STRUCTURE OF THE NORTHERN PART OF THE BRISTOW QUADRANGLE, CREEK COUNTY, OKLAHOMA, WITH REFERENCE TO PETROLEUM AND NATURAL GAS.

By A. E. FATH.

INTRODUCTION.

The Bristow quadrangle lies in Creek County, in northeastern Oklahoma, between meridians 96° 15′ and 96° 30′ and parallels 35° 45′ and 36°. (See Pls. III and IV.) It is bordered by some of the most prolific oil fields of Oklahoma, yet within its boundaries only a few gas wells have been drilled and a very small quantity of oil has been found. To the west are the Cushing oil and gas field and its southward extension in the vicinity of Shamrock. In fact, the nearest wells of the east Cushing field are only about 1½ miles distant from the Bristow quadrangle. About 9 miles east of the quadrangle is the Glenn oil and gas pool, and in the area that lies between the Bristow quadrangle and the Glenn pool there are several minor fields. Several anticlines and numerous faults were found in the northern part of the quadrangle. A few of the anticlines appear to be sufficiently large to be well worth prospecting with the drill. Several others, which are comparatively small and closely related to faults, are not considered to be worth prospecting until after the larger ones have been developed and prove their value. Although faults alone may cause accumulations of petroleum and natural gas, those in this quadrangle are probably of little value for this purpose. As the information collected in the northern part of the quadrangle is valuable at the present time, it is being published at an early date rather than withheld until the examination of the remainder of the quadrangle is completed.

ACKNOWLEDGMENTS.

The writer is indebted to many individuals and companies for information which has added value to the report. To Mr. R. H. Wood, of this Survey, is due credit for unpublished information concerning the stratigraphy of the Hominy quadrangle, to the north. The well logs at the end of the report were donated by the individuals and companies whose names appear with them. To all who have been of assistance the writer is sincerely grateful.

GEOGRAPHY.

SURFACE FEATURES.

The surface of the quadrangle ranges in altitude between 675 and 1,075 feet above sea level. It is dissected by innumerable streams, and the larger part of its surface is covered with a thick growth of timber, which, on the uplands, consists principally of black and post oaks and is generally so low-branched and thick that it cuts off from view almost everything beyond a distance of a few hundred feet. Small areas of open prairie are scattered here and there, and clearings also help to lay the country open to view.

The area is drained by tributaries of both Arkansas and Canadian rivers. The divide between these streams nearly bisects the quadrangle from east to west. Polecat Creek is the main tributary of the Arkansas in this region, and Little Deep Fork Creek of the Canadian. These two creeks and their larger branches carry some water the year round. Flood plains are well developed in the valleys of all the larger streams, and the valleys of even the smaller branches contain a considerable amount of silt. The timber on the flood plains differs from that on the uplands; it consists principally of elm, sycamore, willow, walnut, and pecan.

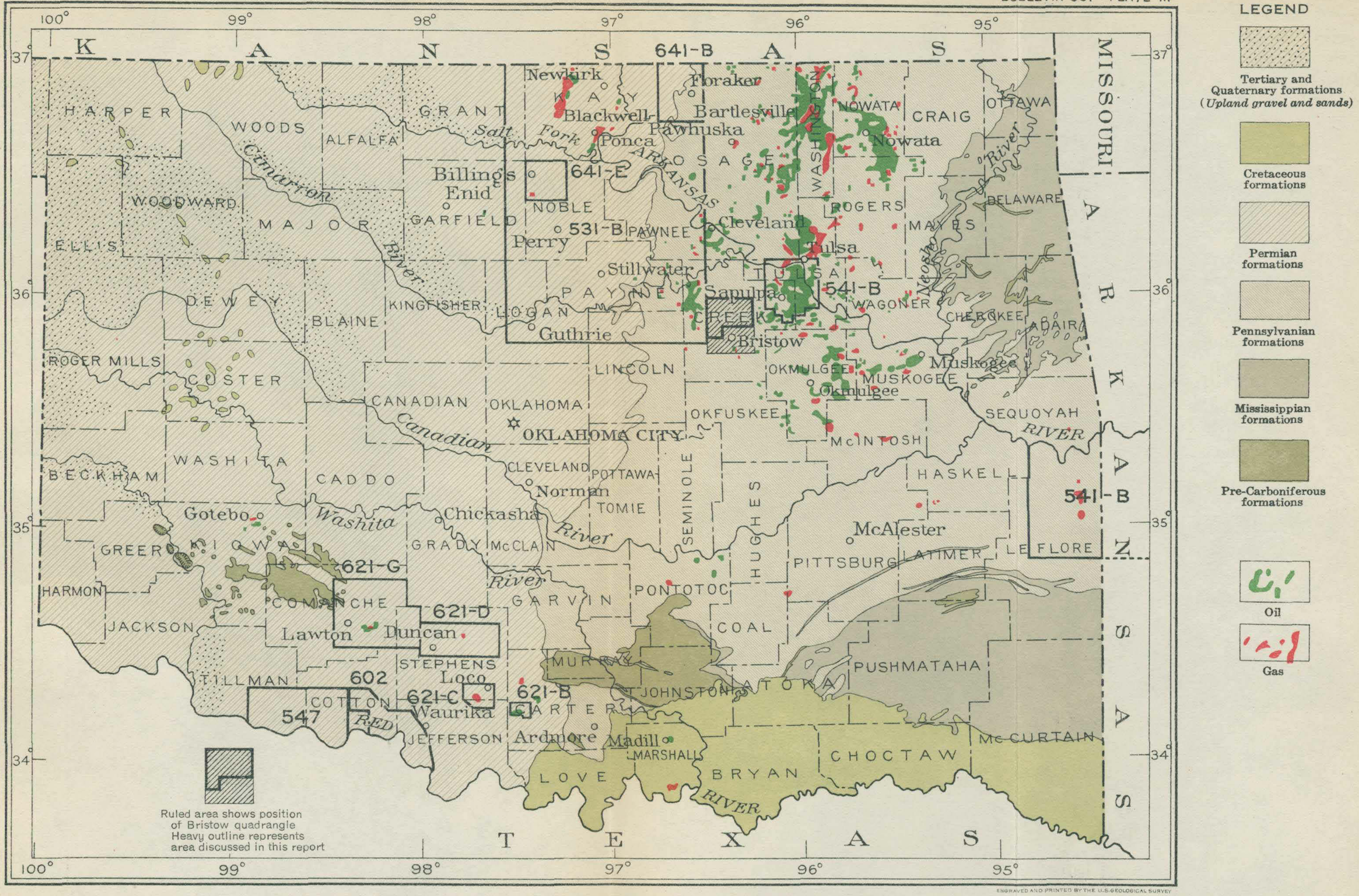
ACCESSIBILITY AND DEVELOPMENT.

But one railway, the St. Louis-San Francisco (Oklahoma City line), traverses the quadrangle. The only town is Bristow, a thriving business center with a population of about 2,500, situated on the railroad in the south-central part of the quadrangle. Bristow lies 83 miles northeast of Oklahoma City and 36 miles southwest of Tulsa. Heyburn, a small settlement about 8 miles northeast of Bristow, consists of a post office, store, cotton gin, and several houses. Bellvue is a store and post office in the northwestern part of the quadrangle. Just beyond the west border, on the railroad, is the town of Depew.

The roads in general are sandy. Most of them follow the section lines; the others follow the older and more natural routes, such as the divides. They receive but little attention, although an effort is made to keep in repair a few of the more traveled routes for the use of automobiles.

Farming is the principal industry of the region, and cotton, corn, hay, and oats, named in the order of their importance, are the chief crops.

Because of its closeness to the developed oil fields, considerable wildcat drilling has been done in the area described in this report. Up to August, 1916, fourteen wells had been drilled, all of which except one gas well, in sec. 36, T. 17 N., R. 9 E., were abandoned as dry holes.



GEOLOGIC MAP OF OKLAHOMA SHOWING OIL AND GAS POOLS

Heavy numbers refer to numbered bulletins in which other oil fields in Oklahoma are described

50 0 50 Miles

1917

GEOLOGY.

STRATIGRAPHY.

GENERAL FEATURES.

The rocks exposed at the surface in the Bristow quadrangle and those beneath it to a depth of 2,500 feet or more are a part of the Pennsylvanian series, the series to which belong the surface rocks throughout the oil fields of northeastern Oklahoma. Below the Pennsylvanian rocks lie those of the Mississippian series, which in the eastern part of this quadrangle have been penetrated by three wells.

The oil man's interest in the rocks is due to the fact that the surface rocks furnish the means of determining the geologic structure, which is the best governing factor in locating favorable oil and gas territory in advance of drilling, and the deeply buried rocks contain the oil and gas bearing sands.

The classification and most of the names used in the text and columnar sections of this paper are derived from the reports on the Cushing[1] and Glenn pool[2] oil fields, and from unpublished manuscript and maps by R. H. Wood, of this Survey, who has worked in the Hominy quadrangle, to the north.

EXPOSED ROCKS.

KINDS OF ROCK AND CHARACTER OF OUTCROP.

The strata exposed in the northern part of the Bristow quadrangle have an aggregate thickness of about 950 feet. They consist almost entirely of alternating sandstone and shale, the only exceptions being a few limy beds in the eastern part of the area. The limy beds, the Dewey limestone and the calcareous Tiger Creek sandstone (the latter here differentiated for the first time), together with the Elgin sandstone, will be described, and their outcrops are indicated in figure 14. All the other sandstones and shales that were used in working out the geologic structure are so similar to one another in lithologic characteristics that descriptions would be of little value to drillers for differentiating them.

Sandstone and shale each constitute about half of the total thickness of the rocks. (See Pl. IV.) The sandstones appear to form much the greater part, owing to the generally sandy nature of much of the surface, but a close study shows that this does not indicate the true character of the rocks beneath the surface soil. The narrowness of the sandstone and shale belts permits the residual sand of the former to wash and blow as a veneer over the outcrops of the latter, and in

[1] Buttram, Frank, The Cushing oil and gas field, Okla.: Oklahoma Geol. Survey Bull. 18, 1914.

[2] Smith, C. D., Glenn oil and gas pool and vicinity, Okla.: U. S. Geol. Survey Bull. 541, pp. 34–48, 1914.

consequence the more prolific vegetation which is dependent on a sandy soil grows equally well on the narrow belts underlain by shale. For this reason the black and post oak timber, which ordinarily is limited to sandstone areas and therefore generally helps to differentiate the sandstone from the shale in regions where the belts of the two rocks are broad, covers most of the Bristow region and in this way disguises the presence of shale. The contacts of the shale with the adjoining sandstone beds, upon which practically all

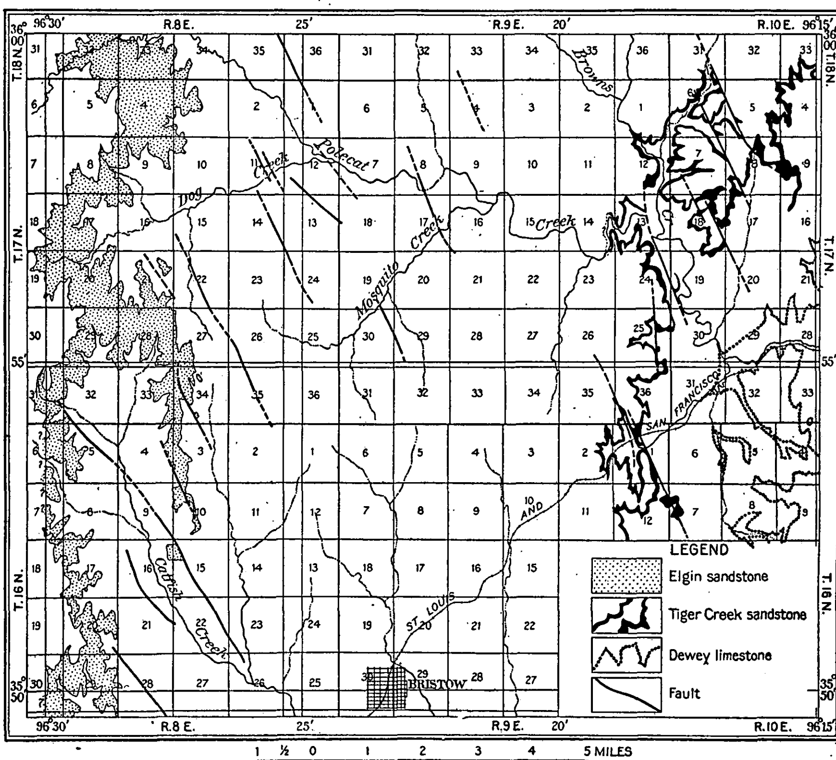
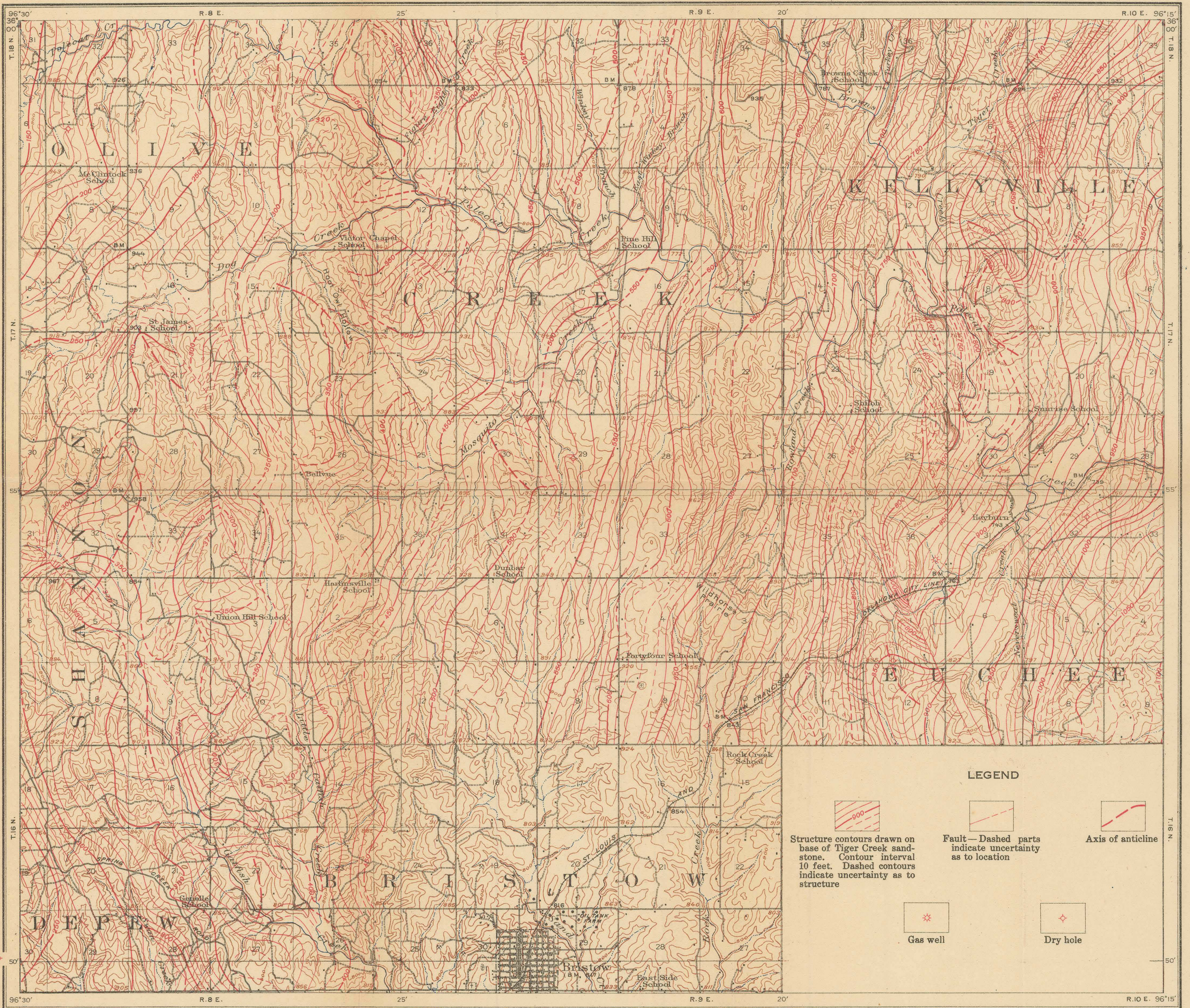


FIGURE 14.—Sketch map showing areal distribution of Elgin sandstone, Tiger Creek sandstone, and Dewey limestone in Bristow quadrangle, Okla.

the geologic work in the quadrangle depends, are therefore distinguishable only with difficulty, a condition which makes the work extremely tedious and in some localities very uncertain.

ELGIN SANDSTONE.

The Elgin sandstone is the highest sandstone bed of considerable thickness in the quadrangle and crops out along or near the western border. (See Pl. V and fig. 14.) It does not differ from most of the other sandstones of the region in lithologic characteristics, but it is described here principally for the benefit of those geologists who may desire to know its position within the quadrangle. It forms



R.B.Marshall, Chief Geographer.
Sledge Tatum, Geographer in charge.
Topography by C.C.Gardner, R.T. Evans, R.R.Monbeck, D.H.Watson, and C.R.Fisher.
Control by C.F.Urquhart, C.B.Kendall, and C.R.Fisher.
Surveyed in 1914-1915.

SURVEYED IN COOPERATION WITH THE STATE OF OKLAHOMA.

TOPOGRAPHIC MAP OF THE NORTHERN PART OF THE BRISTOW QUADRANGLE, OKLAHOMA

SHOWING PROVISIONAL INTERPRETATION OF GEOLOGIC STRUCTURE

Scale $\frac{1}{62,500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 25 feet.
Datum is mean sea level.

1917

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

Structural geology by A. E. Fath

the westernmost thick sandstone in the area described in this report. Where it enters the quadrangle at the north, in secs. 32 and 33, T. 18 N., R. 8 E., its thickness is not determinable, but in the southwest corner of sec. 21, T. 17 N., R. 8 E., a thickness of 50 feet was measured. The base of the sandstone is known to be irregular to the north of this point, and hence it may be assumed that the thickness also varies. To the south of sec. 21, T. 17 N., R. 8 E., the sandstone appears to vary but little for at least 4 miles, but in several places south of secs. 7 and 8, T. 16 N., R. 8 E., its thickness seems to be as much as 80 feet.

The Elgin is overlain by about 150 feet of shale, sandstone, and limestone, which separate it from what is known as the Pawhuska limestone in the Cushing field.[1]

TIGER CREEK SANDSTONE.

The Tiger Creek sandstone, which is differentiated here for the first time, is well exposed in the southern part of sec. 6, T. 17 N., R. 10 E., on the south side of a small tributary to Tiger Creek, from which it receives its name. (See fig. 14.) Its thickness ranges from 20 to 30 feet, and it is low in the stratigraphic section exposed in the Bristow quadrangle. (See Pl. V.) It is the lowest outcropping bed that overlies the shale 100 to 130 feet thick, whose outcrop extends from sec. 4, T. 17 N., R. 10 E., to and beyond sec. 7, T. 16 N., R. 10 E. This position with respect to a thick shale bed not only makes its outcrop more prominent in comparison with other sandstones in the quadrangle, but it has other features that mark its individuality.

Its lower 2 or 3 feet is highly fossiliferous, containing innumerable impressions of the fossil *Fusulina*, which resembles a wheat grain. This probably is its most persistent feature. The *Fusulina*-bearing portion is observable only where the surface conditions are favorable for its exposure, in such places as a roadway cut or a creek bank. The sandstone, as a whole, varies greatly in lithologic character. In some places it is a light-gray to yellowish-brown friable sandstone that can not be distinguished from other sandstones in the region, but in other places as much as one-half or more of it is so calcareous that it can truthfully be called a limestone. In still other places the *Fusulina*-bearing portion is separated from the upper portion by as much as 15 feet of shale. All gradations between these various phases are known—from limestone through sandy limestone and limy sandstone to common siliceous sandstone—and any or all of these phases may be present as layers or lenses in a single exposure. The limestone phase is more highly developed in the northern part of the quadrangle, where it generally forms the top part of the Tiger Creek sandstone, and in this locality it carries fossils, principally segments

[1] Buttram, Frank, The Cushing oil and gas field, Okla.: Oklahoma Geol. Survey Bull. 18, p. 8, 1914.

of crinoid stems and *Fusulina*. The limestone phase is gray on a fresh surface but weathers to reddish brown by the oxidation of its iron content.

In the Hominy quadrangle,[1] to the north, this bed lies above the Avant limestone. At Arkansas River the distance between the two beds is 60 feet. South of Arkansas River both the Avant limestone and the shale that separates the Avant from the Tiger Creek sandstone decrease in thickness, and near the southern boundary of the Hominy quadrangle the Avant limestone is only a foot or two thick and the Tiger Creek sandstone is separated from it by only 3 to 5 feet of shale. The Avant probably thins out and disappears before reaching the Bristow quadrangle. As the base of the Tiger Creek sandstone lies so close to the Avant, only a short distance to the north, it may be assumed to be practically the equivalent of the horizon of the Avant in the Bristow quadrangle. Because the Tiger Creek sandstone is a bed of somewhat unusual character and persistency, it is used as the key bed to which the contours of Plate IV refer.

DEWEY LIMESTONE.

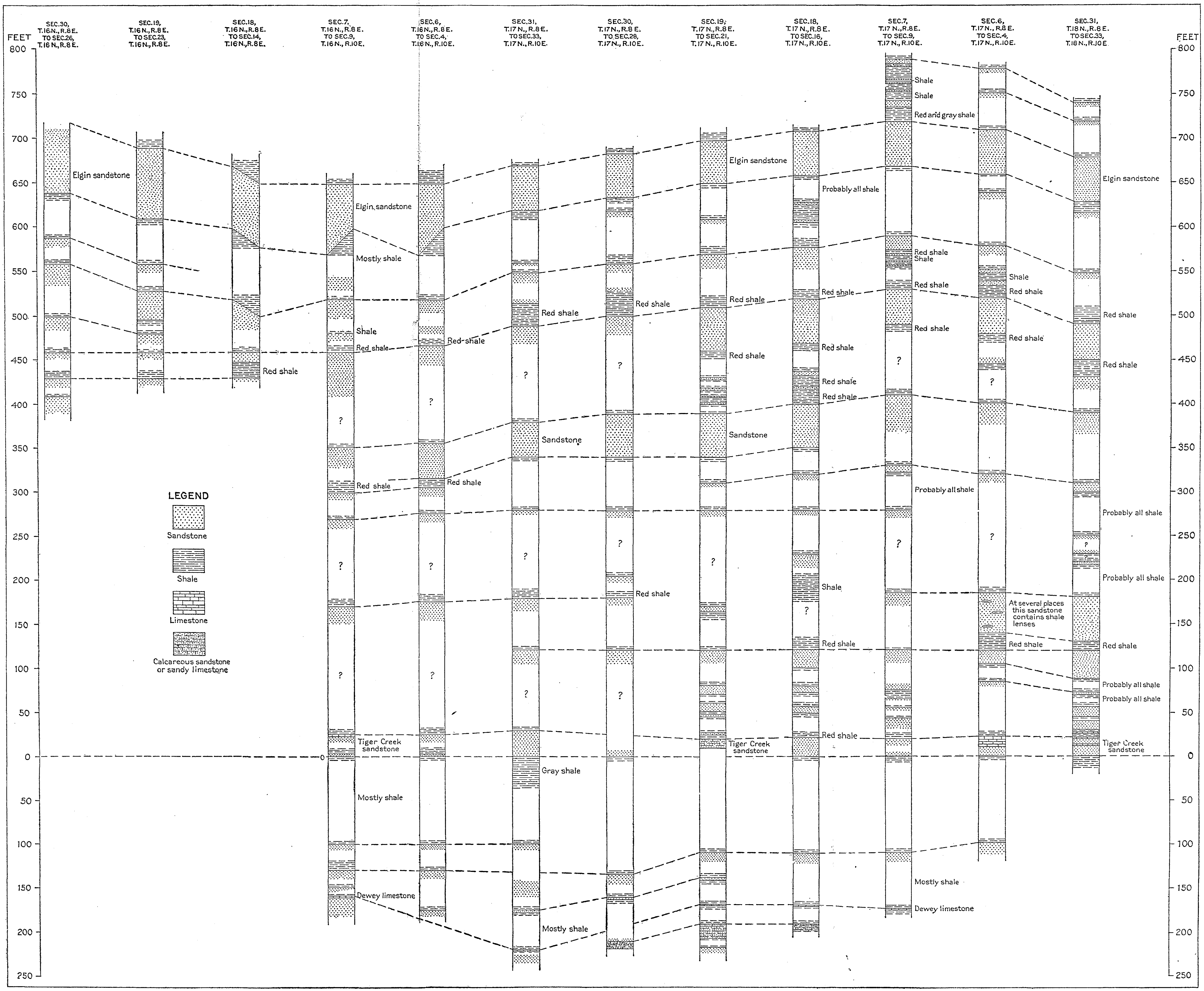
In the Bristow quadrangle the Dewey limestone lies between 160 and 220 feet below the Tiger Creek sandstone. (See Pl. V.) At no place in the quadrangle where it was observed did it measure over 1½ feet, and at several places it measured less than 9 inches in thickness. It is light gray on a fresh surface but weathers yellowish brown to reddish brown, owing to the oxidation of its iron content. It carries abundant fossils of both *Fusulina* and segments of crinoid stems. Because of its thinness its exposures are limited to particularly favorable places, such as stream banks. Its largest exposure is at the ford on Polecat Creek in the SE. ¼ sec. 30, T. 17 N., R. 10 E. (See fig. 14.) Other scattered exposures may be found in secs. 21, 29, and 33, T. 17 N., R. 10 E., and secs. 5, 6, and 8, T. 16 N., R. 10 E. Care must be taken not to confuse the Dewey limestone with a very lenticular limy sandstone (in some places sandy limestone) which lies about 20 feet below it in secs. 21, 28, 29, and 33, T. 17 N., R. 10 E., and which, because of its lenticularity, is not considered to be worthy of a description in this report.

ROCKS NOT EXPOSED.

GENERAL CONSIDERATIONS.

The unexposed rocks of the Bristow quadrangle are of interest in this discussion principally because they contain the oil and gas bearing sands. The most direct method of obtaining information concerning oil and gas sands is from well records, but as the wells in that part of the quadrangle here described are widely scattered, and

[1] Personal communication from R. H. Wood.



STRATIGRAPHIC SECTIONS OF ROCKS EXPOSED IN THE NORTHERN PART OF THE BRISTOW QUADRANGLE, OKLA.

the logs of the drilling are not complete, and for most of the wells not given in detail, information from this source is meager. Moreover, the little information available is rather unsatisfactory because of the nonpersistency of key rocks from well to well, so that it is impossible to determine definitely the nature of the changes that take place in the individual beds.

In the adjoining oil fields, where there are many drill holes, the character of the underground strata is fairly well known. By tracing these beds from well to well toward and into the Bristow quadrangle some suggestions as to the character of the extensions of the beds within the quadrangle may be obtained. This was done by studying numerous well records from the Cushing field, the Glenn pool, and the area separating the Glenn pool from the Bristow quadrangle.

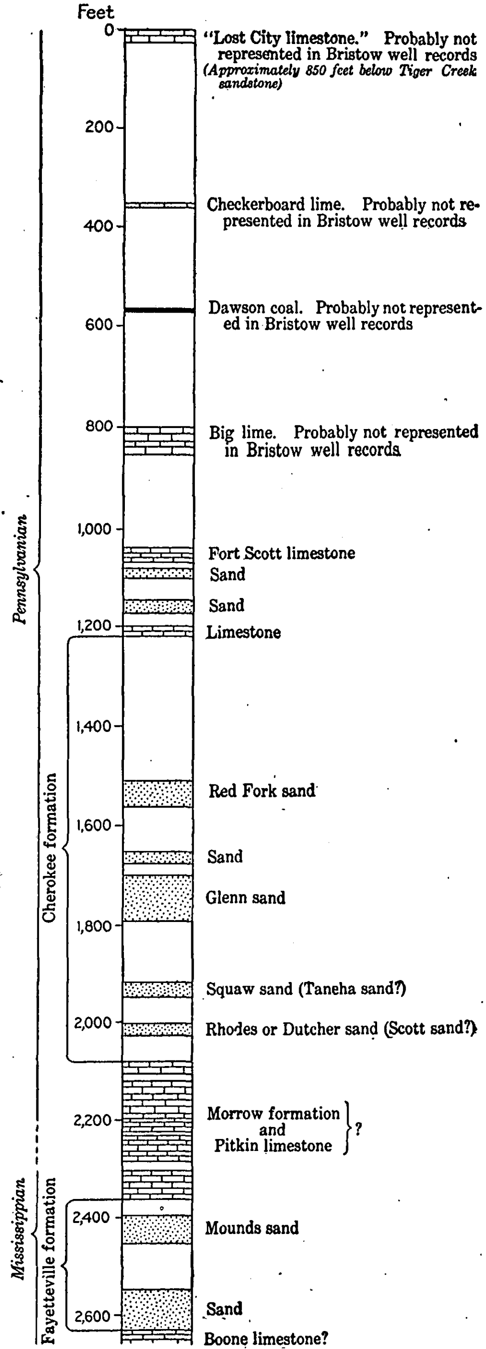


FIGURE 15.—Composite skeleton stratigraphic section of the Glenn pool region, Oklahoma.

LIMESTONES AND OIL AND GAS SANDS OF THE GLENN POOL REGION.

In northeastern Oklahoma the best key rocks, both among those which crop out at the surface and among those encountered in drilling, are limestones. In the Glenn pool region (see fig. 15) the Fort Scott ("Oswego") limestone, a limestone about 150 feet below the Fort Scott, the limestones of the Morrow formation, and the Pitkin limestone are the beds that can be of possible service in correlating from well to well toward the Bristow quadrangle.

The Fort Scott ("Oswego") limestone and the limestone about 150 feet below it are, according to Smith,[1] well-defined beds penetrated by all the wells in the Glenn pool. West and southwest of the Glenn pool, however, the recognition of both or either of these beds in well records is difficult. In the northeastern part of the Bristow quadrangle their identification seems positive, and there is some evidence for believing that the Fort Scott ("Oswego") extends across the northern part of the quadrangle. The limestone 150 feet below the Fort Scott, on the other hand, appears to thin out or else is represented only by a "limy shell" (thin limestone parting in the shale). Toward the south both of these beds are probably absent or are represented only by thin "lime shells."

The Morrow and Pitkin limestones of the Glenn pool are penetrated by three wells in the Bristow quadrangle—in sec. 1, T. 16 N., R. 9 E. (see log, p. 97), sec. 6, T. 16 N., R. 10 E. (see log, p. 98), and sec. 32, T. 17 N., R. 10 E. (see log, p. 99). West of these localities no wells are deep enough to reach these beds. The three wells mentioned have not penetrated below the Pitkin limestone, and hence there is no evidence as to the presence or absence of the Boone limestone ("Mississippi lime").

The productive oil and gas sands of this general region have considerable stratigraphic range. The Cherokee formation, which lies above the Morrow formation and below the Fort Scott ("Oswego") limestone, contains in descending order the Red Fork, Glenn, Taneha, and Scott sands of the Glenn pool region (the Scott is considered by many oil men to be the equivalent of the Rhodes and Dutcher sands), and the Bartlesville and Tucker sands of the Cushing field. The Layton and probably the Wheeler sands of the Cushing field lie above the Cherokee shale. So far as well records show, all these sands are more or less lenticular, varying in thickness from place to place and dividing or even thinning out completely. In some places they are distinct beds and are separated from one another by shale beds of nearly uniform thickness. In other places, however, the oil sands are less distinct and are interbedded with other sands that are not known to bear either oil or gas. Conditions such as these make it difficult and in places impossible to correlate the sands from one well to another unless the wells are close together. The inaccuracy of many well logs greatly increases this difficulty.

The Red Fork sand of the Glenn pool region extends westward into the Bristow quadrangle. It is found at a depth of 2,115 feet

[1] Smith, C. D., The Glenn oil and gas pool and vicinity, Okla.: U. S. Geol. Survey Bull. 541, p. 20 and cross sections of pl. 3, 1914.

in the well in sec. 32, at 2,100 feet in the well in sec. 20, and at 2,055 feet in the well in sec. 30, T. 17 N., R. 10 E.; at 2,275 feet in a well in sec. 6, T. 16 N., R. 10 E.; and at 2,344 feet in sec. 1, T. 16 N., R. 9 E. In the logs of all these wells the sand is reported to contain oil and gas but not in paying quantities. West and southwest of these wells there is much uncertainty in correlation, and the extent of the Red Fork sand in this direction is not known.

The Glenn sand, so far as well records show, is comparatively thick in the northeastern part of the Bristow quadrangle, but to the west it thins rapidly. It is possibly the producing sand at a depth of about 2,500 feet in a few oil and gas wells several miles south of the town of Bristow.

The Taneha sand, which lies 100 or more feet below the Glenn, is probably very thin or else absent in the Bristow quadrangle.

The Scott (Rhodes and Dutcher) sand, which lies a short distance below the Taneha, is the producing sand in the Scott pool, south of Kellyville, a few miles east of the Bristow quadrangle. It is probably a lenticular bed and absent in most of the wells in the quadrangle, although they have penetrated its horizon about 100 feet above the Morrow formation.

The Mounds sand, which is the producing sand south of the Glenn pool, near the town of Mounds, lies in the Fayetteville formation, below the Pitkin limestone. As no wells in the Bristow quadrangle have passed through this limestone, there is no evidence regarding the presence or absence of the sand within the quadrangle.

OIL AND GAS SANDS OF THE CUSHING FIELD.

The Layton sand of the Cushing field extends into the Bristow quadrangle, but it does not appear to be a well-defined bed that can always be recognized by the drillers. Failure to recognize this sand may, however, be due to the fact that it carries no oil where penetrated in the Bristow quadrangle.

The Wheeler sand of the Cushing field, according to Buttram,[1] is a porous limestone that has been considered to be the Fort Scott limestone ("Oswego lime") or its equivalent. As the Fort Scott limestone is believed to be present in some places in the northern part of the Bristow quadrangle, the Wheeler sand, its probable equivalent, should also be considered as present.

The Bartlesville sand, which is the most productive sand in the Cushing field, appears to thin considerably to the east, where it enters the Bristow quadrangle. This thinning and the fact that it is not parallel[2] to the surface rocks in the Cushing field make the recognition of the Bartlesville sand in the wells of the Bristow

[1] Buttram, Frank, The Cushing oil and gas field, Okla.: Oklahoma Geol. Survey Bull. 18, p. 41, 1914.
[2] Idem. This is clearly brought out by comparing Buttram's plates 1 and 11.

region somewhat uncertain. From the meager information to which the writer has access this lack of parallelism seems to be most pronounced below the Layton sand. Owing to the thinning of the Bartlesville toward the east, it can not be differentiated by its thickness from several other sands that are recorded at about the same position in the well logs of the Bristow quadrangle, and hence there is no means by which it may be certainly recognized in this region.

The opinion is prevalent among many oil men that the Bartlesville sand of the Cushing field is the same as the Glenn sand of the Glenn pool. This opinion no doubt is due to the fact that these sands were among the most productive in their respective fields. If they are the same it should be expected that the area between the Cushing field and the Glenn pool, principally the northern part of the Bristow quadrangle, would furnish the proof. But as indicated above, the thinning of the Glenn sand to the west and of the Bartlesville to the east and the lack of parallelism between the Bartlesville and the overlying beds furnish little evidence in support of this contention.

The Tucker sand of the Cushing field does not appear to be a regular and well-defined bed, and the name seems to be more or less loosely applied. Where an oil-bearing sand is found beneath the Bartlesville, it is called the Tucker without much regard as to the distance between them.

STRUCTURE.

DEFINITION.

To many the term "structure" as used in oil reports has a vague meaning and is frequently misunderstood. It pertains to the position or lay of the rock beds and not to their composition or to the material which they may contain. Stratified rocks, like those of the Bristow quadrangle, lie in layers, one upon another in a manner somewhat similar to the leaves of a book. The rock layers, however, are not of uniform thickness, like the leaves of a book; they thicken and thin and may even pinch out. Rock layers that lie horizontal, like the leaves of a flat-lying book, are said to have flat, level, or horizontal structure. The surface of the earth above such flat-lying rocks, on the other hand, may be very far from flat or horizontal, being cut up into hills and valleys.

Few of the rock layers of the earth, however, lie flat; most of them are inclined or tilted, folded, broken, or upturned (vertical), and the structure of such layers is said to be inclined (dipping or monoclinal), folded (anticlinal, domal, or synclinal), faulted, or vertical, as the case may be. The same rocks may be horizontal in one locality and inclined, folded, or faulted in another. An upfold or arch of the beds is an anticline and a downfold or trough is a syncline. These features also as a rule do not correspond with the surface features, for anticlines (upfolds) may occur beneath valleys in the hills and ridges, or on the slopes between hills and valleys, or they may even cross from the highlands into the lowlands. Synclines (downfolds) in like manner may occur beneath either hills or valleys or may extend across both hills and valleys.

By structure, then, is meant the general position in which the rock layers lie. Petroleum geologists often use the term in a slightly different sense; they speak of a "structure" in some particular locality when in reality they mean a structural feature of a particular kind, as an anticline or dome or a feature of some other type that is favorable for the accumulation of oil and gas. The term should preferably be confined to its general meaning—that is, it should be used as an abstract term, like stratigraphy or topography, and of course in that sense the plural "structures" would be as inadmissible as "stratigraphies."

REGIONAL STRUCTURE.

Considered in a broad way, the rock beds of northeastern Oklahoma dip or descend westward at a very low angle. In the Bristow quadrangle the dip is slightly north of west and amounts to about 50 feet to the mile, or a little more than half a degree. As the surface of the quadrangle slopes slightly eastward—that is, in a direction opposite to the dip of the rocks—the rock beds where they come to the surface are beveled at a very low angle and their outcrops extend in belts running in a general way from south to north. The rocks that are stratigraphically the lowest, therefore, crop out at the east side of the quadrangle, and each succeeding belt of outcrops from east to west represents in general beds younger and higher in the stratigraphic section. However, the westward slope of the rock beds is not uniform; it is modified by variations in the rate of dip, local folds, and small faults, all of which are represented on Plate IV by structure contours. As the dip is generally westward, dips to the east are uncommon and are locally referred to as reverse dips. Accumulations of oil and gas are generally found in close relation to local irregularities in the general structure of a region, and it is to such folds and irregularities that attention will be principally directed in this paper.

FIELD METHODS OF DETERMINING STRUCTURE.

The topographic map of the Bristow quadrangle made by the United States Geological Survey in 1914 and 1915, in cooperation with the Oklahoma Geological Survey, was used as the base on which all the geologic observations were plotted. The structure was determined by locating on the map and determining the altitude of the outcrops of numerous specific rock layers, among which are the Elgin and Tiger Creek sandstones and the Dewey limestone, described on preceding pages. Almost all the contacts of shale and sandstone that may be seen in this region and could be traced for even a mile or two were used in determining the structure. Because the several contacts of sandstone and shale can not be differentiated from one another lithologically, it was necessary, in order not to confuse one with another, to traverse the entire outcrop of every such contact traced. Although this was an extremely slow and tedious method, it was the only one that was at all reliable, and even it is not considered infallible for this region. Local stratigraphic sections were measured wherever several successive beds were exposed, and these were helpful as a check to the tracing of the various beds.

The accuracy of determinations of altitude demanded by the present-day standards of geologic work requires the use of a spirit level or refined vertical-angle determinations. The latter method was prohibited by the thick timber of the country, and although spirit-level determinations could have been made the denseness of the timber would have made it impossible to take sights averaging more than 200 or 300 feet in length, and for that reason this method was considered too slow and altogether impracticable. In determining the altitude of the beds the aneroid barometer was the principal instrument used. Many of the altitudes so determined were checked by hand leveling, which was done wherever practicable. To indicate the great care used in the determinations it seems advisable to describe the method in detail. The barometer is set at some point whose exact altitude is given on the topographic map or indicated on the ground by a bench mark, and the time of setting the barometer is noted. The rock outcrops whose altitudes are to be determined are then visited, and the altitudes as given by the aneroid barometer, together with the time of each reading, are recorded. As soon thereafter as possible the barometer is checked on the original or some other accurately determined point. If the reading of the barometer shows any discrepancy from the true altitude at this point, discrepancies probably also exist in the altitudes as read on the outcrops. The readings are then adjusted according to the time which has elapsed between the original setting of the barometer and each reading. The time that elapsed between the setting and checking of the barometer in such traverses ranged between half an hour and two hours. If the atmospheric pressure has been constant or has been changing at a uniform rate, the altitudes thus determined may be considered as approximately correct. If at some subsequent time an outcrop is again visited, a second reading is taken to check the original. Should such a check reading not accord with the original determined altitude within a few feet, or should the geologist have any reason for suspecting any appreciable error in the determination, the work is done over until there is a reasonable check and the determinations can be considered approximately correct. Many determinations of altitude have been checked within a few feet as many as three or four times. Such checking and rechecking leaves but little chance for errors of any appreciable size. The checking has been particularly careful in the areas of the anticlines and faults.

METHOD OF REPRESENTING STRUCTURE.

The most practicable method of representing geologic structure on a map is by means of structure contours. A structure contour is a line connecting all points on the key bed to which it refers that have the same altitude. For instance, the 400-foot contour on Plate IV shows the line along which the base of the Tiger Creek sandstone is 400 feet above sea level, and in like manner the 410-foot contour indicates an altitude of 410 feet, and the 390-foot contour an altitude of 390 feet. The "contour interval" (the vertical distance between the altitudes represented by adjacent contours) used on Plate IV is 10 feet. It is possible to determine from the spacing of the contours the shape or lay of the key rock to which they refer. Where the contours are close together, the dip is greater than where they are widely separated.

Inasmuch as the Tiger Creek sandstone crops out over a relatively small part of the region its altitude in localities west of its area of exposure must be computed by adding or subtracting, as the case may be, its distance below or above the other outcropping geologic contacts which were traced and whose altitude was determined. In thus computing the altitude of the base of the Tiger Creek sandstone over the region it must necessarily be assumed, in the absence of evidence to the contrary, that the intervals between the base of the sandstone and each succeeding bed are the same underground as at the surface, where they can be determined. However, it is almost certain that these intervals are not constant. Well logs, if they recorded the Tiger Creek sandstone, would be a great help in determining the accuracy of the computed altitudes on this bed, but it can be recognized with some uncertainty in only one of the records (see log on p. 97) of the eight wells which penetrate its horizon in the northern part of the Bristow quadrangle.

As already described most of the sandstones and shales vary in thickness from place to place along their outcrops. This is well illustrated by Plate V. If the thicknesses of individual beds are not constant at the surface it is presumable that they are also not constant beneath the surface, and hence that the distances between the several beds and the Tiger Creek sandstone may be variable from place to place. Nevertheless, it is believed that as a whole the strata in this region obey the general law of sedimentary deposits, the local irregularities compensating one another, in effect, so that the beds in the aggregate are parallel except in so far as a regional separation or convergence in some direction is caused by thickening or thinning of some member or group in that direction. However, on account of this variability of individual beds in their areas of exposure, and because it is not possible to check the elevation of the base of the Tiger Creek sandstone by well records, the computed structure as shown by Plate IV must be considered as only approximately correct.

CATFISH ANTICLINES.

SOUTH CATFISH ANTICLINE.

In the west-central part of the Bristow quadrangle, extending from secs. 28 and 29, T. 17 N., R. 8 E., southward to secs. 33 and 34, T. 16 N., R. 8 E., is an area where there is considerable folding and extensive faulting. In this area a short anticline, here called the South Catfish anticline, extends from the NW. ¼ sec. 16 to the NW. ¼ sec. 9, T. 16 N., R. 8 E. The reverse (eastward) dips that mark one side of this fold are seen in the rocks that lie between the valley of Catfish Creek and the fault that crosses secs. 9 and 15. The eastward descent of the beds, which ranges from 10 to 90 feet or more, according to location along the fold, can be determined only by obtaining the altitudes of the same beds on the opposite side of the valley. The beds were correlated by tracing those on the east side northward and across the valley and then southward on the west side of the valley. The fault in secs. 9 and 15, the downthrow of which is on the west side, is probably the cause of most of the easterly dip in the southern part of sec. 9 and the northern part of sec. 16. As the westward dip on the west side of the anticline was observed as far east as the west side of secs. 9 and 16, the crest is located somewhat farther east in a place where there are few if any rock outcrops. Because of the lack of outcrops the details of configuration of the anticlinal crest can not be determined.

The southward extension of the anticline into sec. 16 is interrupted by another fault with a northwesterly trend. The east flank of the anticline continues without interruption for some distance along the northeast side of this fault, as shown by the dip of the rocks lying between this fault and Catfish Creek, in the S. ½ sec. 16. The north end of the anticline plunges gently.

The possibilities of finding oil and gas in this anticline are discussed on pages 89–90.

NORTH CATFISH ANTICLINE.

North of the South Catfish anticline is another fold, the North Catfish anticline, which is terminated on the south by the fault that crosses sec. 5, T. 16 N., R. 8 E. This fold is not symmetrical but pitches northward until it merges into the regional westward dip in secs. 28 and 29, T. 17 N., R. 8 E. The eastward dip on this anti-

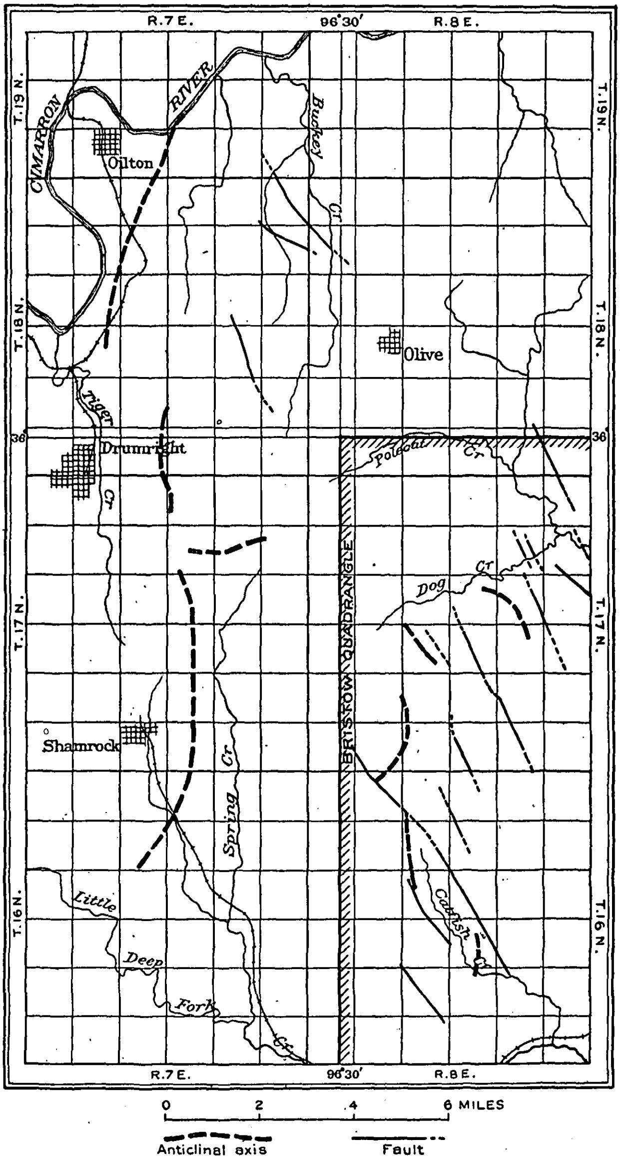


FIGURE 16.—Sketch map showing location of axes of Catfish anticlines and the anticlines of the Cushing oil and gas field, Oklahoma.

cline is slight in sec. 28 and the northern part of secs. 32 and 33, but in the southern part of sec. 32 the upfolding of the upthrown block of the fault to the south is noticeable, and in the northeastern part of sec. 5 and the northwestern part of sec. 4 the maximum eastward dip is reached. This reverse dip extends eastward to the syncline in sec. 4, T. 16 N., R. 8 E., and sec. 33, T. 17 N., R. 8 E.

The possibilities of finding oil and gas in this anticline are discussed on page 90.

RELATION TO CUSHING ANTICLINES.

The combined extent of the North and South Catfish anticlines is about 4 miles, and, if taken together, they are comparable in size to some of the Cushing anticlines. They lie but 6 miles east of the Shamrock dome and its probable extension south of the area mapped by Buttram [1] in the Cushing field and have approximately the same trend. (See fig. 16.)

Because of this close proximity and similar trend, and because the combined extent of the two anticlines is similar to that of some of the Cushing anticlines, it seems reasonable to suppose that the Catfish anticlines were formed at the same time and under the same conditions as the Cushing group of anticlines.

MINOR ANTICLINES.

Scattered over the remainder of the area considered in this report are a few small anticlines that appear to be the result of downfolds in the otherwise northwestward-sloping beds, formed by local folding that accompanied drop faulting, especially where the down-dropped block is on the southwest side. Such an anticline is mapped in sec. 18, T. 17 N., R. 10 E. The folding was caused by the same fault movement that produced the larger or eastern fault. There is little doubt as to the fold in the northwest quarter of this section, but as it enters the valley in the southwest quarter the structure as portrayed on Plate IV may be questioned. The structure in this quarter section is represented as an extension of that to the northeast, but this may not be the true condition, for it is possible that a fault exists in this valley, and, if so, the fold in the northwest quarter must be abruptly terminated.

Other small anticlines, which appear to be due to similar folding that accompanied fault movements, are present in the NW. ¼ sec. 21, T. 17 N., R. 8 E.; sec. 14, T. 17 N., R. 8 E.; sec. 30, T. 17 N., R. 9 E.; the southwestern part of sec. 1 and the northern part of sec. 12, T. 16 N., R. 9 E.; and sec. 22, T. 16 N., R. 8 E. Folds of a similar nature are mapped in secs. 11 and 12, T. 17 N., R. 8 E., but as the field evidence in these localities is not conclusive the folds are shown on the map by dashed contours.

The possibilities of finding oil and gas in these minor anticlines are discussed on pages 90–92.

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[1] Buttram, Frank, op. cit., pl. 1.

FAULTS.

The faults of the Bristow quadrangle are in general parallel and trend approximately N. 30° W. They are all of minor magnitude, both in vertical displacement and areal extent; the largest stratigraphic throw is about 130 feet and the greatest length is about 3¼ miles. The faults are roughly grouped in belts that cross the country approximately parallel to the strike of the rock beds.

In this region, where the rock outcrops are so poor and unsatisfactory for determining the details of the geologic structure, it may be well to describe briefly the criteria upon which the mapping of the faults is based. The best evidence, which at the same time is the most unusual, consists in slickensided faces of sandstone outcrops. Plate VI shows the most prominent of such slickensided fault planes observed in the region. At most places such exposures are very small and stand but a foot or two above the surface. An intermittent row of such outcrops marks the course of a fault with certainty. As mentioned above, however, such exposures are exceptional. Moreover, they are limited to places where sandstone and shale are on opposite sides of the fault plane and the shale has been eroded, the sandstone being left standing above the adjacent surface.

The fault movements sheared the rocks adjacent to the fault planes in a zone several feet thick. The fractures in these shear zones have subsequently been filled by veinlets of siliceous or calcareous material, and these veined shear zones are to be seen at many places where the slickensided fault planes are not exposed. Moreover, they are exposed where the opposite sides of the fault consist of sandstone.

Another method of detecting faults is by the discordance of beds on the two sides of the fault, an unsatisfactory method where there are no good horizon markers, as in areas where shale is the surface rock. Still another method, the discrepancy in the position of contour lines as determined from the evidence in hand, was employed in locating a supposed fault in an area of no outcrops in sec. 12, T. 17 N., R. 8 E.

The slickensided surfaces developed in sandstone represent the positions of the fault planes. The plane of the fault in the north-central part of sec. 5, T. 16 N., R. 8 E., is thus indicated as dipping 60° SW. As the dropped block is in the direction of the dip of the fault plane, the fault is of the normal type. The same is true of the fault in the NE. ¼ SW. ¼ sec. 15, T. 16 N., R. 8 E., which dips 55° SW.

There is no direct evidence that thrusting has taken place along any of the faults, nor do any of the structural features suggest thrust faulting, and hence, without evidence to the contrary, all the faults will be considered normal. The dip of the fault planes probably varies. At some places it is probably greater than 60° and at other places less than 55°, which are the measured dips at the localities mentioned above. It is probable that the individual fault planes change in dip from place to place. Those faults whose traces are not altogether straight but are more or less curved or bowed as shown on Plate IV may have these irregular courses because of variation in dip.

A feature of several of the faults, the significance of which has not been determined, is the relation of the buckling of the strata on the upthrown and downthrown sides. As illustrated in figure 17, the beds on the upthrown side are sharply upturned near one end of the

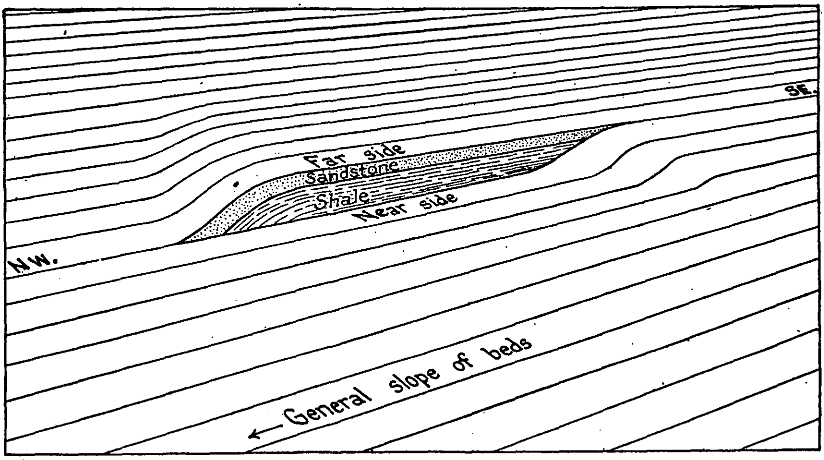
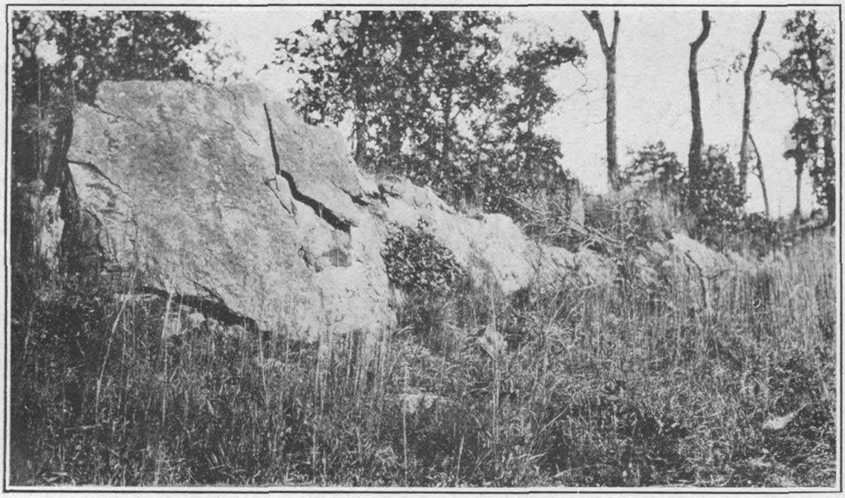


FIGURE 17.—Sketch of a faulted sandstone bed showing the upthrown block (far side) sharply turned down at the northwest end of the fault and the downthrown block (near side) sharply turned up at the southeast end of the fault.

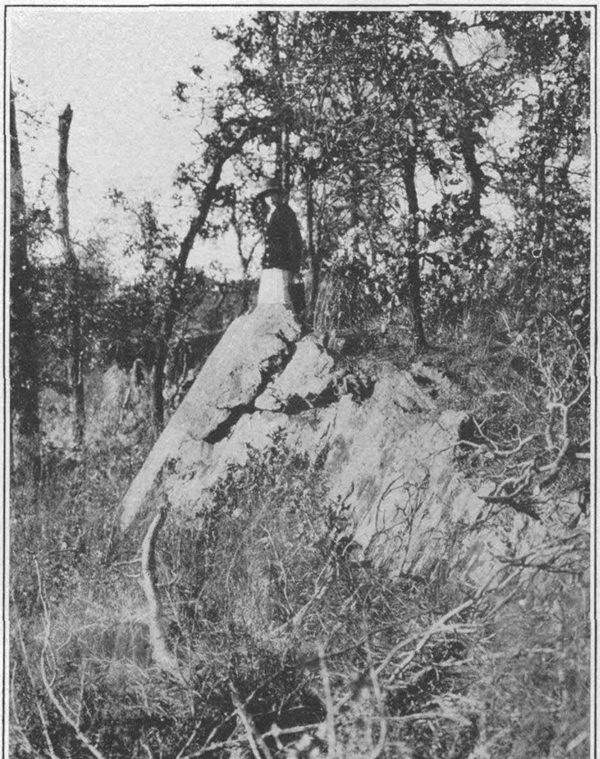
fault and those of the downthrown side are sharply downfolded near the other end. This relation is indicated on the structure contour map (Pl. IV) by the bunching of the contours on opposite sides of the faults near the opposite ends of the displacements. Most of the faults represented on Plate IV show this feature.

The contouring of the structure in the northern and eastern parts of sec. 3, T. 17 N., R. 8 E., is subject to doubt. There is some evidence of a fault here, but no faults are represented on the map. Because of the doubt as to the real structure in this place, the contouring of the valley region to the north, in secs. 34 and 35, T. 18 N., R. 8 E., must also be considered doubtful.

The oil and gas possibilities of the faults are considered on pages 88 and 92.



A.



B.

FAULT SCARP SHOWING SLICKENSIDED SURFACE OF SANDSTONE PRODUCED BY FAULT MOVEMENT.

RELIABILITY OF THE REPRESENTATION OF STRUCTURE IN THE ABSENCE OF ACCURATE WELL RECORDS.

The representation of the structure on Plate IV is dependent on the visible evidence as to the structure of the surface rocks. In many places the information thus obtained is meager and not absolutely reliable. Nevertheless, the results here given represent much painstaking work, the relative reliability of which in different parts of the region is shown by solid and dashed contours.

As the contouring of the structure of the Tiger Creek sandstone over a large part of the region is based on the structure of its overlying and underlying strata, which form the surface rocks, the actual configuration of this sandstone may vary considerably from the configuration as represented on the map. However, no other method of determining the structure is possible until numerous accurate well records are available to furnish more reliable information, which can be used as a check on the calculated intervals between the strata used in this provisional mapping.

The importance of accurate well records for determinations of structure can not be overstated. They give the most reliable and in many places the only clue as to the actual conditions beneath the surface. The value of reliable knowledge concerning the underground strata for the systematic development of any property is being more fully recognized by many of the oil and gas producers, but as yet there has been no corresponding or really satisfactory advance in the reliability of the logs kept by many of the drillers.

Limestones and producing sands are the best key rocks to be recorded in well logs, and their depth and thicknesses should be determined by steel-line measurements. A statement in a well record of every such steel-line measurement insures greater usefulness for the data and far greater confidence therein on the part of the engineer and geologist. Steel-line measurements should not be limited to limestones and producing sands; they should be made to other beds also, to check the measurements made by the drilling cable. The habit of estimating depths and thicknesses of strata by drillers, however proficient they may be, should be unqualifiedly condemned, as should also their identification of the strata they are drilling by the feel of the cable or the rate at which the drill is progressing. By this method hard sand is very often recorded as limestone and soft sand as shale. Many other discrepancies also appear that could be eliminated by an examination of the drill cuttings. The great discrepancies so frequently to be noted in logs of neighboring wells, which should in fact be very similar, shows how prevalent this habit is and how little value is placed by the driller on data that may be of the greatest importance to the operator in determining the structure and selecting sites for subsequent drilling.

PROSPECTIVE OIL AND GAS AREAS.

GEOLOGIC FEATURES GOVERNING THE OCCURRENCE OF OIL AND GAS.

The geologic features that affect the accumulation of oil and gas may be divided into two general classes—those which can be determined at the surface and those which are due to local conditions beneath the surface. Those features which can be determined at the surface are structural in nature and consist of rock folds (anticlines, domes, etc.) and faults.

Accumulations of oil and gas in rock folds are generally situated at the crests, and the crests are therefore the more favorable localities for testing folds. Faults, on the other hand, may or may not affect the accumulation of oil and gas by sealing the oil and gas bearing

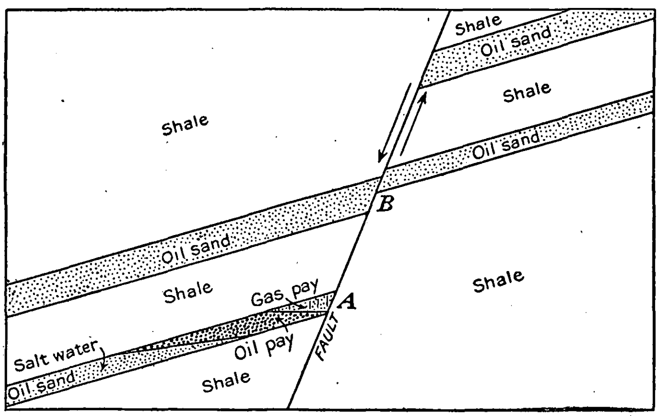


FIGURE 18.—Diagrammatic cross section showing (at *A*) an accumulation of oil and gas caused by a fault and (at *B*) a possible condition under which a fault may not cause oil and gas to accumulate.

sands which they break. Where a fault cuts a rising oil and gas bearing sand, the fault may seal the sand in such a way that the oil and gas are arrested in their upward journey and caused to accumulate. The lower sand at *A* in figure 18 illustrates such a case. A shale bed brought opposite the broken end of a sand bed is probably the most effective method of sealing it. This, however, is not the necessary result of any fault which cuts an oil and gas bearing sand, for another sand may be brought opposite the first sand, as is shown at *B* in figure 18, or the fault plane may be more or less open, so that the sealing in of the oil and gas is not effected. It may be that a sand is sealed over part of the length of a fault and not over the rest. Search for the sealed portions is therefore a very blind process. Obviously the conditions caused by a fault where it cuts an oil and gas bearing sand can not always be determined by an examination of the rocks at the surface.

Of those local underground geologic features which affect accumulations of oil and gas and which can not be detected by a study of the surface rocks, important examples are sandstones whose upper surfaces are convex, owing to their lenticular shape or to an unconformable relation with the overlying beds; sandstones in which some parts have a higher porosity than other parts; and underground anticlines, domes, and monoclinal folds that do not appear in the rocks at the surface because of unconformities or irregularities in the rocks between.

LOCALITIES OF FAVORABLE STRUCTURE.

GENERAL CONDITIONS.

Surface indications of oil and gas, such as oil or gas seeps or asphalt deposits, were not observed in the Bristow region. However, from the fact that some gas and good showings of oil have been found in the wells that have been drilled, and from the further fact that large quantities of oil and gas have been developed in the Cushing field, immediately to the west, where favorable geologic structure appears to be the controlling influence, it is believed that areas of similar favorable structure are likely to contain paying quantities of oil and gas in the Bristow quadrangle.

SOUTH CATFISH ANTICLINE.

The crest of the South Catfish anticline lies in the western part of sec. 9 and the northwestern part of sec. 16, T. 16 N., R. 8 E. The uncertainty as to the configuration of this crest and the presence of faults near by leave some doubt as to the best location for a test well. As the plane of the fault to the east dips southwestward, any test well should probably be as far from it as possible and yet be near the crest of the anticline. Presumably it is also advisable to keep away from the fault in sec. 16, because its northwestern extremity is not definite. With the above factors in mind, the most promising locality appears to be the SW. ¼ SW. ¼ sec. 9, T. 16 N., R. 8 E. If oil or gas in paying quantities is found in this locality, any additional producing territory will probably include most of the W. ½ sec. 9 except its northeasternmost part, the E. ½ sec. 8, the NE. ¼ sec. 17, and the NW. ¼ sec. 16.

If a well is drilled in the SW. ¼ SW. ¼ sec. 9, as above mentioned, the Layton sand, if it extends into this region, will probably be found at about 400 feet below sea level, or at a depth of about 1,250 to 1,300 feet. Inasmuch as the distance between the Layton and Bartlesville sands in the Cushing field varies from place to place, any estimate as to the depth of the Bartlesville may differ from the true depth, if that sand exists here, by several hundred feet. The distance between these sands as given in the record of a well in sec. 10,

T. 16 N., R. 7 E., is about 1,375 feet, and if this is the interval in the SW. ¼ sec. 9, T. 16 N., R. 8 E., the Bartlesville should be found there at 1,775 feet below sea level, or at a depth of about 2,600 to 2,650 feet; but it may be necessary, on account of the variation in the distance between the sands, to go several hundred feet deeper.

NORTH CATFISH ANTICLINE.

The North Catfish anticline lies in secs. 28, 29, 32, and 33, T. 17 N., R. 8 E., and in the northeastern part of sec. 5, T. 16 N., R. 8 E., and is described in detail on pages 82–83. As the highest part of this anticline is adjacent to the fault in sec. 5, the possible effect of this fault on the accumulation of oil and gas must be considered. The fault plane may have acted as a channel for the escape of any oil or gas which might have been in the sands that were broken, but no evidence of such escape was observed at the surface. Oil and gas, however, could have escaped along the fault plane even if none reached the surface, for they may have entered some other porous sand below the surface. (See fig. 18.) If the fault plane did not permit the escape of oil or gas originally confined in the anticline, it should have made the area immediately northeast of the fault a place for the accumulation of any oil or gas which the sands may have contained, by sealing them in. If such are the conditions the place for a well to obtain the greatest possible production, provided the sands are continuously porous and well stored, is at the highest part of the block on the northeast side of the fault, in the northeastern part of the NE. ¼ NW. ¼ or the northeastern part of the SW. ¼ NE. ¼ sec. 5, T. 16 N., R. 8 E. As the fault plane dips to the southwest it will not be penetrated by any wells drilled to the northeast of its trace at the surface. If the fault does not seal the sands here and a test well drilled at this point proves a failure, the area to the north, which lies west of the slight reversal of dip, should not be condemned but should be tested by a second well drilled in the SE. ¼ sec. 32, T. 17 N., R. 8 E., preferably near the center or in the north half of this quarter section.

The position of the Layton and Bartlesville sands at these localities—the north-central part of sec. 5, T. 16 N., R. 8 E. and the center of the SE. ¼ sec. 32, T. 17 N., R. 8 E.—should be, respectively, about 30 or 40 feet more and 10 or 20 feet less than those given above for sec. 9, T. 16 N., R. 8 E.

LOCALITIES OF POSSIBLE FAVORABLE STRUCTURE.

MINOR ANTICLINES.

The possibilities of the anticline in sec. 18, T. 17 N., R. 10 E., appear uncertain. Because the unknown factors mentioned on pages 83 and 85 are so numerous, no specific location for a test well will be recommended. However, it is suggested that the crest of the anticline has the best possibilities. In view of the fact that the main (eastern) fault to the east probably dips to the southwest, a test well, to avoid passing through the fault, should be as far southwest of it as possible and still be near the crest of the anticline. Such a test would probably reach the Fort Scott limestone at about 1,000 feet below sea level; an oil and gas sand reported in the well in sec. 1, T. 16 N., R. 9 E. (see log on p. 97) at 1,170 feet; the Red Fork sand at 1,474 feet; and the Glenn sand at 1,640 feet.

Of the smaller anticlines whose reversed dips appear to be due to folding that accompanied the dropping of a fault block, the one in secs. 1 and 12, T. 16 N., R. 9 E., has been tested by a well drilled during the winter of 1915–16 by the Atlas Oil Co., near the south line of sec. 1. This well, whose log is given on page 97, is said to have found oil and gas at several horizons, as follows: 3,000,000 cubic feet of gas at 788 feet, a little gas at 1,065–1,083 feet; 1,000,000 cubic feet of gas at 1,145 feet, a showing of oil and gas at 2,040–2,074 feet, and a light showing of oil at 2,344–2,369 feet. The quantity of gas discovered was not considered sufficient to make it a paying gas well, and hence the hole was abandoned. From this meager showing of a well favorably located for such a structure, it would appear that this anticline is not sufficiently closed to the southeast to confine either oil or gas in large quantities. Considering the failure of this well, the prospects offered by similar folds in this area are not full of promise. There probably will come a time, however, when small producing wells will pay, and to find them the oil producer will drill all these minor folds that offer any promises of success. It is believed that the folds in sec. 30, T. 17 N., R. 9 E., sec. 14, T. 17 N., R. 8 E., sec. 21, T. 17 N., R. 8 E., and sec. 22, T. 16 N., R. 8 E., will give better chances than most of the surrounding territory.

The locality that appears best for a test of the anticline in sec. 30, T. 17 N., R. 9 E., is the center of the section. Not only is there a slight fold here, but the fault to the east may help influence the accumulation of oil or gas at this place, in the way described on pages 88 and 92. In drilling at this locality the strata that were found in the well in sec. 29, T. 17 N., R. 9 E. (see record on p. 95), will be found about 60 feet lower with reference to sea level.

The best locality for a first test of the anticline in sec. 14, T. 17 N., R. 8 E., is probably in the NE. ¼ SW. ¼. The fault to the east of this locality also may have some influence in causing oil and gas to accumulate. A guide as to what may be found here is afforded by the log of the well in sec. 26, T. 17 N., R. 8 E. (see p. 95), and the formations will be found about 20 to 30 feet lower with reference to sea level.

The fold in sec. 21, T. 17 N., R. 8 E., may first be tested by a well in the center of the NW. ¼. As the fault to the east is small, its influence in causing oil and gas to accumulate is probably negligible. The strata to be found here will probably be the same as those encountered in the wells in sec. 20, T. 17 N., R. 8 E., but at this locality they will probably be about 50 feet higher with respect to sea level. The records of these wells are given on pages 93–94.

For the anticline in sec. 22, T. 16 N., R. 8 E., the NW. ¼ SE. ¼ appears to be the most favorable locality for a test well. The displacement of the fault to the east is small, and its confining effect in causing oil and gas to accumulate here is probably also small. Some idea of the strata to be found here may be obtained by consulting the records of the wells in sec. 30, T. 16 N., R. 8 E., and sec. 3, T. 16 N., R. 8 E., which are given on page 94. The strata recorded in the well in sec. 30, T. 16 N., R. 8 E., should be found from 125 to 175 feet higher with reference to sea level, but those of the well in sec. 3, T. 16 N., R. 8 E., will be found at about the same position here.

The occurrence of several other folds whose form or even actual presence is questionable is mentioned on page 84. As the representations of these folds on the contour map are not based on well-determined facts, no suggestions for testing them will be given.

FAULTS.

The effectiveness of simple faults in causing oil and gas accumulations has not been well demonstrated in the Mid-Continent field. The faults of the Bristow region are small, and it may be that they affect only the rocks near the surface and do not reach the oil and gas bearing sands. Furthermore, they do not break the strata at right angles to the dip but at a small acute angle; hence, even if they do reach the oil and gas sands, their effectiveness in causing the oil and gas to accumulate is not at its maximum. Because the possibilities of finding paying quantities of oil and gas on the down dip (west) side of the faults are uncertain, search for such possible accumulations is not recommended until the more favorable areas of the Bristow region have been tested and their value proved.

LOCALITIES OF UNFAVORABLE STRUCTURE.

The localities of unfavorable structure in this region are those outside of the faulted zones and anticlines, in which the rock beds have the normal westward dip. The sands in the areas of normal structure probably carry some oil and gas in quantities sufficient to give showings in wells that penetrate them, but it requires some special feature, similar to those described on pages 88–89, to produce any accumulation large enough to pay for its development.

In the southeastern part of sec. 36, T. 17 N., R. 9 E., the structure seems to be normal, but sufficient gas was encountered in a well at a depth of 990–1,018 feet to make it worth while to close it in and save it for utilization at some future time. This is the only one of 13 wells drilled in the areas of normal structure in this region that found paying quantities of either oil or gas. For the locating of similar small paying wells no help can be expected from a study of the surface geology, and the chances for finding in this region other paying localities similar to the one mentioned appear small.

WELL RECORDS.

The wells whose records are given below are either in the area described in this report or in its immediate vicinity.

Log of P. M. Kerr's Elijah Hendrickson well No. 1, in the northwest corner E. ½ SW. ¼ sec. 5, T. 17 N., R. 8 E.

[From M. J. Munn; authority, P. M. Kerr. Casing: 12½-inch, 2 joints; 10-inch, 780 feet; 8¼-inch, 1,590 feet.]

	Depth.		Depth.
	Feet.		*Feet.*
Layton sand (small show for oil)	1,450–1,548	Wheeler sand (dry)	2,220–2,255
Jones sand (small show for oil)	1,790–1,808	Bartlesville sand (gas)	2,620–2,700
Cleveland sand (dry)	1,900–1,910	Tucker sand (water)	2,800–2,812

Log of U. Logan well No. 1, in the NW. ¼ sec. 20, T. 17 N., R. 8 E.

[From Bermont Oil Co. Contractor, American Drilling Co. Drilled Nov. 7, 1912, to May 16, 1913. Casing 20-inch, 19 feet; 16-inch, 57 feet; 12½-inch, 625 feet; 10-inch, 990 feet; 8¼-inch, 1,479 feet.]

	Depth.		Depth.
	Feet.		*Feet.*
Sand	907–946	Sand (little oil)	1,805–1,920
Lime (sprayed oil at 1,400 feet)	1,390–1,412	Wheeler sand (no oil)	2,270–2,320
Layton sand (no oil)	1,440–1,470	Oswego lime (no oil)	2,380–2,420
Sand	1,545–1,570		

Log of White & Sinclair's Capadenna Cox well No. 1, in southwest corner sec. 20, T. 17 N., R. 8 E.

[From R. C. McClellan, driller. Drilled July 12 to Aug. 31, 1915. Casing: 15½-inch, 36 feet; 12½-inch, 451 feet; 10-inch, 810 feet; 8-inch, 1,070 feet; 6-inch, 2,423 feet; 5$\frac{3}{16}$-inch, 3,010 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Water sand	10	70	Red rock	20	480
Red mud	40	110	Sand (water)	30	510
Sand	20	130	Blue mud	30	540
Red mud	30	160	Unrecorded	5	545
Sand (water)	20	180	Blue mud	55	600
Blue mud	70	250	Sand (water)	25	625
Sand (water)	10	260	Red rock	65	690
Red rock	40	300	Sand	10	700
Sand	20	320	Red rock	30	730
Red rock	30	350	Sand (water)	20	750
Sand (water)	25	375	Red rock	6	756
Red rock	50	425	Sand	14	770
Sand (water)	35	460	Lime	4	774

Log of White & Sinclair's Capadenna Cox well No. 1, in southwest corner sec. 20, T. 17 N., R. 8 E.—Continued.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sand (water)	16	790	Slate	34	1,534
Red rock	35	825	Sand (water, 20 bailers)	16	1,550
Lime (water)	5	830	Slate	170	1,720
Red rock	5	835	Lime	4	1,724
Sand (water)	25	860	Slate	93	1,817
Red rock	20	880	Lime	9	1,826
Lime	20	900	Jones sand	20	1,846
Red rock	75	975	Slate	134	1,980
Sand	25	1,000	Lime	16	1,996
Slate	15	1,015	Slate	429	2,425
Lime (gas and water)	15	1,030	Wheeler sand	75	2,500
Slate	45	1,075	Slate	40	2,540
Lime	5	1,080	Lime	10	2,550
Slate	20	1,100	Sand	95	2,645
Lime	8	1,108	Slate	55	2,700
Slate	17	1,125	Sand	50	2,750
Lime	5	1,130	Slate	120	2,870
Slate	70	1,200	Sand	30	2,900
Lime	12	1,212	Slate	90	2,990
Slate	253	1,465	Sand	45	3,035
Layton sand	35	1,500			

Log of Oklahoma Natural Gas Co.'s Daniel West well No. 1, in sec. 30, T. 16 N., R. 8 E.

[From Oklahoma Natural Gas Co. Drilling completed Oct. 16, 1913. Contractor, Kaw Drilling Co. Casing: 12½-inch, 309 feet; 10-inch, 801 feet; 8-inch, 1,285 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sand	50	50	Slate	70	1,100
Slate	35	85	Lime	10	1,110
Sand (hole full of water at 130 feet)	70	155	Sand	50	1,160
Red rock	125	280	Slate	130	1,290
Sand	20	300	Sand	40	1,330
Red rock	65	365	Slate	230	1,560
Sand (hole full of water at 365 feet)	75	440	Lime shells	40	1,600
Red rock	70	510	Slate	250	1,850
Sand	30	540	Sand (2 bailers of water per hour at 1,900 feet; show of oil)	115	1,965
Red rock	65	605	Slate	535	2,500
Sand	30	635	Slate and shells	223	2,723
Slate	25	660	Sand	12	2,735
Sand	25	685	Slate	115	2,850
Red rock	65	750	Brown shale	50	2,900
Sand	40	790	Slate	85	2,985
Slate	100	890	Lime	24	3,009
Sand (hole full of water at 890 feet)	120	1,010			
Lime	20	1,030			

Log of White & Sinclair's Johnny Myers well No. 1, in northeast corner SE. ¼ sec. 3, T. 16 N., R. 8 E.

[From White & Sinclair. Drilling completed May 28, 1913. Contractor, Kiester Drilling Co. Casing: 16-inch, 141 feet; 12½-inch, 355 feet; 10-inch, 856 feet; 8 inch, 1,406 feet; 6⅝-inch, 2,321 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sand (water at 2,360 feet)	20	2,374	Water	....	2,872
Shell	....	2,724	Total depth	....	2,875
Sand	80	2,810			

Log of Noble Cobb well No. 1, in sec. 26, T. 17 N., R. 8 E.

[From Bermont Oil Co.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
"Surface"	25	25	White shale	15	1,205
Quicksand (water)	15	40	Sand (10 bailers of water)	25	1,230
Red clay	50	90	Lime	5	1,235
Sand (water)	10	100	White shale	65	1,300
Red clay	20	120	Sand	27	1,327
Sand (water)	25	145	Brown shale	78	1,405
Red rock (water)	20	165	White slate	73	1,478
Sand	5	170	Sandy lime	10	1,488
Red rock	20	190	Shale	43	1,531
Sand	5	195	Lime	19	1,550
Soapstone	35	230	Sand	15	1,565
Sand	5	235	White slate	35	1,600
Blue shale	25	260	Black slate	30	1,630
Sand (water)	20	280	Sand	1	1,631
Red rock	55	335	White shale	4	1,635
Sand	5	340	Oil sand (show of oil)	20	1,655
Red rock	5	345	White shale	10	1,665
Lime (very hard)	10	355	Sand (little gas)	10	1,675
Red rock	15	370	White shale	25	1,700
Sand (water)	25	395	Lime	5	1,705
Break	2	397	Shale	120	1,825
Sand	54	451	Black shale	345	2,170
Red rock	39	490	Lime	4	2,174
Sand (water)	7	497	Shale	6	2,180
Break	2	499	Lime	25	2,205
Sand	10	509	Black slate	30	2,235
Break	3	512	Sandy lime	20	2,255
Lime	8	520	White shale	25	2,280
Broken lime	5	525	Sand	35	2,315
Slate	100	625	Sandy shale	25	2,340
Sand (show of gas)	20	645	Brown shale	30	2,370
Unrecorded	17	662	Sand	30	2,400
Brown shale	7	669	White shale	70	2,470
Sand (hole full of water)	11	680	Hard sand	10	2,480
Blue shale	45	725	White shale	80	2,560
Shell	5	730	Black shale	60	2,620
Brown shale	5	735	Lime	10	2,630
Lime	10	745	White shale	5	2,635
Blue shale	95	840	Sand	20	2,655
Lime	5	845	Gray shale	85	2,740
White slate	25	870	Black slate	17	2,757
Sand	5	875	Sandy lime (3 bailers per hour)	10	2,767
Blue slate	5	880	White shale	9	2,776
White slate	95	975	Broken sand	24	2,800
Slate	135	1,110	Water sand (hole full of water last three screws)	78	2,878
Sandy shale	20	1,130			
Lime	60	1,190			

Log of B. B. Jones and Hoppy Toad Oil Co.'s Maxey well No. 1, in sec. 29, T. 17 N., R. 9 E.

[From C. T. Freeland and Glen Craker. Drilled November, 1913, to January, 1914. Contractors, Freeland & Craker. Casing: 12½-inch, 338 feet; 10-inch, 852 feet; 8-inch, 1,340 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
"Surface"	4	4	Lime (hole full of water)	30	500
Sand	7	11	Slate	20	520
Slate	29	40	Lime	15	535
Lime (water)	20	60	Slate	35	570
Red mud	40	100	Sand (water)	5	575
Lime	20	120	Lime	20	595
Sand	25	145	Sand	8	603
Slate	65	210	Lime	7	610
Sand (water)	30	240	Slate	40	650
Red rock	60	300	Lime	5	655
Lime	38	338	Slate	95	750
Sand	62	400	Lime	35	785
White lime	30	430	Break	2	787
Slate	40	470	Lime	13	800

Log of B. B. Jones and Hoppy Toad Oil Co.'s Maxey well No. 1, in sec. 29, T. 17 N., R. 9 E.—Continued.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sand	5	805	Sandy shale	90	1,830
Shale	7	812	Slate	75	1,905
Sand	40	852	Sand	10	1,915
Slate	6	858	Slate	45	1,960
Lime	6	864	Dark shale	60	2,020
Slate	36	900	Lime	50	2,070
Slate, shelly	70	970	Dark shale	20	2,090
Lime	35	1,005	Lime, Baker sand (dry)	10	2,100
Slate	25	1,030	Shale	80	2,180
Sand (11 bailers of water)	50	1,080	Sand	5	2,185
Light shale	20	1,100	Shale	80	2,265
Black shale	207	1,307	Wheeler sand	40	2,305
Sand	33	1,340	Shale	50	2,355
Light shale	5	1,345	Sand	15	2,370
Sand	5	1,350	Shale	110	2,480
Dark shale	12	1,362	Sand	35	2,515
Lime	6	1,368	Shale	40	2,555
Layton sand (show of oil at 1,368–1,380 feet)	39	1,407	Black shale	10	2,565
Shale	8	1,415	Bartlesville sand; top hard (show of oil at 2,640–2,646 feet; 1 bailer of oil after standing over Sunday)	85	2,650
Lime	10	1,425	Shale	10	2,660
Slate, shelly	55	1,480	Water sand	40	2,700
Slate	20	1,500			
Sand	30	1,530			
Shale	210	1,740			

Log of Hoppy Toad Oil Co.'s Joseph Bell well No. 1, in sec. 33, T. 17 N., R. 9 E.

[From Bermont Oil Co. Casing: 8¼-inch, 1,564 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Red rock	130	130	Sand	10	1,490
Sand	15	145	Sand (10 bailers of water)	10	1,500
Red rock	25	170	Sand	75	1,575
Sand	78	248	Lime	43	1,618
Lime	17	265	Slate	182	1,800
Red rock	13	278	Black slate (cave)	100	1,900
Sand	12	290	Slate	150	2,050
Red rock	15	305	Cave	25	2,075
Sand	15	320	Slate	5	2,080
Red rock	10	330	Lime	8	2,088
Slate	78	408	Slate	4	2,092
Lime	52	460	Lime	20	2,112
Red sand	20	480	Slate	6	2,118
Lime	10	490	Sand	38	2,156
Water sand	25	515	Slate	64	2,220
Lime	41	556	Hard lime	7	2,227
Brown sand	6	562	Slate	29	2,256
Slate	89	651	Wheeler sand	10	2,266
Lime	7	658	Black shale	66	2,332
Slate	94	752	Sand	30	2,362
Sand (enough water to drill with at 777 feet)	30	782	Black shale	78	2,440
Slate	78	860	Black cave	60	2,500
Sand (hole full of water)	35	895	Sand	5	2,505
Slate	75	970	Shale	5	2,510
Lime	30	1,000	Sand	52	2,562
Slate	40	1,040	Lime shell	3	2,565
Sand	10	1,050	Sand	36	2,601
Slate	160	1,210	Sandy shale	6	2,607
Black shale	58	1,268	White shale	27	2,634
Slate	73	1,341	Black shale	10	2,644
Lime and sand	10	1,351	Sand (top hard)	13	2,657
Slate	39	1,390	Sandy shells	38	2,695
Lime	8	1,398	Sand (1½ bailers of water)	30	2,725
Slate	77	1,475	Unrecorded	6	2,731
Sand (gas and oil)	5	1,480	Sand (hole full of water at 2,737 feet; through sand)	19	2,750

Log of Selby Oil Co.'s and Frank Barnes's Stubblefield well No. 1, in the SW. ¼ SW. ¼ sec. 10, T. 16 N., R. 9 E.

[From C. T. Freeland and Glen Craker. Casing: 10-inch, 453 feet; 8¼-inch, 800 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Red quicksand	50	50	Sand	5	1,360
Red rock	20	70	Unrecorded	55	1,415
Sand (water)	20	90	Sand (little gas)	5	1,420
Red rock	30	120	Unrecorded	5	1,425
Sand	50	170	Sand shells	15	1,440
Shale	80	250	Sandy lime	20	1,460
Sand	15	265	Slate	160	1,620
Red rock	15	280	Black slate	20	1,640
Sand (this may be the Tiger Creek sandstone)	35	315	Slate	200	1,840
			Black slate	20	1,860
Slate	75	390	Slate	40	1,900
Sand	55	445	Hard lime shell	2	1,902
Unrecorded	265	710	Unrecorded	178	2,080
Sand (hole full of water)	35	745	Lime	15	2,095
Unrecorded	105	850	Unrecorded	30	2,125
Lime (show of water)	12	862	Lime	5	2,130
Unrecorded	338	1,200	Unrecorded	80	2,210
Lime	10	1,210	Red rock (little gas)	30	2,240
Unrecorded	50	1,260	Unrecorded	90	2,330
Sand	22	1,282	Black shale, caved	58	2,388
Unrecorded	38	1,320	Sand	12	2,400
Sand	5	1,325	White sandy shale	110	2,510
Unrecorded	30	1,355	Black slate.		

Log of Atlas Oil Co.'s Allan Ralston well No. 1, in SW. ¼ sec. 1, T. 16 N., R. 9 E.

[From Harry R. Johnson. Drilling began Dec. 30, 1915. Casing: 10-inch, 826 feet; 8¼-inch, 1,648 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Dirt	4	4	Sand	6	1,386
Sand	31	35	Shale	414	1,800
Mud (red and blue)	115	150	Sand	8	1,808
Water sand (12 bailers fresh water per hour)	45	195	Shale	62	1,870
			Lime (Big lime)	25	1,895
Black shale (mud)	86	281	Shale	5	1,900
Lime	49	330	Sand, limy	18	1,918
Shale	30	360	Shale	65	1,983
Lime	15	375	Lime (Oswego)	8	1,991
Shale	65	440	Shale	49	2,040
Water sand (5 bailers at 443 feet)	30	470	Sand (show of oil and gas)	34	2,074
Shale (hole full of water)	98	568	Shale	11	2,085
Sand	12	580	Lime shell	5	2,090
Shale	124	704	Shale	55	2,145
Hard lime	8	712	Sand	8	2,153
Shale	15	727	Shale	191	2,344
Lime	7	734	Sand (light show of oil)	25	2,369
Shale	46	780	Shale	81	2,450
Sand (3,000,000 feet of gas at 788 feet)	20	800	Shell	10	2,460
			Shale	40	2,500
Black shale	265	1,065	Sand (hole full of water at 2,535 feet)	62	2,562
Sand (light gas)	18	1,083			
Shale	27	1,110	Cave	29	2,591
Lime	7	1,117	Lime shell	15	2,606
Shale	24	1,141	Cave	18	2,624
Sand (1,000,000 feet of gas at 1,145 feet)	30	1,171	Shale	234	2,858
			Cave	30	2,888
Shale	60	1,231	Black shale	32	2,920
Sand	14	1,245	Hard lime	30	2,950
Shale	95	1,340	Shale	40	2,990
Sand	7	1,347	Broken lime	5	2,995
Shale	33	1,380	Lime	183	3,178

Log of Oklahoma Natural Gas Co.'s John F. Ralston well No. 1, in sec. 6, T. 16 N., R. 10 E.

[From Oklahoma Natural Gas Co. Drilled Dec. 1, 1910, to Feb. 4, 1911. Casing: 12½-inch, 52 feet; 10-inch, 450 feet; 6⅝-inch, 2,420 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil and dirt	15	15	Slate	19	1,214
Quicksand	37	52	Limestone	83	1,297
Slate	38	90	Slate and shells	568	1,865
Sand	5	95	Sand	15	1,880
Slate	235	330	Slate	80	1,960
Sand (2 bailers of water at 330 feet; 5 bailers of water per hour at 340 feet)	10	340	Sand	10	1,970
Slate	85	425	Slate	305	2,275
Sand (hole full of water at 440 feet)	15	440	Sand	15	2,290
Slate	515	955	Slate	95	2,385
Sand (gas at 960 feet)	60	1,015	Sand (hole full of water at 2,418 feet)	33	2,418
Slate	121	1,136	Slate	259	2,677
Sand (3 bailers of water per hour at 1,150 feet)	59	1,195	Sand shell (oil at 2,678 feet)	1	2,678
			Slate and shells	122	2,800
			Limestone	202	3,002

Log of Oklahoma Natural Gas Co.'s Bertha M. Self well No. 1, in sec. 36, T. 17 N., R. 9 E.

[From Oklahoma Natural Gas Co. Drilled Mar. 18 to Apr. 5, 1911. Contractor, Charles McKeever. Casing: 12½-inch, 38 feet; 10-inch, 453 feet, 8-inch, 530 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil	20	20	Sand (water at 485 feet)	10	490
Quicksand	18	38	Unrecorded	80	570
Sand (water)	97	135	Lime	10	580
Unrecorded	265	400	Unrecorded	110	690
Sand	10	410	Lime	10	700
Unrecorded	70	480	Sand (gas at 990–1,010 feet)	....	1,018

Log of Oklahoma Natural Gas Co.'s Henry A. Self well No. 1, in sec. 30, T. 17 N., R. 10 E.

[From Oklahoma Natural Gas Co. Drilled June 8 to Aug. 28, 1911. Casing: 12½-inch, 58 feet; 10-inch, 475 feet; 8¼-inch, 1,175 feet; 6⅝-inch, 2,359 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil and quicksand	58	58	Sand (6 bailers of water at 1,150 feet)	41	1,176
Slate and shells (3 bailers of water at 155 feet)	192	250	Lime	458	1,634
Sand shell (2 bailers of water at 252 feet)	5	255	Unrecorded	112	1,746
Slate	75	330	Oswego lime	6	1,752
Sand (10 bailers of water at 335 feet)	20	350	Unrecorded	123	1,875
Sand (hole full of water at 365 feet)	55	405	Sand	30	1,905
Unrecorded	155	560	Unrecorded	149	2,054
Sand (6 bailers of water at 565 feet)	16	576	Sand	16	2,070
Unrecorded	298	874	Unrecorded	158	2,228
Sand	36	910	Sand	131	2,359
Unrecorded	90	1,000	Unrecorded	2	2,361
Cave	50	1,050	Cave	2	2,363
Unrecorded	85	1,135	Lime shell	2	2,365
			Unrecorded	330	2,695
			Sand	105	2,800

Log of Oklahoma Natural Gas Co.'s Jake Brown well No. 1, in sec. 20, T. 17 N., R. 10 E.

[From Oklahoma Natural Gas Co. Drilled June 29 to Aug. 2, 1912. Contractor, Braden Drilling Co. Casing: 12½-inch, 465 feet; 10-inch, 1,400 feet; 8¼-inch, 1,625 feet; 6⅝-inch, 2,230 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
"Surface"	20	20	Slate	204	2,029
Sand	100	120	Shell	6	2,035
Slate and shells	280	400	Slate	65	2,100
Sand (hole full of water at 400 feet)	35	435	Red Fork (top streak sand; 180,000 cubic feet of gas at 2,109 feet; small show of oil at 2,115 feet)	25	2,125
Slate	565	1,000	Slate	5	2,130
Slate and lime shell	100	1,100	Red Fork (second sand)	20	2,150
Slate	100	1,200	Slate	87	2,237
Sand (small amount of gas at 1,210 feet)	50	1,250	Glenn sand (water at 2,240 feet in Glenn sand)	12	2,249
Slate	400	1,650			
Big lime	65	1,715			
Slate	85	1,800			
Sand (2 barrels of water per hour at 1,800 feet)	25	1,825			

Log of Oklahoma Natural Gas Co.'s Kelly Yellowhead well No. 1, in sec. 32, T. 17 N., R. 10 E.

[From Oklahoma Natural Gas Co. Drilled Sept. 2 to Oct. 30, 1912. Contractor, Braden Drilling Co. Casing: 10-inch, 481 feet; 8¼-inch, 1,186 feet; 6⅝-inch, 2,368 feet.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil	5	5	Broken lime	10	1,585
Shale	15	20	Hard lime	4	1,589
Lime	10	30	Shale	11	1,600
Break	5	35	Lime shell	3	1,603
Lime	10	45	Shale	27	1,630
Shale	15	60	Light shale	10	1,640
Shale and shell	65	125	Lime	8	1,648
Broken lime	15	140	Shale	98	1,746
Shale	60	200	Sandy shale	10	1,756
Lime	15	215	Lime, hard	7	1,763
Break (water)	5	220	Shale	118	1,881
Sand	15	235	Sand (show of oil)	18	1,899
Shale, lime, and shell	75	310	Black shale	216	2,115
Sand (water)	15	325	Dark sand	15	2,130
Shale	5	330	Shale	68	2,198
Sand, hard	95	425	Lime	4	2,202
Shale	60	485	Broken lime	10	2,212
Lime	12	497	Shale	18	2,230
Shale and shells	133	630	Sand (water)	138	2,368
Lime	20	650	Shale	6	2,374
Light shale	45	695	Sand, hard	22	2,396
Lime	5	700	Shale	4	2,400
Light shale	175	875	Lime, hard	12	2,412
Lime	12	887	Shale	88	2,500
Light shale	111	998	Lime, hard	8	2,508
Lime	4	1,002	Shale	12	2,520
Shale	103	1,105	Lime	4	2,524
Lime, shale, and shells	20	1,125	Black shale	21	2,545
Sandy shale	10	1,135	White shale	35	2,580
Sand (hole full of water)	33	1,168	Black shale	110	2,690
Shale	10	1,178	Lime	25	2,715
Broken lime	35	1,213	Shale	40	2,755
Shale	362	1,575	Lime	17	2,772