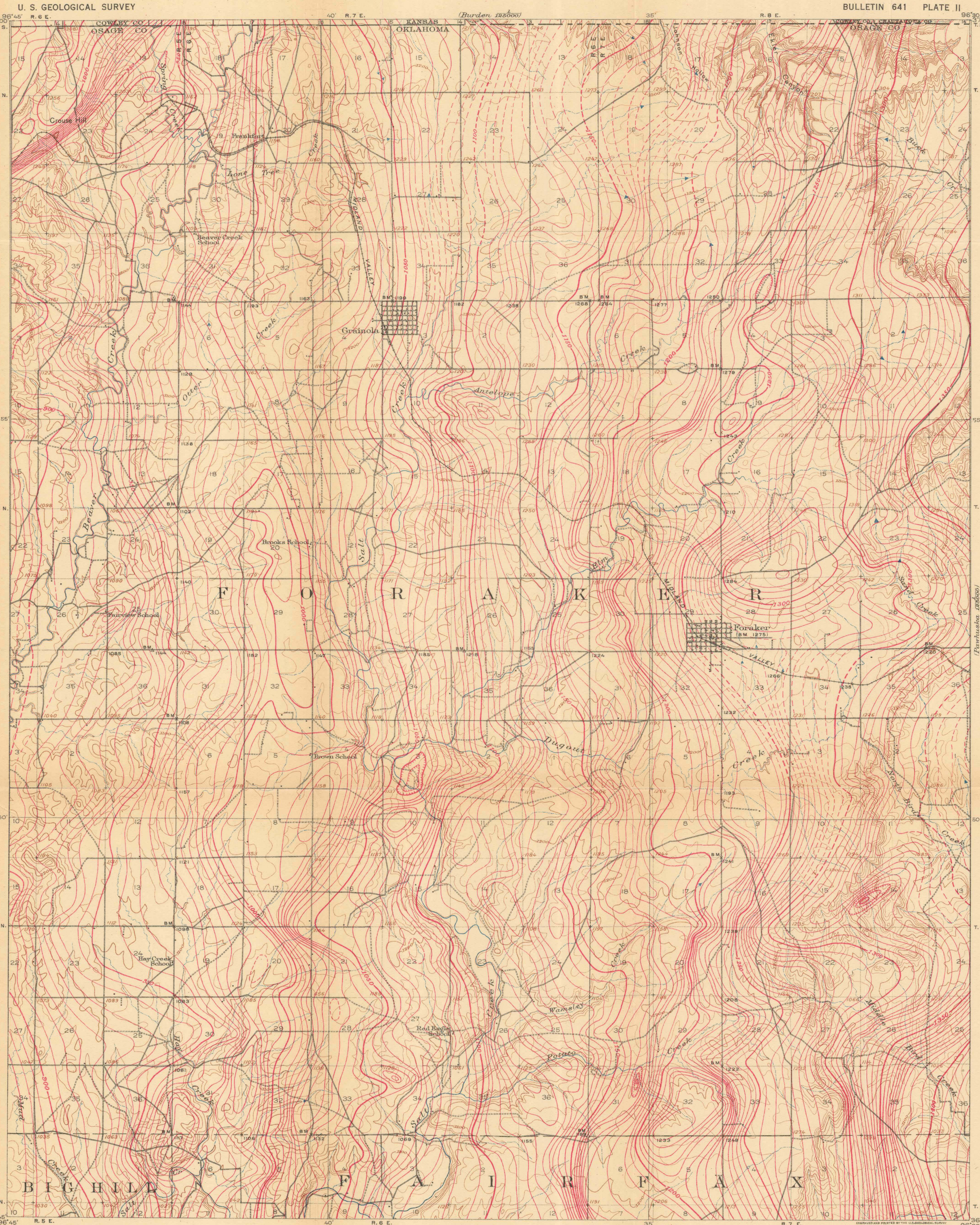
Drainage and water supply.—Most of the Foraker quadrangle is drained by Salt Creek, which heads a little south of the Kansas line and flows southward through the center of the area. About 30 square miles in the northwest corner is drained by Beaver Creek, and the water from a narrow strip along the east edge flows into the headwaters of Buck Creek, Sand Creek, North Bird and Middle Bird creeks, which are pushing west and encroaching on the Salt Creek drainage basin.

In years of slight rainfall all the streams are intermittent and a large percentage of the wells in the quadrangle go dry. The water in the wells comes from joint planes in limestone, as is clearly indicated by several shallow wells that give an abundance of water, though comparatively deep wells near by are dry. For this reason it is suggested that drilling for water should not go to a depth exceeding 75 feet, not only because the cost of drilling increases with increasing depth, but because joint planes are presumably more abundant near the surface. All the water in the area is limy and would doubtless leave quantities of scale in boilers.

Culture.—The Foraker quadrangle is traversed by but one railroad, the Midland Valley, whose trains stop at Foraker, Grainola, and Frankfort. Foraker and Grainola are small towns, the only ones in the quadrangle, and Frankfort is a flag station. The southwestern part of the district can be more easily reached from the town of Burbank, on the Santa Fe Railway, only 4 miles south of the southwest corner of the quadrangle.

The greater part of the land is given over to the cattle industry, which is in a very thriving condition. Agriculture is not neglected, however, and there are few places in the quadrangle that are more than a mile from cultivated land.

The road net is very good, although the roads themselves are not. A large percentage of the section lines are open, and in dry seasons practically any of them may be traveled with a team, or even with an automobile. Good roads could be made along any of them with comparatively little expense. The many limestone outcrops could furnish an abundance of excellent road metal for use in places that are inclined to be soft in rainy weather, and slight detours from section lines would do away with the necessity of grading any bad hills. The most troublesome feature is the lack of bridges over the larger streams, which during very rainy weather may be impassable for several days at a time. The only good wagon bridge in the quadrangle is the one over Elm Creek, 2½ miles west of Foraker. This is a very serviceable bridge, built of rock quarried at the bridge site. More work of this nature would go far toward making travel throughout the quadrangle possible in any weather.



R.B. Marshall, Chief Geographer.
Sledge Tatum, Geographer in charge.
Topography by Stuart T. Penick and R.R. Monbeck.
Control by E.L. McNair, R.R. Monbeck, R.W. Burchard, and R.M. Copeland.
Surveyed in 1914.

SURVEYED IN COOPERATION WITH THE STATE OF OKLAHOMA

MAP OF FORAKER QUADRANGLE, OKLAHOMA

SHOWING TOPOGRAPHY AND STRUCTURE CONTOURS

Scale 1/62500

Contour interval 25 feet.
Datum is mean sea level.

Structure contours drawn on top of the Foraker limestone, by K. C. Heald.

STRATIGRAPHY.

ROCKS EXPOSED.

AGE AND GENERAL CHARACTER.

The stratigraphic column in the Foraker quadrangle is made up of rocks of lower Permian and upper Pennsylvanian age.

The exposed rocks are all sedimentary. Limestone and shale are the most abundant, but some sandstone is present. The conspicuous outcrops of the limestone beds and the control they exert over the surface features make them much the most important rocks of the section when structural mapping is attempted, because they can be easily traced. By means of elevations taken on these beds the position and slope of the strata may be determined.

No complete description of the stratigraphy will be given in this paper, but for the convenience of those who wish to do detailed geologic work in this region the most prominent beds or key rocks are described in detail below. The general relations of the beds are shown in figure 3.

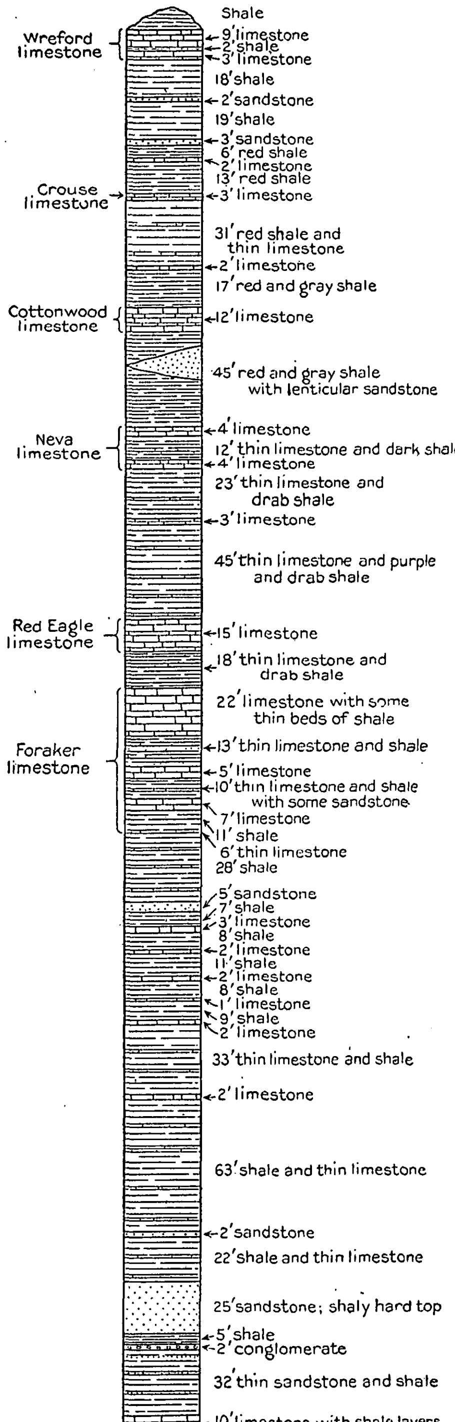


FIGURE 3.—Stratigraphic section of rocks exposed in the Foraker quadrangle, Okla.

KEY ROCKS.

Wreford limestone.—The Wreford limestone is from 10 to 14 feet thick in the Foraker quadrangle. It occurs in three distinct layers. Between the middle and bottom layers there may be a bed of shale, which has a thickness of 2 feet at the locality where it appeared best developed.

The distinguishing features of the Wreford are the buff color of the middle bed and the character and mode of occurrence of the chert which forms a large part of the rock. The chert, owing to its greater hardness than the limestone in which it is embedded, weathers into all manner of irregular projecting lumps and knobs. At some localities imperfectly silicified limestone takes the place of the chert and projects from the body of the rock in prominent layers, large pieces of which litter the ground in the neighborhood of the outcrop.

The character of the formation is shown in detail in the following section:

Section of Wreford limestone half a mile east of Hardy, Okla.

	Feet.
Limestone, blackish gray on weathered surface, light buff to brownish gray on fresh surface; in several slabby beds 2 to 6 inches thick; top bed is massive, 12 to 16 inches thick, hard and dense; lower beds break into slabby, lenticular pieces. Fossiliferous; considerably limonitized; has many echinoid spines; is in places full of smooth cylindrical holes half an inch to 3 inches in diameter. Above this is a mass of shale and limestone	4
Limestone, buff, hard, dense, massive; full of chert; yellowish brown on weathered surface, blue-gray on fresh surface. About 25 per cent of the rock is chert, in irregular nodules and layers, lens-shaped concretions roughly parallel to bedding most common; chert is fossiliferous	3
Shale, limy, yellow-gray to green-gray; looks sandy but no grains distinguishable; bedding regular; fossiliferous	2
Limestone, light buff on both weathered and fresh surfaces, dense, hard, compact; full of fossils, which are locally replaced by glassy or milk-white calcite; in two beds with a 1-inch shale parting; the many crystalline fossils give the rock a spotted appearance	3
	12

Crouse limestone.—A prominent limestone about 3 feet thick, the Crouse, lies approximately 70 feet below the base of the Wreford. Its outcrop is almost invariably conspicuous, and the rock is distinctive enough to make it easily recognizable. The characteristic features of this limestone are the form of the outcrop, which shows many large, massive blocks, the absence of recognizable fossils in any abundance, with the exception of small Fusulinas, which are plentiful, and the presence of many smooth, round holes that are vertical or steeply inclined to the bedding. There are similar holes in other limestones of this region, but nowhere were they noted in such numbers as in the Crouse limestone.

Cottonwood limestone.—The Cottonwood limestone is from 10 to 16 feet thick in the Foraker quadrangle. It is thickest near the

Kansas line and thins to the south. Of the total thickness usually only the top 2 feet is visible, the remainder being covered with soil. This is due to the fact that the top 2 feet consists of hard, resistant limestone, while the remainder of the formation is made up of thin oolitic limestone and shale. In some localities there is a thin limestone conglomerate at the base of the formation. Although the thin limestones at the base do not form prominent outcrops, they are the most easily recognizable feature about the formation, because of their lithologic character and the fact that they carry many fossils, among which a small coiled shell (Schizostoma) is common. This coiled shell was rarely observed at any other horizon. In this quadrangle a thin oolitic limestone, with an abundance of fossils, especially Schizostoma, is almost certain to be at the base of the cottonwood limestone.

The following section measured north of Grainola gives a detailed description of the formation:

Section of Cottonwood limestone in the SW. ¼ SE. ¼ sec. 21, T. 29 N., R. 6 E.

	Ft.	In.
Massive limestone, bluish white on weathered surface, light gray to light buff on fresh surface; surface uneven and full of round holes as much as 2 inches in diameter, but it is not as rough as the Neva (see below); occasional rough pieces have dark surfaces; no chert	2+	
Thin shale and oolitic limestone	11	0
Limestone conglomerate, blue-gray to yellowish; made up of rolled pebbles of limestone, shell fragments, and some little hematite pebbles; degree of cementation varies; a good deal of crystalline calcite; many fossils; coiled shells (Schizostoma) and fluted, long-nosed brachiopods (Meekella) most characteristic		6
Shale, olive-drab, clayey	2	0
Limestone conglomerate as above, except that it contains more pebbles and less lime; fossiliferous (Myalina, productids); cross-bedded; largest pebbles seen about half an inch in diameter	2	0
Shale or marl, pink, greenish gray, and white; bedding irregular; beds form overlapping lenses; contact with overlying conglomerate very irregular	2	6
	20+	

Neva limestone.—The Neva limestone furnishes one of the most prominent outcrops in the Foraker quadrangle. It is easily distinguished from any of the limestones occurring higher in the section, and also from those lower in the section, with the exception of the Red Eagle limestone, which lies about 55 feet below the Neva. The total thickness of this formation is 15 to 20 feet. It is made up of massive beds, 4 to 6 feet thick, at the top and the base, with thin beds of limestone and shale between. The total thickness of the top bed is rarely seen, as the rock is evidently very soluble. The float is covered with jagged points and pinnacles which are so sharp and numerous that it is painful to handle a piece. A fresh fracture discloses numerous irregular cavities which may be filled with light-colored incoherent granular material.

In many places the weathered surface of the lower bed is very rough, but it does not reach the degree of irregularity that is shown by the upper bed. The cavities in the lower bed are usually lined with bright-brown limonite. Both of the massive beds are fossiliferous, but the thin beds between them are much more so. These thin beds also carry much chert. In many localities a very persistent cherty bed is found about 2 feet above the lower massive bed.

Red Eagle limestone.—The Red Eagle limestone is so named because of its excellent exposures near the Red Eagle School, southwest of Foraker. Its total thickness was not surely determined; in some places it is at least 17 feet, but in others it is probably much less. The Red Eagle consists of a number of distinct beds of limestone, between which are beds of shale in some localities. One of the most distinctive features of the top bed of the limestone in much of the quadrangle is the character of the fresh surface, which shows an abundance of tiny grains of crystalline calcite, giving the surface the appearance of having been covered with frost or light snow. The following section gives the details of the upper part of the limestone in the southwestern part of the quadrangle. At this locality there are no shale partings, but the limestone varies in character. The thickness of the several members is estimated.

Section of Red Eagle limestone on tributary of Hay Creek, a quarter of a mile east of corner of secs. 1, 2, 11, and 12, T. 26 N., R. 5 E.

	Ft.	in.
Limestone, gray, thin bedded, slabby, clayey	3	9
Limestone, creamy buff on weathered surface, medium hard; breaks easily but is not glassy brittle; fossiliferous; lower part of bed has much limonite	1	0
Limestone, thin bedded, blocky rather than slabby, light gray, brittle, hard, fossiliferous	4	0
Limestone, dove-gray on fresh surface, massive, clean, hard, brittle, fossiliferous; good bed to burn	1	6
Limestone, dove-gray, pure; makes persistent bed but weathers back under overlying bed		3
Limestone, thin bedded, rough, slabby, whitish gray on weathered surface, blue-gray on fresh surface; in part good limestone, in part rather clayey; fossiliferous (corals, productids)	4	0
Limestone, pigeon-blue on weathered surface, brownish gray on fresh surface, much limonitized; does not weather rough; fossiliferous; medium hard	2	0
	16	6

In tracing this limestone for the purpose of determining structural conditions great care must be exercised, as it is easy to mistake the outcrop of one bed for that of another and so introduce an error. A mistake of small actual amount may be relatively great in its effect because of the low dips prevalent in this region.

Foraker limestone.—The Foraker limestone, which forms the rim of Ekler Canyon and is prominent along the line of bluffs in the eastern part of the quadrangle, is about 74 feet thick. Although the great part of this thickness is made up of limestone, much of the rock is so soft and thin bedded as to give no outcrop. Some soft shale is also present. The heavy limestone may be easily recognized by the large number of Fusulinas which it contains, the rock in places being fairly jammed with them. Another distinguishing mark is the great abundance of chert concretions which occur in this limestone. The fresh surface of the chert has in general a light blue-gray color, and the concretions usually include fossils which show white against the bluish background. The most common fossil in the chert is *Fusulina secalica* Say, but there are also small brachiopods and a few corals and crinoid stems.

Sandstone.—A sandstone, to which no name has been given, occurs about 28 feet below the base of the Foraker limestone. It is a particularly good horizon marker, as it is some distance either above or below other sandstones with which it might possibly be confused. Its lithologic character also makes its identification simple.

The average thickness of this bed is about 3 feet, though locally it is more, a thickness of 7 feet having been observed at one place. In some localities, however, this sandstone is probably absent—at least there is no trace of it on the surface.

The color of the weathered surface is reddish gray. The fresh surface is lighter in color and thickly dotted with small coffee-brown spots which are probably manganiferous. The most distinctive feature is the presence of muscovite. In many places this mineral is very prominent, and it can always be detected if the rock is examined carefully. The sand making up the body of the rock is extremely fine grained translucent quartz. Many of the grains are but slightly rounded, crystal faces with clean, sharp corners being present in abundance. This feature may be observed without the help of a lens, as the sunlight is reflected from many tiny flashing points on a fresh surface of the rock. In places this sandstone is somewhat limy, but in most of the localities where it was tested no calcium carbonate was present.

ROCKS NOT EXPOSED.

IMPORTANCE.

In order to predict with any degree of probability as to the occurrence of oil or gas at any particular locality, it is necessary to have a knowledge not only of the structure which may be detected by examination of the strata that crop out at the surface, but also of that shown by the strata that occur below the surface to any depth which may be reached by the drill. An anticline whose shape is favorable for the accumulation of oil and gas and which is surrounded by a plentiful gathering ground but which lacks the proper succession of strata to transport and retain the oil would be of as much value to the oil man as a dry creek bed would be to a man in search of water. Without the proper succession of pervious and impervious strata oil accumulation will seldom take place. On the other hand, a knowledge that such a succession of strata is probably present will make it desirable to explore many localities where, if such knowledge were lacking, the chance of finding oil would not be considered good enough to justify the expense of drilling.

The deepest of the sands which probably underlie this field and which have been proved to contain oil at adjacent localities is that known as the Tucker or Meadows sand. Although it is possible that there are oil-bearing sands below this one, it has never been proved for north-central Oklahoma, and only the strata lying between the Tucker sand and the surface will be considered in this paper.

SOURCES OF INFORMATION.

Knowledge of the strata which underlie any given locality may be obtained in two ways. The first is by actual observation of the strata where they rise to the surface at some distance from the locality concerning which information is desired. In comparatively few places do the strata maintain a horizontal position for any great distance. More commonly they are tilted to a greater or less degree, and where this is the case it is only necessary to travel in a direction opposite to that toward which they are tilted to reach the outcrop of any persistent bed. This is particularly true of a region where the strata uniformly dip in one direction, as in northeastern Oklahoma. The difficulty encountered where the beds have been only slightly tilted is the great distance that must be traversed before a bed which lies at any considerable depth will be found at the surface. Even when the point of outcrop is attained, it may be found that the soil is so thick that nothing can be learned of the character of the rocks which lie below. In northeastern Oklahoma, where the average dip to the west is only about 30 feet to the mile, it would be necessary in order to measure a section having a vertical extent of 3,000 feet, to determine the character and thickness of the beds outcropping over a distance of about 100 miles. It is therefore evidently impracticable if not impossible to obtain in this way accurate knowledge of the strata which lie below the surface.

The second source of information is that furnished by the records of the strata passed through when wells are drilled. All such records are valuable and should be preserved. A good well record furnishes more accurate information concerning the succession of the strata below the surface than can be obtained in any other way, and by the study and comparison of such records it is possible for a geologist to determine the changes that occur in the thickness and character of the strata, and under some conditions to tell with precision what succession of beds will be encountered in regions which have not been explored by the drill but which are not far removed from those that have been.

No wells have been drilled in the Foraker quadrangle, but several have been sunk at points not very far distant, and the logs of these wells, supplemented by surface data, permit tracing of the underground formations with small probability of error.

GENERAL CHARACTER AND AGE.

The strata between the surface and the Tucker sand are of Pennsylvanian age, with the exception of the uppermost beds in the northwest corner of the quadrangle, which include some of the Permian rocks that crop out farther east.

The upper thousand feet of the rocks below the surface are dominantly shale and, in slightly less total thickness, limestone. Lower down the limestones are of insignificant amount in comparison to the shale and sandstone. Most of the lower part of the section above the Tucker sand is occupied by shale, which may be blue, black, or brown, with scattered red bands. The nature of the formations encountered in a well drilled a short distance west of the quadrangle is shown in the log given on page 28.

Log of Mary Hess well No. 1, in sec. 4, T. 28 N., R. 4 E.

[By E. W. Marland and others.]

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	8	8
Lime	17	25
Shale	20	45
Red rock	5	50
Lime	20	70
Red rock	20	90
"Slate"	20	110
Red rock	20	130
Lime [Wreford limestone]	20	150
Red rock	15	165
Shale	5	170
Red rock	20	190
Lime	5	195
Red rock	5	200
Lime	20	220
Red rock	10	230
Lime	5	235
Red rock	10	245
Lime	5	250
Shale	5	255
Lime	10	265
Red rock	15	280
Lime [Cottonwood limestone]	20	300
Red rock	65	365
Lime	30	395
Shale	5	400
Lime	20	420
"Slate"	5	425
Lime }	40	465
Lime slate } [Foraker limestone]	5	470
Lime }	60	530
"Slate"	10	540
Lime	20	560
Shale	15	575
Lime	10	585
Shale	45	630
Lime	10	640
"Slate"	18	658
Lime	17	675
"Slate"	25	700
Lime	10	710
"Slate	35	745
Lime	10	755
Shale	22	777
Lime	3	780
Shale	20	800
Lime	3	803
Shale	19	822
Lime	23	845
Shale	20	865
Lime	5	870
Shale	5	875
Lime	40	915
Shale	25	940
Lime	10	950
Shale	26	976
Lime	8	984
Shale	12	996
Lime	4	1,000
Shale	8	1,008
Lime	2	1,010
Shale	10	1,020
Lime	10	1,030
Shale	15	1,045
Sand	10	1,055
Shale	65	1,120
Lime	10	1,130
Shale	15	1,145
Lime	75	1,220
Shale	7	1,227
Lime	15	1,242
Shale	16	1,258
Lime	12	1,270
Shale	10	1,280
Lime	23	1,303
Shale	37	1,340
Sand (water)	80	1,420
Shale	25	1,445
Sand	30	1,475
Shale	77	1,552
Lime	8	1,560
Shale	5	1,565
Red rock, pink	5	1,570
Sand and shale, cavy	20	1,590
Red rock	13	1,603
Sand	5	1,608
Lime	4	1,612
"Slate"	48	1,660
Red rock	35	1,695
"Slate"	10	1,705
Broken sand	30	1,735
"Slate"	95	1,830
Lime	5	1,835
"Slate"	20	1,855
Sand (water and gas)	50	1,905
"Slate	6	1,911
Red rock	10	1,921
"Slate"	182	2,103
Sand	27	2,130
Sand	65	2,195
"Slate"	12	2,207
Lime	18	2,225
"Slate"	130	2,355
Sand	12	2,367
Sand (water)	38	2,405
Bottom sand	5	2,410
Lime and slate	10	2,420
Sand	80	2,500
Red rock	30	2,530
"Slate"	35	2,565
Shale	60	2,625
Sand and shale	15	2,640
Shale	70	2,710
Lime	6	2,716
Black shale	6	2,722
Lime	7	2,729
Shale	101	2,830
Lime	5	2,835
Shale	5	2,840
Sand	15	2,855
Black shale	28	2,883
Lime	52	2,935
Sand	8	2,943
Shale	5	2,948
Lime	22	2,970
Sand	24	2,994
Black shale	10	3,004
Sand	13	3,017
Coal	5	3,022
Sand	7	3,029
Black shale	48	3,077
"Slate"	63	3,140
Sand	25	3,165
Gray sand (water)	20	3,185
Shale	58	3,243
White lime	5	3,248
Black lime	18	3,266
Limy sand; plugged at 3,485 feet	219	3,485

CORRELATIONS.

The determination of the rocks underlying the surface of the Foraker quadrangle was much simplified by the work of the Oklahoma Geological Survey in identifying the Neva limestone, which crops out just west of the town of Cushing, and determining the relation of the Neva to the Pawhuska limestone, which crops out at Drumright, the Neva and Pawhuska limestones forming the top and base, respectively, of a measured stratigraphic section. This section shows that the top of the Pawhuska lies 552 feet below the base of the Neva limestone.[1] As the relation of the oil sands to the Pawhuska limestone in the Cushing field is known, their relation to the Neva is also determined. The Neva limestone crops out extensively in the Foraker quadrangle. There are differences between the succession of strata lying below it here and that in the Cushing field, dependent on the persistency of the individual beds, both as regards thickness and character, but the changes may be recognized by a study of the logs of the wells in the territory between the two areas.

The approximate horizons of the formations occurring at the mouths of holes drilled near Ralston, Blackburn, Fairfax, Ponca City, and Newkirk are known, and thus starting points were available for the comparison of each well record with others. In this way the formations occurring at Cushing were traced northward through Pawnee, Osage, and Kay counties, with small probability of error, and were recognized in wells that have been drilled only a few miles west of the Foraker quadrangle. From the proximity of these wells to the quadrangle it is inferred that the same succession of beds will be found here as in the localities where the wells were drilled.

As a result of the work described above, it may be confidently stated that below the surface of the Foraker quadrangle there are sands at the horizons of the main producing sands of the Cleveland and Cushing fields. In addition to these sands, which lie more than 2,000 feet below the surface, there are undoubtedly some of the higher sands which have been found to carry oil and gas in the western part of Kay County. If oil and gas are not found in the Foraker quadrangle, it will not be for lack of strata which are suitable to contain them.

The approximate distances between the top of the Foraker limestone and the sands corresponding to those of the Cleveland pool are as follows: Foraker limestone to Layton sand, 1,680 feet; to Cleveland sand, 1,940 feet; to Wheeler sand, 2,420 feet; to Bartlesville sand, 2,850 feet. So far as could be determined there is no break between the

[1] Buttram, Frank, The Cushing oil and gas field, Okla.: Oklahoma Geol. Survey Bull. 118, pp. 9–10, 1914.

Bartlesville and Tucker sands in this region. The relations of the sands found at Cushing to those found west of the Foraker quadrangle and a little south of the Kansas line are shown in figure 4.

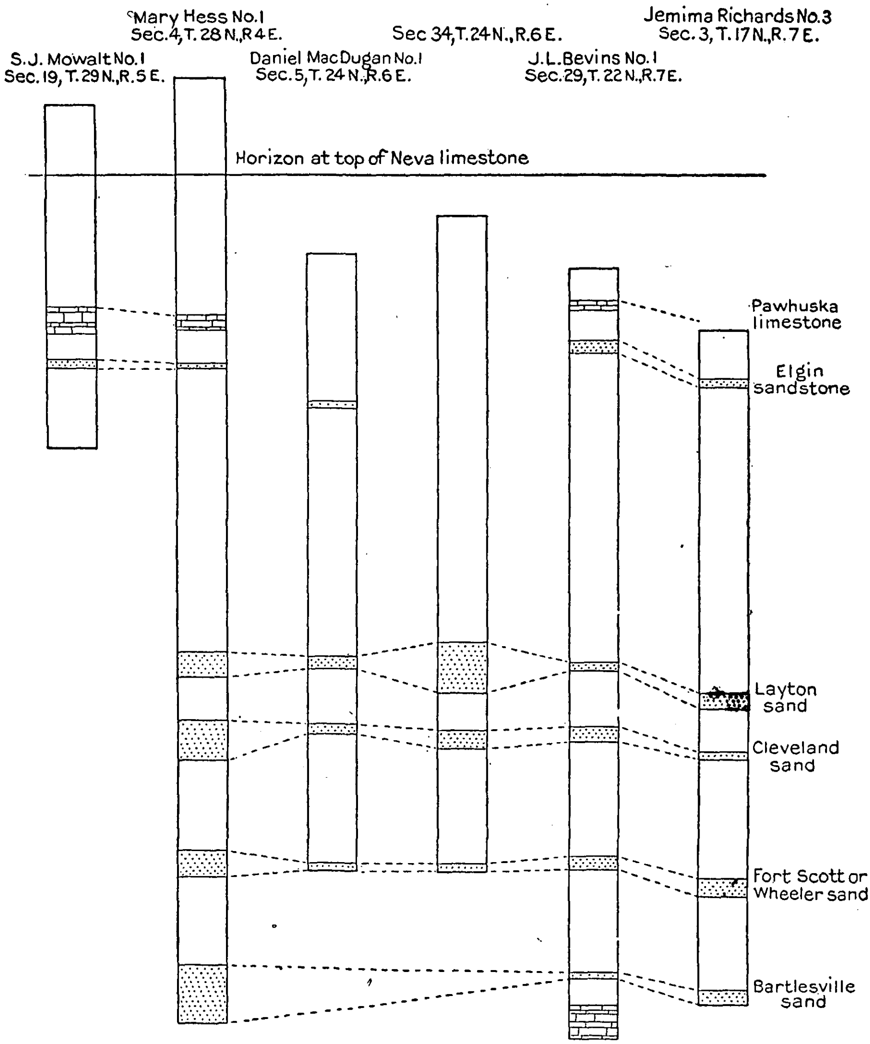


FIGURE 4.—Skeleton logs of wells in north-central Oklahoma, showing correlation of sands.

The conclusions reached agree very closely with the tentative correlations suggested by Wood[1] and by Ohern and Garrett.[2]

[1] Wood, R. H., Oil and gas development in north-central Oklahoma: U. S. Geol. Survey Bull. 531, p. 32, 1911.

[2] Ohern, B. W., and Garrett, R. E., The Ponca City oil and gas field: Oklahoma Geol. Survey Bull. 16, p. 29, 1912.

STRUCTURE.

DEFINITION.

The term "structure" as used in this report is limited to mean the form taken by the strata, whether level, warped, folded, or faulted. Geikie[1] speaks of the structure as "the architecture of the earth's crust." It must, however, be differentiated from the sculpture of the earth's surface. The practical oil man is likely to limit the applition of the term to those structural features which he considers favorable for oil accumulation. When the possibilities of oil accumulation in any region are being discussed, the question is commonly asked, Is there any structure? This usage is entirely too narrow and should be discouraged.

METHOD OF DETERMINING STRUCTURE.

In order to determine the structure of a region in which the folding is very slight, as in the Foraker quadrangle, it is necessary to obtain a great number of accurately located elevations on some one key rock. The points at which these elevations are taken must, if possible, be scattered over the whole area whose structure it is desired to ascertain. As no one bed crops out over so great an area, it is necessary to take observations on the outcrops of many different beds, from which the elevation of the key rock is computed by adding or subtracting, as the case may demand, the vertical distance between the bed on which an elevation is taken and the key rock. For example, if the Neva limestone is chosen as the key rock, and the Cottonwood limestone crops out at the surface, a careful determination of the elevation of the top of the Cottonwood will be made. It has been determined by measurements made in localities where both Cottonwood and Neva limestones are exposed that the vertical distance from the top of the Neva down to the top of the Cottonwood is about 57 feet. If the elevation determined on the Cottonwood is, say, 1,100 feet, 57 subtracted from 1,100 will give 1,043 feet, the elevation of the Neva at that point.

In order to obtain the data for mapping the structure the first step is to study the rocks exposed and learn the distance between the prominent beds on which elevations may be taken and the characteristics of those beds, so that when an outcrop is encountered it will be possible to say which bed it is and just how far above or below the key rock it should be. The second step, which may often be combined with the first, is to determine the elevations at many points on the outcrops scattered over the area which it is desired to map, locating each determined point on a map and recording the bed upon which it was taken. The third step is to compute from these elevations those of the key rock as outlined above, and by connecting

[1] Geikie, James, Structural and field geology, 3d ed., p. 104, 1912.

points of equal elevation on the key rock to draw the structure contours, which show, to those who understand reading contour maps, the form of the surface of the key rock as plainly as if all the earth and rock were stripped from above it, leaving it exposed to view. (See explanation of contours below.) The structure in the deeply buried sands does not as a rule exactly parallel that shown in the beds at the surface, and hence there is always a possibility of error. When wells are drilled in this region, the well logs will furnish information by means of which the structure may be ascertained much more exactly than is possible through work with surface outcrops alone, and the structure contours may be revised. It is hoped, therefore, that when the full report for this quadrangle is prepared well logs will be available.

METHOD OF REPRESENTING STRUCTURE.

Structure may be shown graphically by structure contours, by cross sections, and by block diagrams or stereograms.

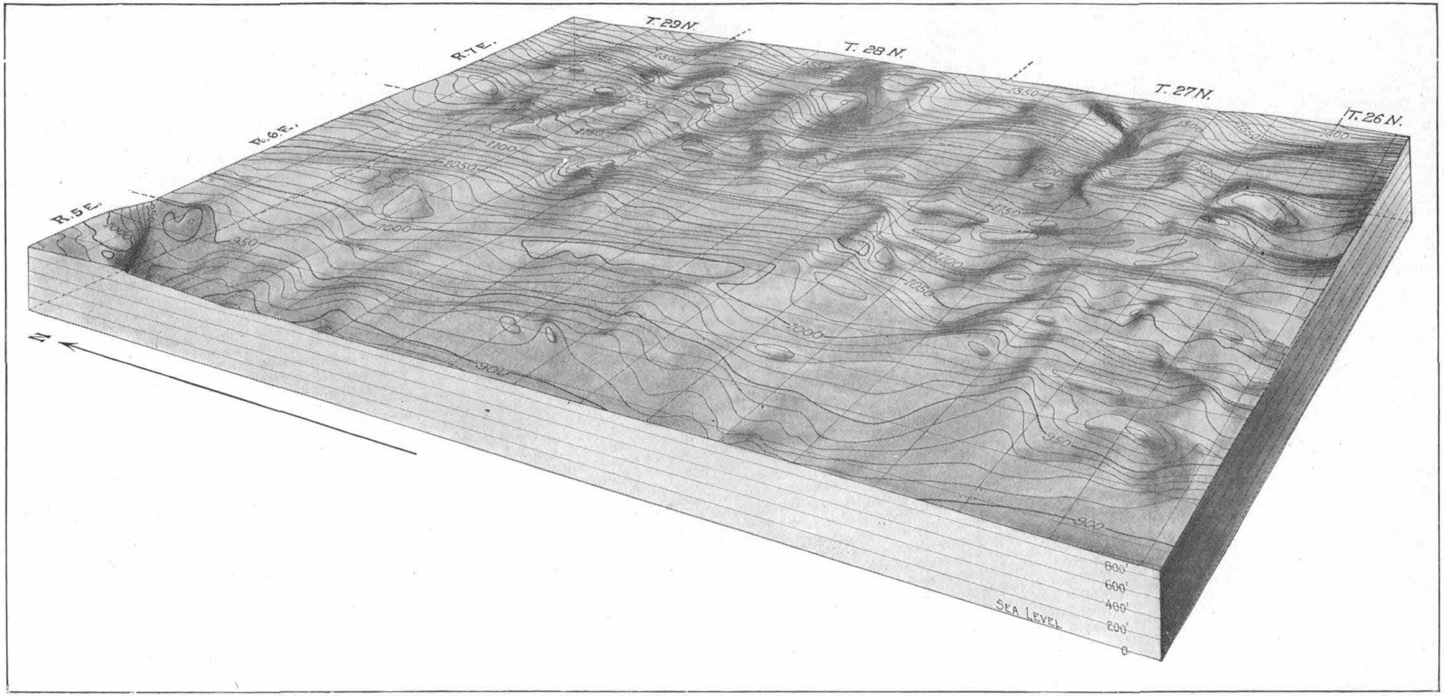
Contours.—A structure contour, like a surface contour, represents a line all points along which are uniform in elevation. Thus any point on the key rock which lies on the line represented by the contour marked 1200 is at an elevation of 1,200 feet above sea level, and any point on the line represented by the contour marked 1250 lies 1,250 feet above sea level. Every tenth contour is printed on the map in a heavy line as a matter of convenience in reading and tracing the lines. The contours are spaced at intervals of 5 feet—that is, for example, the contours between those marked 1200 and 1250 represent lines at elevations of 1,205, 1,210, 1,215 feet, etc. By means of these lines it is possible to tell to what degree and in what direction the beds dip.

Cross sections.—Cross sections show the configuration of the strata along some one line, as if the earth had been slashed with a great knife and it were possible to see the side of the gash so made.

Stereograms.—Stereograms are sketches of the surface of the key rock as reconstructed from the contours. The sketch is so shaded that the features of the surface appear to stand out in relief, just as if the surface were exposed and had been actually sketched from some point at a distance and slightly above it. The vertical scale is much exaggerated in the stereogram, so that the relief is greatly emphasized.

MAJOR STRUCTURE.

The Foraker quadrangle is situated on the west flank of a great regional uplift, the center of which is occupied by the Ozark Plateau. The west flank includes a great area in southwestern Missouri, southeastern Kansas, northeastern Oklahoma, and northwest-



STEREOGRAM OF THE FORAKER QUADRANGLE, OKLAHOMA.

Represents surface of Foraker limestone.

ern Arkansas in which the prevalent dip of the strata is to the west. In the Foraker quadrangle the general dip is almost due west at an average rate of 30 feet to the mile. However, the dip is far from uniform, being in comparatively few places exactly or even approximately 30 feet to the mile. There are many steepenings where the slope may be as much as 80 feet to the mile, and a few where it is twice that. These are compensated by flattenings where the strata may be horizontal or even dip toward the east for a short distance.

If all the earth and rock were removed from above some persistent stratum which at present lies wholly below the surface, the stratum would appear as a broad plain sloping gently westward. The uniformity of this plain would be modified by low, rounded hills with broad, slightly arched tops; low ridges, most of them running in a general westerly direction and pitching to the west; and wide, shallow valleys with smoothly curving sides. At no place would there be such abrupt rises or steep-sided depressions as are visible on the present surface. The whole plain would be characterized by smoothness and very gradual changes in the direction and degree of slope. (See Pls. II and III.)

MINOR STRUCTURE.

The term minor structure is used to indicate subordinate folds whose forms differ noticeably from that of the major structure upon which they are situated.

ANTICLINES.

BEAVER CREEK ANTICLINE.

The Beaver Creek anticline, named from its position west of Beaver Creek, is by far the most pronounced fold in the Foraker quadrangle. It is in the northwest corner of the quadrangle, and only a small part of the complete fold is shown on the map, as its northeasterly extension lies in Kansas and its southwesterly extension in Kay County, Okla.

The part lying in the Foraker quadrangle trends southwest from a point about three-tenths of a mile west of the northeast corner of sec. 14, T. 29 N., R. 5 E., and passes into Kay County near the middle of sec. 22, T. 29 N., R. 5 E. The easterly dip, which persists for about half a mile, is at an average rate of 120 feet to the mile. The maximum vertical depression caused by this easterly dip is 60 feet, which is twice that of the Foraker anticline, the next largest fold shown on the map. The shape of the Beaver Creek anticline is undetermined, as the portions lying in Kay County and in Kansas were not mapped. However, it was observed that the easterly dip is much steeper than the westerly dip, and that the length of the anticline is much greater than the breadth. On the east flank of this fold there is a minor fold whose long axis extends about 1½ miles and trends about N. 70° E.

The structure contours showing this anticline are based on elevations at different points on the outcrops of the Wreford and Crouse limestones. Exposures are so plentiful that no difficulty was experienced in getting sufficient data for accurate contouring.

LONE TREE DOME.

The Lone Tree dome, named from its situation just east of Lone Tree Creek, is a small upwarp about 1 mile long and half a mile wide at its widest point. The center of this dome lies about a quarter of a mile south and an eighth of a mile east of the northwest corner of sec. 28, T. 29 N., R. 6 E. Its outline is that of a triangle with rounded corners and the base toward the south. The long axis runs almost due north, and the short one almost due east. The fold is nearly symmetrical with respect to the long axis. The easterly dip is small in vertical extent, the maximum vertical descent of the beds being about 10 feet. The change from easterly dip to westerly dip in the region directly east of the fold is not perceptible, as the slopes of the beds in either direction are so slight that their approach to horizontality is difficult to detect. On the west the slope of the dome merges with that of the westward-dipping monocline, the rate of dip being about 40 feet to the mile.

Elevations on the Cottonwood limestone were used in drawing the structure contours that depict this dome.

GRAINOLA ANTICLINE.

The Grainola anticline lies west of the town of Grainola. Its highest point as expressed on the surface is about a quarter of a mile east of the southwest corner of sec. 32, T. 29 N., R. 6 E. The arch of the fold is very low, the vertical extent of the easterly dip being about 12 feet. The easterly dip persists for about half a mile before it dies out and is replaced by the prevalent westerly dip.

This fold is pear-shaped. Its longitudinal axis is about 1¼ miles long, and its transverse axis about three-quarters of a mile long at the widest point. The long axis runs in a northeasterly direction; the short axis is perpendicular to it. The structure is continued on the west in an anticlinal fold that pitches westward at a rate of 40 feet to the mile for the first half mile and at 80 feet to the mile for the next quarter of a mile.

The elevations on which the contours are based are exclusively on the Cottonwood limestone, which crops out on the flanks of the fold. The crest of the fold is occupied by a valley containing no outcrops upon which elevations could be taken.

BROOKS ANTICLINE.

The Brooks anticline is a long, relatively narrow fold whose major axis runs southward from the middle of the southwest corner of sec. 17, T. 28 N., R. 6 E., to the middle of the SE. ¼ sec. 32, T. 28 N., R. 6 E. It lies west of the Brooks School. Its length is a little over 3 miles, and its maximum width less than three-quarters of a mile. The highest point is about in the center of sec. 20, T. 28 N., R. 6 E. The elevations on the west flank of this fold were taken on the Cottonwood limestone; those on the east flank on the top of the Neva limestone. The strata along the crest are hidden by a cloak of soil, and the correctness of the contouring is dependent on the accuracy of the assumption as to the distance between the Cottonwood and Neva limestones. The assumed distance of 55 feet was obtained by projecting dips observed on the two beds and is subject to an error of not more than 10 feet. If the distance used is 10 feet too great, there would be a marked flattening of dips but no actual reversal, and the wrinkles on the west side would still be present. In other words, there would be on the west side a series of small folds with their long axes trending almost due east and having a pronounced flattening at their east ends.

The east flank is mapped as being smooth and free from cross folds, but it is probable that the apparent smoothness is due more to the lack of rock outcrops on which observations could be taken than to actual absence of minor folds.

BROWN ANTICLINE.

The Brown anticline is a large, low upwarp, the highest point of which lies about a quarter of a mile south of the northeast corner of sec. 8, T. 27 N., R. 6 E., near the Brown School. It is really more of a terrace than an anticline, as the total easterly dip amounts to only about 12 feet. The flattening is very marked, however, and is prevalent over a large area.

The axis of this anticline runs in a direction a little east of north and is a little over 2 miles long. East of the axis the strata dip eastward at a rate of about 40 feet to the mile for a distance of three-tenths of a mile, beyond which the direction of dip is reversed and the beds rise to the east at a rate of more than 50 feet to the mile. For the first mile west of the axis the dip averages about 12 feet to the mile. Farther west the slope steepens, but so gradually that at no point can a pronounced change be seen. To the north the region of low dips includes a part of sec. 32, T. 27 N., R. 6 E., where it merges into the terrace structure of the Brooks anticline. The contours on the crest and east flank of this fold were determined from elevations taken on the upper part of the Neva limestone, and those on the west flank from elevations on the Cottonwood limestone. If there is any inaccuracy in the use of these beds it is in placing them too far apart, and the possible error does not exceed 10 feet. If the elevations on the west side of the fold are 10 feet too great the real structure is much like that shown on the map, except that the dip to the west is steeper and the anticline therefore more pronounced.

NEVA ANTICLINE.

The Neva anticline is a short, blunt fold which shows dips in three directions only—to the north, west, and south. The axis of this fold trends westward from a point about an eighth of a mile east of the southwest corner of sec. 16, T. 27 N., R. 6 E., to the quarter corner between secs. 17 and 20, N. 27 N., R. 6 E. The top of the fold is broad and flat, the east end showing a dip to the west not exceeding 10 feet to the mile. The steepest dip is on the south side of the tip, where the beds plunge to the southwest at a rate of 100 feet to the mile. On the north side of the anticline the dip is about 70 feet to the mile. The greatest change in the amount of dip occurs in the NW. ¼ NW. ¼ sec. 17, T. 27 N., R. 6 E.

The contours representing this fold are based entirely on elevations taken on the top bed of the Neva limestone. Exposures are scarce, and comparatively few elevations could be obtained; therefore, while the general shape of the fold is as mapped, it is quite probable that there are minor irregularities which do not appear on the map.

HAY CREEK ANTICLINES.

The Hay Creek anticlines, named from their location near the mouth of Hay Creek, are three in number. The east-west distance from the highest point of one anticline to the highest point of the next is about a mile. The middle one is the farthest north; the western one the farthest south. In point of size they are successively larger from east to west. The elevations on which the structure contours of these folds are based are mostly on the Neva limestone, but some of them are on a limestone which lies about 23 feet below the base of the Neva. Exposures are good and no trouble was experienced in getting abundant data.

The highest point on the western anticline is about an eighth of a mile due south of the northeast corner of sec. 1, T. 26 N., R. 5 E., from which point the rocks dip gently in all directions. To the east, south, and west the dip is at the rate of 70 feet to the mile. To the north there is almost no dip for the first half mile, and then the strata dip north at about 50 feet to the mile. The dip on the east persists in that direction for about half a mile and then reverses, the beds rising gently toward the east. The flattened top of this dome is less than half as wide as it is long. The long axis trends a little east of north throughout most of the length, but swings sharply northwest at the north end. The long sides bow in toward each other in the middle and the ends are rather blunt.

The highest point of the middle Hay Creek anticline is about a quarter of a mile due south of the northwest corner of sec. 32, T. 27 N., R. 6 E., from which point the axis trends a little east of north and west of south. The length of the axis is about 1¼ miles. The outline of this fold is something like the blade of a knife which lies with its point to the north, the length being about three times the width. The dip either east or west of the axis is at the rate of about 60 feet to the mile. That on the east side has a total vertical amount of only 12 feet, however, the horizontal distance over which it extends being short. To the north and south the dips are very gentle and merge into the general westerly dip of the region without any perceptible change.

The eastern Hay Creek anticline is the smallest of the three folds. Its highest point lies a little southwest of the quarter corner between secs. 32 and 33, T. 27 N., R. 6 E. In outline it is like the blade of a narrow, round-ended, round-shouldered trowel. The long axis of the anticline points a little east of north. It is a little less than a mile long, and its greatest width is about a quarter of a mile. The easterly dip is insignificant, amounting to a little over 5 feet at its point of greatest development. To the west, however, the beds dip steeply for this region, showing for about a quarter of a mile a grade of 100 feet to the mile. The change in dip at the upper end of this relatively steep slope is very pronounced, giving the structure more the form of a terrace than that of an anticline.

WAMSLEY CREEK ANTICLINE.

The Wamsley Creek anticline is a low, irregular fold south of Wamsley Creek. It is made up in reality of two distinct low folds or structural swells whose highest points appear at the surface in the middle of the SE. ¼ sec. 25, T. 27 N., R. 6 E., and about one-tenth of a mile south of the corner of secs. 25, 26, 35, and 36. In shape this fold is like a V having thick, uneven sides and pointing northwest. The highest points occur at about the middle of each side and are separated by a narrow, shallow depression. The long axis of the east side of the fold points about N. 40° W., and that of the west side about N. 30° W. The fold, considered as a whole, is about 2 miles long and 1 mile wide. The actual reversal of dip is very slight, the maximum eastward descent being about 10 feet. The dip to the east is at the rate of about 40 feet to the mile, and that to the west has a maximum of about 80 feet to the mile.

The structure contours showing this fold are based on elevations taken on several beds of the Foraker limestone. Exposures were abundant and the beds could be accurately correlated, so there is small doubt about the exact form of this anticline.

POTATO CREEK ANTICLINE.

The name Potato Creek anticline has been given to a pronounced fold whose highest point is in the SW. ¼ SW. ¼ sec. 32, T. 27 N., R. 7 E., south of Potato Creek. This anticline is irregular in outline, forming an uneven oblong with ends and sides only approximately parallel. The major axis is about 1½ miles long and trends about N. 20° E. The greatest width of the anticline is near the north end and amounts to a little more than a mile. The top of the fold is almost flat and covers an area of about half a square mile. It pitches to the north at an average rate of 70 feet to the mile, and the beds dip to the west at the same rate. Toward the south the dip is not so pronounced, the maximum drop being about 40 feet to the mile. On the east there is a drop of 15 feet at a rate of 120 feet to the mile, followed by a sharp reversal, the easterly dip being met by a westerly dip of equal steepness. It is possible that a small fault separates the beds here, although there is no evidence of such a break except the abrupt reversal of dip.

On the west flank of the anticline, about a mile southwest of the summit, there is a structural terrace. The dip to the west flattens to about 10 feet to the mile and then steepens abruptly to almost 150 feet to the mile. The front of this terrace extends along the east line of sec. 1, T. 26 N., R. 6 E.

NORTH BIRD CREEK ANTICLINE.

The North Bird Creek anticline is a long narrow fold whose axis extends southwestward from a point three-tenths of a mile south of the northwest corner of sec. 12, T. 27 N., R. 7 E., near North Bird Creek, to a point about one-tenth of a mile south of the quarter corner between secs. 17 and 20, T. 27 N., R. 7 E. The dips on this fold are to the north, west, and south. On the east the fold merges into the general westward-dipping monocline without any perceptible change in the general dip. The greatest flattening shown on this fold is in the southwest corner of sec. 11, T. 27 N., R. 7 E., where the average dip is about 15 feet to the mile toward the southwest. The steepest dip is at the very tip of the fold, where the beds slope westward at an average of 110 feet to the mile. At one place on the south side of the fold the dip is as steep as that shown on the tip, but only for less than one-fifth of a mile.

Most of the elevations on which the contours of this fold are based were taken on beds in the Foraker limestone, but some of them were taken on the sandstone which lies about 43 feet below the base of the Foraker. Outcrops were abundant and correlations could be easily and accurately made.

FORAKER ANTICLINE.

The Foraker anticline is a low upwarp, the crest of which is just northwest of the southeast corner of sec. 21, T. 28 N., R. 7 E., northeast of Foraker. The outline of this low swell is much like the bottom of a flatiron with a blunt rounded point and the back side of the flatiron slightly curved in toward the center. The major axis, which trends a little south of west, is about 2½ miles long. The greatest breadth of the anticline is about 1¼ miles, at the east end. The dips to the north, west, and south are fairly uniform and about 75 feet to the mile. On the east flank of the fold the dip to the east averages 25 feet to the mile. The top of the anticline, about a quarter of a square mile in extent, is very flat, and dips in any direction are hard to detect.

A good deal of difficulty was experienced in mapping this anticline, as continuous outcrops are rare, and the dip to the east was determined not by continuous tracing of a single bed but by correlating scattered outcrops. It could not be proved that much of the apparent easterly dip is not due to a fault, but the fact that no faults or indications of faults were seen elsewhere in the quadrangle would make the existence of a fault here seem very improbable. It is, however, possible to say definitely that to the north the strata are not broken. Of the exact structure south of the crest of the fold very little could be ascertained, as there are practically no rock outcrops in that area. It was possible to determine the general dip, however, and although the structure on the south side is probably not so regular as the map indicates, it is unlikely that the mapping diverges greatly from the true structure.

ELM CREEK ANTICLINE.

The Elm Creek anticline is a small upwarp lying on the headwaters of Elm Creek, in the W. ½ sec. 9, T. 27 N., R. 7 E. The axis of the fold is about 1¼ miles long and trends about N. 25° E. The anticline is really made up of two small domes which are separated by a slight saddle. These domes are small oval swellings of nearly equal size. Their major axes have a length of half a mile and their minor axes a length of a little more than a quarter of a mile.

The dips on all sides of the fold are gentle. East of the principal axis the beds dip eastward for less than a quarter of a mile, to a point where the slope is reversed, and the highest point of any bed in the anticline is less than 15 feet above the lowest point that the same bed may reach east of the anticline. West of the principal axis the beds slope away from it at a rate of about 35 feet to the mile for a quarter of a mile and at 100 feet to the mile for about a quarter of a mile more before the dip merges into the general westward dip of the region.

The Red Eagle limestone crops out over the surface of this anticline, and the structure contours are based on elevations on the top of this bed.

ANTELOPE CREEK ANTICLINE.

The Antelope Creek anticline lies in secs. 10 and 11, T. 27 N., R. 6 E., just south of Antelope Creek. It is a transverse fold with a curving axis trending about N. 75° W. The general outline of the compound structure is something like that of a two-pronged tooth with the prongs pointing west.

The dips to the north, west, and south are at the rate of 60 feet to the mile. No dip to the east appears except in one small area on the very crest of the wrinkle. Here the beds are inclined to the east for a horizontal distance of about one-eighth of a mile, in which there is a depression of 10 feet.

The structure contours for this fold were determined from elevations on the Neva limestone, which crops out along the flanks of the fold.

SYNCLINES.

No detailed description is given of the synclines, as the purpose of this paper is primarily to point out those features which are of economic importance with relation to oil and gas, and a syncline is such a feature only where oil-bearing strata do not carry water. As such a condition has not been found to exist in any of the oil pools in the region surrounding the Foraker quadrangle, it is fair to assume that the sands underlying the surface in this quadrangle carry water. A mention of the positions of the axes of the larger synclines may be of some value, however, as the bottoms of these structural troughs are theoretically the most unfavorable places for accumulations of oil and gas, and they should accordingly be avoided in wildcatting operations.

Synclines occur north and south of the Foraker anticline. The axis of the one to the north strikes about N. 75° E. and extends from the quarter corner between secs. 24 and 25, T. 28 N., R. 6 E., to a point about 500 feet south of the middle of sec. 16, T. 28 N., R. 7 E. The one on the south is a sharper fold but is not so long. The axis of this trough trends northeastward from a point a little northwest of the middle of sec. 33, T. 28 N., R. 7 E. About 1,000 feet south of the middle of sec. 27, T. 28 N., R. 7 E., the axis divides, one branch continuing northeast for about a mile and the other trending a little south of east for about 1½ miles, to the place where the syncline dies out.

Just south of the North Bird Creek anticline there is a small, well-defined syncline whose axis begins 1,000 feet west of the southeast corner of sec. 15, T. 27 N., R. 7 E., and trends northeastward to a point 1,000 feet north of the southwest corner of sec. 12, T. 27 N., R. 7 E.

A large, pronounced syncline lies south of the one just described, and its axis, which is slightly curved, extends from a point 3,000 feet southwest of the northeast corner of sec. 29, T. 27 N., R. 7 E., to the middle of sec. 24, T. 27 N., R. 7 E., where it passes out of the quadrangle.

In the southwest corner of the quadrangle there is a well-defined syncline whose axis extends from a point 1,000 feet north of the southeast corner of sec. 26, T. 27 N., R. 5 E., to a point 2,300 feet south of the northwest corner of sec. 29, T. 27 N., R. 6 E., just northwest of the middle Hay Creek anticline.

Just north of the Antelope Creek anticline there is a short syncline with a curved axis about a mile long extending from the southwest corner of sec. 3, T. 28 N., R. 6 E., to a point about 1,000 feet east of the southwest corner of sec. 12, T. 28 N., R. 6 E.

East of the Beaver Creek anticline there is a syncline whose axis trends northeastward from the quarter corner between secs. 27 and 34, T. 29 N., R. 5 E., to the middle of sec. 23, T. 29 N., R. 5 E.

In the north-central part of the quadrangle there is a pronounced structural depression with an axis trending in a general southeasterly direction from the quarter corner between secs. 25 and 26, T. 29 N., R. 6 E., to the middle of the NW. ¼ sec. 5, T. 28 N., R. 7 E.

Besides the synclines described above there are many small ones whose influence on oil and gas accumulation is minor and in some cases probably negligible.

ACCUMULATION OF OIL AND GAS.

The various theories which attempt to give the reasons for the accumulation of hydrocarbons at certain selected points in the rocks will not be discussed in this paper. The essential thing is a knowledge of certain definite rules which repeated observation has shown are followed by the oil and gas in their journey to the points where pools are found, and of the conditions under which such accumulations of oil and gas are known to occur.

Gas, in its journey through the rocks, tends always to reach the highest possible point, regardless of the degree to which the rocks are saturated with water. Petroleum also persistently climbs the slope of inclined water-containing strata, if they are pervious enough to permit its passage. If water is absent, however, the direction of movement is reversed and the oil will tend to travel down the dip of the containing beds.

An oil pool must occupy a reservoir capable of containing the oil and so situated that the oil can not escape until the pool is tapped by the drill. Such reservoirs are usually formed by porous beds of rock confined beneath impervious beds. The porous bed is usually a sandstone, although it may be a limestone or even an igneous rock; the impervious bed is commonly a shale. Although a shale is not absolutely impervious, and under some conditions petroleum will undoubtedly travel through it, a shale cap over a porous sandstone is sufficiently impassable to oil to make possible the largest accumulations of petroleum and natural gas that have been discovered up to the present time.

Where the succession of strata is such that a suitable reservoir is provided, oil accumulations have been found to be in direct relation to three factors. These are the attitude of the strata, whether horizontal or tilted; the degree to which the strata are saturated with water; and the permeability of the strata, which depends on their porosity and on the size of the openings between their grains or particles. Any one of these three factors may be the dominating one, but the first named has appeared to be much the most influential. This may be due, in part at least, to the fact that comparatively little study has been given to the third, largely because of the difficulty in obtaining data that bear on it. Also, while the third factor is doubtless important, there is no means of telling anything about it in untested territory, so that even an absolutely clear understanding of its action would be of little assistance to the geologist in locating promising territory for prospecting. The same thing is true, to a less extent, as to the saturation of the strata with water. A single wildcat well goes far toward determining this factor. In the present state of knowledge, therefore, the attitude of the strata is the most practical and important indication available to the prospector.

If the influence of the permeability of the strata which contain the oil is disregarded, there are four principal conditions which should be discussed, each taking into consideration the attitude of the beds and the degree to which they are saturated with water.

1. Where the strata are approximately level and contain water oil and gas accumulations of commercial importance appear to be rare. The controlling factor of those which have been found appears to be the porosity of the bed that contains the oil or gas, the pools selecting the most porous lenses or "streaks" and occupying them to the exclusion of other parts of the bed. Pools of this type are particularly likely to occur where there are great quantities of

oil in the rocks, and it is presumable that the oil in the pools is but a small fraction of that which is disseminated through the rock in quantities too small to repay drilling. It is likely that some of the oil fields of Washington and Nowata counties, Okla., belong to this type. The discovery of such accumulations is always the result of chance drilling, as surface features can give no indication of their presence.

2. Where the strata are approximately level and "dry" oil might accumulate in "pay streaks" such as are described in the preceding

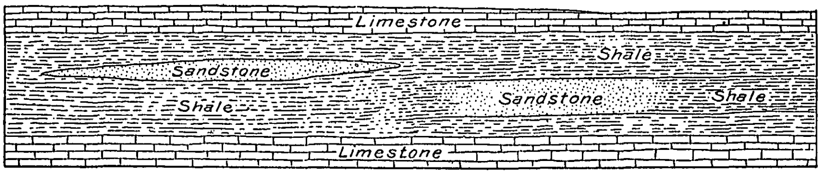


FIGURE 5.—"Pay streaks" of oil in level strata.

paragraph and shown in figure 5. Some contend that even where drill holes are apparently dry the microscopic interstices between the grains of the rocks contain water which is prevented from escaping by the capillary attraction exerted by the minute openings that hold it. No known oil pools have been shown to have the conditions described, and the possibility of such accumulations may be disregarded.

3. Inclined strata containing water present the conditions most commonly found in oil fields and accordingly by far the most important. These conditions are known to exist in the most productive districts of Oklahoma, such as the Cushing field,[1] the Healdton field,[2] and the Ponca City field.[3]

The oil travels up the slope formed by the rising strata until some obstacle which it can not pass intervenes and stops it. This obstacle may be furnished by the pinching out of the bed. In that case a condition such as is shown in figure 6 will result, the pool forming at the highest point of the porous bed which it can reach. The limits of such a pool can not be even guessed from anything which appears at the surface of the ground, its discovery being dependent on chance drilling.

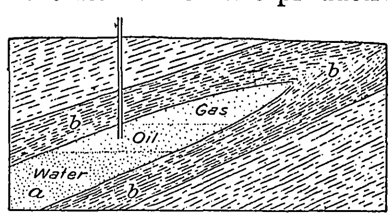


FIGURE 6.—Cross section illustrating theoretical pinching out of oil-bearing strata. *a*, Sandstone; *b*, shale.

[1] Buttram, Frank, The Cushing oil and gas field, Okla.: Oklahoma Geol. Survey Bull. 18, 1912.

[2] Wegemann, C. H., and Heald, K. C., The Healdton oil field, Carter County, Okla.: U. S. Geol. Survey Bull. 621, pp. 13–30, 1916 (Bull. 621–B).

[3] Ohern, D. W., and Garrett, R. E., The Ponca City oil and gas field: Oklahoma Geol. Survey Bull. 16, 1912.

In most of the large fields, however, the obstacle to the upward movement of the oil and gas is produced by the flattening or actual reversal of direction of the dip of the oil-bearing beds. The flattening produces a terrace, as shown diagrammatically in figure 7. The reversal indicates an anticline, as shown in figure 8. Either one may cause an accumulation of oil. In the Cushing, Healdton, and Ponca City pools there is an actual reversal of dip of considerable amount. This is the condition which is generally held to be most favorable and upon which recommendations for drilling are most commonly based. There are no recorded oil pools in Oklahoma occurring in structural terraces. That accumulations may occur in such a position, however, is altogether probable, as they are recognized in other parts of the United States.

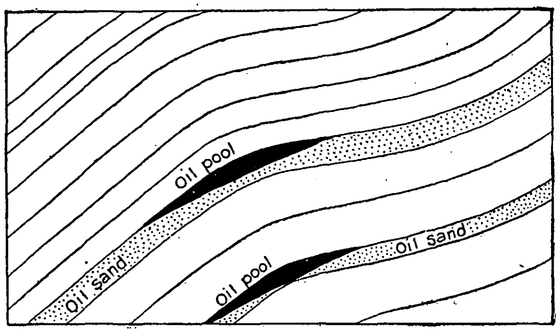


FIGURE 7.—Cross section illustrating theoretical accumulation of oil on terrace.

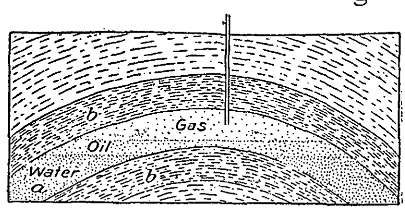


FIGURE 8.—Cross section illustrating theoretical accumulation of oil in anticline. *a*, Sandstone; *b*, shale.

A third way in which the upward journey of oil and gas may be stopped is through the agency of faults. If there is a displacement of the strata which results in the porous bed being broken off and left abutting against an impervious bed, the migration of the oil and gas will be effectually stopped unless the fault leaves an open fissure along which escape is possible. There are several considerable accumulations of oil and gas which are believed to have been caused by faults. Some of those in southern Osage County are believed to be of this type.[1] This condition is graphically shown in figure 9.

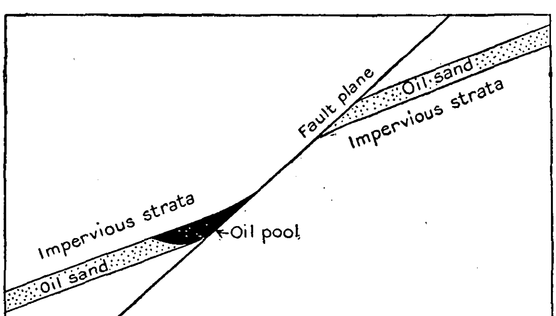


FIGURE 9.—Cross section illustrating theoretical accumulation of oil due to faulting.

[1] Wood, R. H., personal communication.

4. Inclined and dry strata have never been certainly recognized in regions where oil has been found. This condition is believed to exist, however, and to be the cause of the accumulation of oil in the lowest parts of the containing porous rocks. The theoretical relations of such an oil accumulation and the strata are shown in figure 10. The petroleum gathers in the porous bed, travels down the slope, and is collected in the bottoms of troughs or synclines formed by the folding of the strata. In the few known oil pools found in this position the containing strata have yielded no water, a fact which appears to bear out the theory. No pools of this type occur in Oklahoma, so far as is known to the writer.

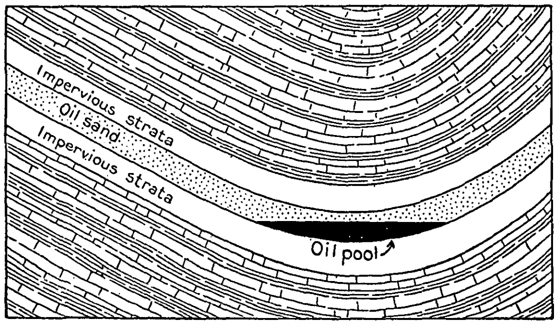


FIGURE 10.—Cross section illustrating theoretical accumulation of oil in syncline.

RECOMMENDATIONS FOR PROSPECTING.

There is a distinct order of preference which should be considered in the exploration of the anticlines of the Foraker quadrangle. Should a fold which is favorably located and structurally suited to contain oil and gas be found to contain no such accumulation, the presence of pools in adjacent territory structurally less favorable would be much less probable. Prospecting should not be indiscriminate but should first test thoroughly the localities where the structure appears most favorable, and if one of these localities fails to yield oil and gas, prospecting should be at least temporarily moved to a point some distance away.

However, no fold should be condemned on the evidence offered by a single hole. The attitude of the strata is by no means the only factor governing the accumulation of oil and gas, and some one of the others may interfere so strongly that a fold which is otherwise pronouncedly favorable for such an accumulation will prove barren. One of the most potent of these other factors is believed by the writer to consist in the porosity and the nature and size of the openings in a bed which the oil and gas can occupy. For accumulations of gas the porosity is the more important. For accumulations of oil large interstices between grains are probably more essential than high porosity. These factors can vary greatly within a short distance, and that is one of the principal reasons for the above recommendation that at least two test holes should be drilled before an apparently favorable fold is abandoned.

In the Foraker quadrangle the anticline which offers the best structural conditions for the accumulation in commercial amount of oil and gas is the Beaver Creek anticline, in the extreme northwest corner. The best point for prospecting is on the very crest of the fold, which is a little south of the center of sec. 15, T. 29 N., R. 5 E. A well drilled here should reach the horizon of the Bartlesville sand at a depth of about 3,240 feet. In case oil or gas in considerable quantities are not found in the initial test, a second should be drilled about half a mile south and a quarter of a mile west from the first. Failure to find oil or gas in the Beaver Creek anticline would have little bearing on the possibility of their accumulation in other folds in the Foraker quadrangle, as the Grainola anticline, which is the nearest one of any great promise, is about 4 miles from the Beaver Creek anticline and has ample gathering ground to supply hydrocarbons sufficient for any accumulation which it would be likely to hold.

The fold which appears to be second in promise is the Foraker anticline. This anticline, though small compared to those in many of the Oklahoma oil fields, still offers all the structural conditions that are necessary for the formation of an oil pool of considerable proportions. Owing to the comparatively low dip on all sides of this fold a hole sunk on the top of the fold, which is shown on the surface, would strike the highest point of the continuation of this fold at reasonable depth. Although it is impossible to say that this fold has the same shape underground as it shows at the surface, the outlines should be roughly the same, and the best that can be done is to choose the point at which the surface indications are the most promising. It is recommended that the first test hole on this anticline be sunk 600 feet west and 100 feet north from the southeast corner of sec. 21, T. 28 N., R. 7 E. It should reach a depth of at least 2,800 feet. If the first test fails to get oil or gas, a second should be drilled about 500 feet north of the quarter corner between secs. 21 and 28. The failure of these tests would tend to indicate the absence of accumulations of oil and gas not only in the Foraker anticline, but also in the Elm Creek anticline. If the more pronounced fold does not contain an accumulation of oil, it is unlikely that such an accumulation has formed under the less favorable structural conditions present in the smaller fold.

Third in importance is the Potato Creek anticline. This fold, while less well developed than the Foraker anticline, still offers all the structural requisites for a large oil pool. The dips on the several sides of this fold do not differ in degree enough to affect the accumulation of oil, and the best point for prospecting is the highest point of the fold as expressed on the surface. This point is roughly 500 feet east and 200 feet north from the southwest corner of sec. 32, T. 27 N., R. 7 E. Should a hole at this point fail to show oil and gas in considerable quantity, a second one should be drilled about 2,000 feet due south of the quarter corner between secs. 29 and 32. These tests should reach a depth of at least 2,800 feet, which should bring them to the horizon of the Bartlesville sand. A good showing of oil at that depth would justify drilling 100 or 200 feet deeper. In case the Potato Creek anticline is barren of petroleum or gas, prospecting the near-by Wamsley Creek anticline would not be advisable unless work to the west should disclose producing territory.

The three localities mentioned above are structually the most favorable ones in the quadrangle. The order of importance of the other folds that have been described in detail is believed by the writer to be as follows: Western Hay Creek, Grainola, Lone Tree, Brown, North Bird Creek, Antelope Creek, Elm Creek, Wamsley Creek, middle Hay Creek, eastern Hay Creek, Brooks, and Neva. The best points for drilling are on the highest points of the folds, which are mentioned in the detailed descriptions. In deciding on the relative importance of these folds weight was given not only to their expression on the structure map, but also to the completeness of the data on which the structure contours are based.

PROBABILITY OF FINDING OIL AND GAS IN THE FORAKER QUADRANGLE.

There can be little doubt that oil and gas will be found in the Foraker quadrangle. Producing fields, some of them of immense yield, have been opened to the north, east, south, and west of this area. Oil has been found in commercial quantity in Kay County, less than 2 miles from the west edge of the quadrangle, and also in Kansas about a mile from the north line. Various test wells near the quadrangle have established the fact that there are in this region numerous sands which are excellently fitted to hold accumulations of oil and gas. The anticlinal structure, while less pronounced than that in most of the largest oil fields of Oklahoma, is quite as well developed as that in many of the smaller fields, both in Oklahoma and elsewhere. In short, all the factors which conduce to large accumulations of petroleum are believed to be present here, and it is most probable that drilling will disclose pools in at least some of the favorable places described in the preceding pages.