DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 759

GEOLOGY OF THE BRISTOW QUADRANGLE CREEK COUNTY, OKLAHOMA

WITH REFERENCE TO PETROLEUM AND NATURAL GAS

BY

A. E. FATH

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
40 CENTS PER COPY

CONTENTS

ILLUSTRATIONS

GEOLOGY OF THE BRISTOW QUADRANGLE, CREEK COUNTY, OKLAHOMA, WITH REFERENCE TO PETROLEUM AND NATURAL GAS

By A. E. Fath

INTRODUCTION

The Bristow quadrangle, in Creek County, Okla., embraces a large part of the area lying between two of Oklahoma's greatest oil fields, the Cushing and Glenn. (See Pl. I.) Prior to July, 1915, the quadrangle had been tested for oil and gas by 35 drill holes, the result of which was only four small gas wells and one small pumping oil well. These successes seemed too few for an area lying between two of Oklahoma's large oil fields, and to ascertain if possible the reason for this apparent scarcity of oil in this area a detailed geologic study of the quadrangle was undertaken by the United States Geological Survey.

Field work in the area was begun in July, 1915, and the entire investigation was carried on by the writer. The obscure character of the geology made the work slow, and by the end of the first field season, in February, 1916, only the northern part of the quadrangle had been examined. This first season's work revealed the presence of two untested anticlines having considerable promise. They appeared sufficiently important to warrant a special report[1] describing them, before the work on the entire quadrangle was completed. The ensuing drilling developments on these anticlines, based on the information given in the report, resulted in the discovery that both controlled good oil and gas pools.

The southern part of the quadrangle was examined during a second field season that began in December, 1916, and on its completion, in May, 1917, a comprehensive report to cover the entire quadrangle was begun immediately. Its completion at that time was prevented by more urgent work incident to the World War, and since the end of the war other interruptions have occurred. It was

[1] Fath, A. E., The structure of the northern part of the Bristow quadrangle, Creek County, Okla.: U. S. Geol. Survey Bull. 661, pp. 69–99, 1917.

not until the spring of 1922, nearly five years after the field work was done, that opportunity was available to finish writing the report.

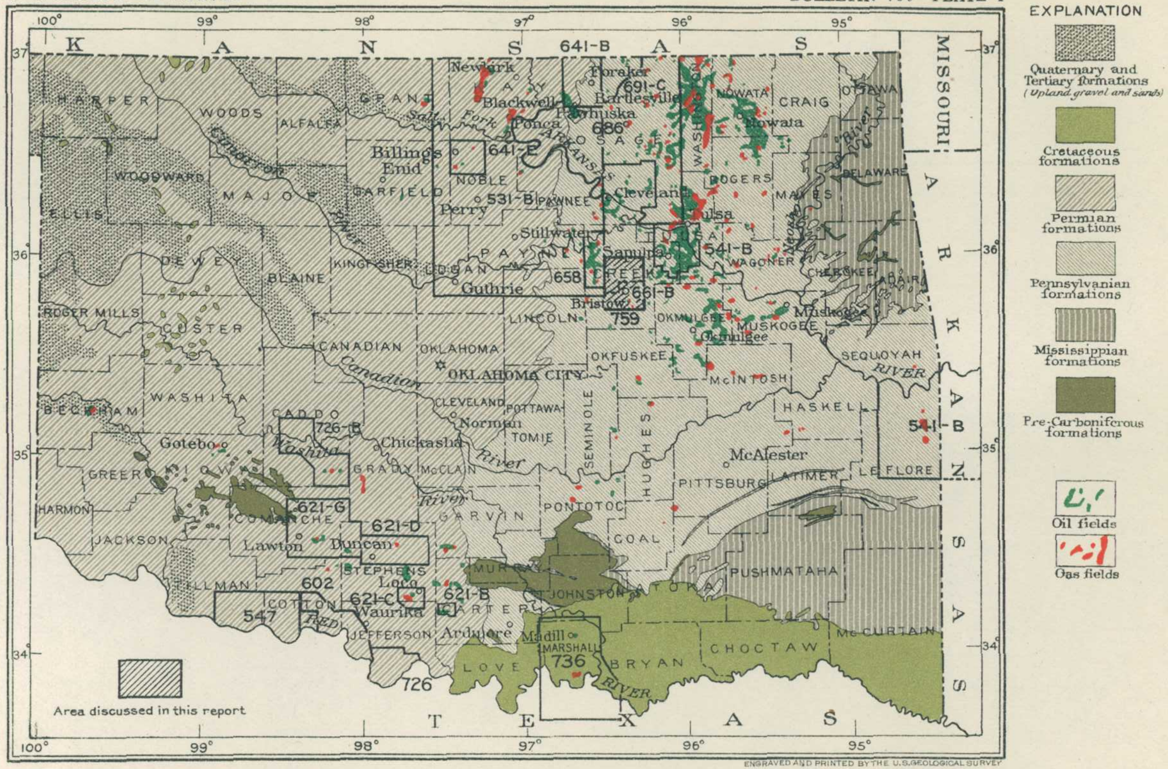
After 1918 a great amount of oil-field development work was done within the quadrangle. To keep in touch with the new drilling the field was revisited for brief periods on two occasions, the second time in June, 1920. The maps and text therefore in the main represent conditions of that date. For some localities, especially for the Slick pool, much more recent information became available, and hence some developments that took place as late as the spring of 1922 have been added to the maps and brought into the text.

A noteworthy advance in the development of the oil and gas resources of the area was made in 1920 and 1921 by the discovery of rich oil accumulations in the Dutcher and "Wilcox" sands. The Dutcher sand is thought by the writer to be separated from the overlying strata by an unconformity, though the evidence is not sufficiently conclusive to warrant a positive statement. The "Wilcox" sand, on the other hand, is generally recognized as lying beneath two or more unconformities. These conditions are believed to explain the presence of large pools of oil and gas in these strata where "favorable" structure is not reflected in the surface rocks. Most of the development of these sands took place after the field was last visited by the writer, and hence in this report it can not be treated with the degree of fullness that it deserves.

In spite of the length of time that has elapsed and the great developments in the area since the field work was completed it is believed that the geologic information originally obtained still deserves publication. Because of the delay in the appearance of the report, however, it has been deemed advisable to lessen both its scope and the detail of the treatment.

ACKNOWLEDGMENTS

The obscure nature of the geology in the Bristow quadrangle presented a most discouraging outlook when the field work was started, and the continuation of the work to a satisfactory conclusion was due principally to unfailing encouragement from David White, under whose direction the work was done. To R. H. Wood, formerly of the United States Geological Survey, is due credit for unpublished information concerning the stratigraphy of the Hominy quadrangle, to the north. The well logs used for Plates IV, V, VI, XI, and XIII and Figures 2 and 3 and the many additional logs that were obtained and studied but not published were generously supplied by the operators. The notes on the early drilling developments, as well as much detailed information on individual wells, were furnished by Claude Freeland. To all who have been of assistance the writer is sincerely grateful.



INDEX MAP OF OKLAHOMA SHOWING OIL AND GAS FIELDS

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

50 0 50 Miles

1924

GEOGRAPHY

Location, railroads, and towns.—The Bristow quadrangle lies between meridians 96° 15′ and 96° 30′ and parallels 35° 45′ and 36°, in Creek County, Okla. It is traversed by one trunk railroad, the Oklahoma City line of the St. Louis-San Francisco Railway Co., on which is the town of Bristow, a thriving business center with a population of 3,460 (1920). A short-line railroad, ultimately to connect Bristow and Okmulgee, was built in 1920 and 1921 from Bristow through the oil-field town of Slick, in the southeastern part of the quadrangle, to Nuyaka, Okmulgee County. This railroad is not shown on the map.

The town of Bristow lies 83 miles by rail northeast of Oklahoma City and 36 miles southwest of Tulsa. It is supplied with both natural gas and electricity and has several paved streets. It is a prominent cotton market, the five or six gins of the town drawing their supply of this staple from a large territory on all sides, and this traffic has made Bristow a general trading center for a considerable area. There were in 1920 five other post offices in the quadrangle—Heyburn, Tabor, Bellvue, Crowson, and Slick. Heyburn is on the railroad 8 miles northeast of Bristow and comprises a store, a cotton gin, and a small group of houses. At Tabor, 3½ miles north of the southeast corner of the quadrangle, there are two stores, a church, a school, a blacksmith shop, and a combined cotton gin and sawmill. The Crowson and Bellvue post offices are associated with country stores, Crowson in the southeast corner of the quadrangle and Bellvue 9 miles by road northwest of Bristow. On the railroad just beyond the west border of the quadrangle is the town of Depew. Since the development in 1920 of the oil fields in the southeastern part of the quadrangle, the town of Slick has grown up in the E. ½ sec. 17, T. 15 N., R. 10 E., along the route of the short-line railroad running southeast from Bristow.

Relief.—The Bristow quadrangle lies in the "Osage plains," a timbered strip of land which extends from Texas to northern Kansas. The uplands of this strip represent a peneplain that was probably developed in Tertiary time.[2] In the Bristow quadrangle this peneplain has been dissected by numerous streams, and the relief developed amounts to about 400 feet, the surface ranging between 675 and 1,075 feet in altitude.

In the eastern and southeastern parts of the quadrangle there are a few low southeastward-facing escarpments, which indicate westward-sloping strata of varying degrees of resistance. The geologic structure is not different throughout the remainder of the quadrangle,

[2] Taff, J. A., Geology of the Arbuckle and Wichita mountains, in Indian Territory and Oklahoma: U. S. Geol. Survey Prof. Paper 31, pp. 16–17, 1904.

but the surface generally shows no similar characteristic forms, owing to the greater homogeneity of the strata.

Drainage and water supply.—The area is drained by the tributaries of Arkansas and Canadian rivers, the divide between which 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 throughout the year. The smaller branches are intermittent.

The household water supply in the rural districts is obtained almost altogether from wells. Good-tasting water in quantities sufficient for individual households is available at depths ranging from 15 to 300 feet. Two types of wells are used—shallow wells that derive their supply from near-by surface drainage and relatively deep wells that derive their supply from water-bearing sandstones and are so situated and constructed that they receive no near-by surface contamination.

The shallow wells are prevalent on farms in the valleys, for, as there is generally an adequate supply of palatable water at depths of 15 to 35 feet, no thought is given to going deeper. No trouble is experienced from the water of these wells throughout most of the year, but during the summer there is considerable sickness on the farms that use them, and it appears to be due in part to pollution of the water.

Little or no trouble is experienced from the water from the deeper wells, whose supply is derived from buried water-bearing sands and guarded from surface pollution by tight casing. The depth at which such sands may be reached ranges from 25 feet to 200 feet or more. If a well passes through a considerable thickness of shale before reaching a water sand it can generally be assumed that the water is not derived from near-by surface drainage, although this conclusion is not necessarily true, for the outcrop of the water sand may be close at hand and in an unsanitary locality.

The town of Bristow obtains water of excellent quality from wells ranging between 200 and 300 feet in depth.

Water for drilling and other oil-field uses is obtained principally from wells put down for this purpose to water-bearing sandstones at a depth of a few hundred feet. The major streams generally carry sufficient water to supply oil-field developments in their vicinity.

Roads.—The roads of the quadrangle generally follow the section lines and average very poor. The generally sandy surface material furnishes no good natural base, and the abundant timber presents an obstacle of no little moment in road building. It is no wonder, therefore, that the roads received little attention prior to the development of the oil fields. Beginning in 1914 attempts were made to keep a few of the roads radiating from Bristow passable for automobile travel, but not until 1916 was any serious consideration given to good automobile roads. Since then a clay-surface graded road, with many short cuts from the otherwise rectangular road system, has been built across the quadrangle. This road, a part of the Ozark Trail running from St. Louis through Tulsa and Oklahoma City, Okla., and Amarillo, Tex., to Las Vegas, N. Mex., roughly parallels the railroad. It has been built so recently that it is not shown on the topographic map. Since the completion of this road other similar roads have been projected, and it is probable that the main highways will be hard surfaced within a few years.

Vegetation.—A very small part of the quadrangle was originally prairie land. Most of it is covered by a thick growth of timber, which, however, is rapidly being cleared to make the land available for agriculture. The distribution of the timber and prairie corresponds almost exactly to that of the sandstone and shale outcrops, the timber being found on the sandstone areas and the prairies on the shale. On the uplands the timber consists principally of blackjack and post oaks, with some hickory; in the bottom lands it consists of elm, sycamore, willow, pecan, birch, and cottonwood.

Industries.—Agriculture is the principal industry of the quadrangle, although stock raising on a small scale is becoming more prevalent. Most of the tilled plots represent clearings, and this is particularly true of the best farm lands, which lie in the valleys. The principal crops, named in the order of their value, are cotton, corn, and hay.

Although drilling for oil and gas had been done in this area more or less intermittently ever since the development of the Glenn, Cushing, and other smaller oil and gas pools of the surrounding region, it was not until the discovery of the gas field 5 miles southeast of Bristow, in the fall of 1916, that well drilling became active in the area. The next field of importance to be discovered is 3 miles north of Bristow, and after that the Red Bank fields, to the west, in and around sec. 9, T. 16 N., R. 8 E. In 1920 the Slick field, at the east side of the quadrangle, was the scene of intensive drilling, and in 1921 the Continental pool, a mile or two east of Bristow, was the principal area of interest. Other fields of more recent date have also been developed. Just outside the Bristow town limits is an oil refinery that is a complete skimming plant and in May, 1917, had a daily capacity of 2,000 barrels and a storage capacity of 125,000 barrels.

STRATIGRAPHY

EXPOSED ROCKS

KINDS OF ROCK AND CHARACTER OF OUTCROP

The rocks exposed at the surface in the Bristow quadrangle consist of sandstone and shale, with here and there a more or less local limy bed, all of Pennsylvanian age. From north to south along the strike of the beds the sandstones become thicker and more numerous and the shales become thinner, though the series as a whole increases slightly in thickness. This change in the character of the beds from north to south is reflected topographically by a decrease and in places the complete obliteration to the south of the low escarpments that are present here and there in the northern part of the quadrangle. Plate II shows the areal distribution of the different formations.

The sandstone as a general rule is soft and friable and is colored various shades of brown. The color is due to the iron oxides which coat the grains and discolor the siliceous cement. The outcrops are rarely bold but are generally so weathered down that they are completely covered with soil except at widely separated intervals. Where the sandstone is exposed under conditions showing the original bedding planes ripple marks are generally present. It is to the greater resistance to erosion of the sandstone than of the shale that the few escarpments of the quadrangle are due. The sandy soil of the sandstone belts favors the growth of the abundant oak timber of the uplands. This timber, however, is not confined to the sandstone outcrops but in places flourishes also over the shale belts, especially the narrow outcrops of the thinner shale beds, over which the residual sand of the sandstone has been washed or blown. Lithologically the sandstone consists of quartz sand cemented by small amounts of iron-stained silica, and the individual beds are so nearly alike that there is no ordinary way in which they can be differentiated. The sand grains are about midway in size between what are commonly understood to be fine and medium grains, and the little variations that occur are in places discernible in a small hand specimen.

The clay shale of the quadrangle is well exposed in a few places only, where cuts have been made for the railroads and roads and where streams have cut deeply into their banks. It forms the surface rocks over considerable areas, but as it is the least resistant rock of the region it has been eroded down to smooth surfaces, and the location of the thicker beds is indicated principally by the prairies. The thinner shale beds show no such marked surface features, for the residual sand of the adjacent sandstone has generally been washed or blown over their surfaces.

The shale is of two general types, distinguished by color, dark gray and red. The gray shale probably represents the deeper-water accumulations of mud, and that at one place is known from its fossils to be of marine origin. To this type belong the two thick beds of shale that crop out near the east side of the quadrangle and the thicker parts of some of the shale beds at the north side of the quadrangle, which thin toward the south and change from gray to red. The red shale occurs in thinner beds and probably represents shallow-water deposition, to which the red color may be due. No well-preserved fossils were found in any of the red shales, hence evidence for deep-water or marine conditions is lacking. These shales are interbedded with the lenticular sandstones, the alternation with which probably represents not variations in the depth of the water in which the sediments were deposited but rather variations in the supply of material under shoal-water conditions. As a general rule the red shale occurs only in the Bristow and higher formations. (See Pls. III–VI.)

But one limestone bed of stratigraphic importance, the Dewey limestone member, has been recognized in the quadrangle. It is a thin bed, ranging, where observed, from 9 to 15 inches in thickness, and contains considerable quantities of ferruginous impurities, indicated by its reddish-brown color on weathered surfaces. In its southward course across the eastern part of the quadrangle (shown in Pl. II) it thins out in T. 16 N., R. 10 E. Other lenticular beds of impure limestone less than a foot thick are present here and there in the quadrangle, but they are very local in extent and of no stratigraphic value. These thin limestone beds, generally interbedded with shale, do not, however, include all the limy material in the quadrangle.

Associated with sandstone beds, and in particular with the basal part of the Bristow formation, are limy beds that range from a few inches to 20 feet or more in thickness. These limy beds vary greatly in lithology, even within a few feet; in places they are as truly limestone as the Dewey, but elsewhere they are sandy limestone and may even grade through calcareous sandstone into ordinary sandstone. There is no apparent regularity in their distribution, either stratigraphically or in their relations to the sandstone beds with which they are associated. In some places they are lenses within a sandstone bed; in others they form the base or top. At still other places they constitute the major part of a bed, so that the relations may seem reversed—that is, the sandy portions of the bed may at these places be considered merely as parts of a limestone bed. These limy beds decrease in thickness from north to south and in this respect are similar to the exposed strata as a whole, which increase in sandy material toward the south to the exclusion of shale and limy material.

This relation of limestone to sandstone is apparently peculiar to this general region. It is a common observation among the geologists working in northeastern Oklahoma that many beds which are limestone in Kansas and northern Oklahoma change to sandstone toward the south. This change, however, does not apply to the Dewey and Avant limestone members, described in this report.

LENTICULARITY OF BEDS

The individual beds of shale, sandstone, and limy sandstone vary in thickness from place to place, and many of them are not persistent for more than a few hundred yards. They may be said to constitute a mass of more or less lenticular beds, representing rapid and local changes in amount and character of material deposited. The beds are not all truly lenticular, for in many places the lateral change is not in thickness but in character of material. Thus a sandstone may grade laterally through shaly sandstone and sandy shale into true shale. This lateral change may be gradual or abrupt. In places the different layers change at different rates, and in such places it is generally impossible, because of the poor exposures, to determine to what part of the original bed the persistent layers belong.

At a few places sandstone beds of considerable thickness are only local in extent, and the bedding planes of these lenses may give a wrong impression of the underground structure. One such lens occurs near the middle of the east side of the quadrangle. Its north end lies just below the Dewey limestone in sec. 4, T. 16 N., R. 10 E. As it increases in thickness to the south its upper surface rises stratigraphically until the sandstone displaces not only the Dewey limestone but also the 53-foot shale bed which to the north lies between this limestone and the overlying sandstone. This sandstone lens is exposed in the escarpment that crosses secs. 4, 9, 16, 21, 28, and 33, T. 16 N., R. 10 E., and thin stringers of it extend to a point near the south border of the quadrangle in sec. 30, T. 15 N., R. 10 E. Its maximum thickness probably can not be accurately determined, but in sec. 16, T. 16 N., R. 10 E., it seems to be more than 125 feet thick. In the western part of sec. 28, T. 16 N., R. 10 E., the base of this sandstone lens rises stratigraphically at an unusually rapid rate. No other locality in the quadrangle is known where the thinning out of bed upon bed is so well shown. Near the southwest corner of this section one bed of sandstone is underlain by thick shale, but in tracing this bed to the north the underlying shale is found to be replaced by bed after bed of sandstone until within less than half a mile the thickness of the sandstone has increased over 50 feet.

The above description of this sandstone gives only a few of its characteristics as shown by poor exposures; moreover, these features are only those shown in a line of exposure along the strike. The characteristics of the sandstone westward down the dip are obviously not known, but it seems probable that similar changes take place in this direction also. Similar lenses occur at several other places in the quadrangle, but none are so well exposed.

In sec. 11 and the eastern part of sec. 10, T. 15 N., R. 8 E., a very abrupt change from sandstone to shale is well illustrated. Here a sandstone bed, which to the south appears to be persistent and to have a thickness of 30 feet or more, changes toward the north into red shale. This change is best seen in the first valley east of the west quarter corner of sec. 11, where it takes place within a distance of 100 yards. It is not merely a local change but appears to persist along an east-west line as far as the bed is exposed.

Another feature that is occasionally seen is the thinning out of one sandstone bed at or near a place where another, lying below or above it, begins. In this region, where continuous outcrops are few, confusion may result by incorrectly correlating such beds. As this investigation was made principally to ascertain the structure, it will be realized that where conflicting evidence was found as to the direction and rate in which the strata dip there may be doubt as to the accuracy of the conclusions. In places the thinning or thickening of some bed is greater than the rate of dip, causing an apparent dip to the east, for example, where all other evidence indicates a regular dip to the west. Such conditions probably exist along the railroad at Tank Lake, in sec. 35, T. 16 N., R. 8 E., and less certainly in sec. 15, T. 15 N., R. 8 E.

SOURCE OF SEDIMENTS

The foregoing generalized descriptions indicate that for the most part the strata of the Bristow quadrangle were deposited in shallow water. The ripple marks, cross-bedding, rapid lateral change in character of material, and rapid succession of shale and sandstone are all evidence for such a conclusion. The larger proportion of sand in the southern part of the quadrangle indicates that this part was nearer to the land from which the material was derived than the northern part, and that the deeper and more open waters extended northward. This inference is further supported by the continued increase in shale northward beyond the quadrangle and the coming in of limestones in northern Oklahoma and their increased development still farther north in Kansas.

From the changes in the underground strata described elsewhere in this paper it would appear that the land mass that furnished the material for the exposed rocks of the Bristow quadrangle lay to the south-southwest. That such a land mass lay to the south of the Bristow quadrangle in Pennsylvanian time and even earlier is becoming more and more evident as data are being accumulated. The published information pertaining to this subject has been ably summarized by Miser,[3] who concludes that the evidence points to the presence of a large body of land throughout most of Paleozoic time in Louisiana and eastern Texas, with its boundaries at times perhaps extending as far north as southern Oklahoma.

Although the strata of the Bristow quadrangle are indicative of shallow-water sedimentation, they do not show any great and rapid variation in the coarseness of their materials such as would be presented by coarse sandstone and conglomerate alternating with medium to fine-grained sandstone, and it is believed that the absence of such variations indicates that the deposits were not laid down near the shore. This conclusion is in accord with the location of the supposed source of the sediments, the land mass in eastern Texas and Louisiana.

STRATIGRAPHIC SEQUENCE

Except for the recent alluvium that covers the flood plains of the streams the strata exposed in the Bristow quadrangle embrace about 1,350 feet of sediments belonging as a whole to the upper portion of the Pennsylvanian series as developed in Oklahoma.

In subdividing these Pennsylvanian strata into formations the dividing lines have been placed at the more pronounced lithologic boundaries. Because of the southward increase in the amount of sandstone the formation boundaries become more obscure in that direction, and it is therefore probable that the formations as differentiated in the Bristow quadrangle can not be traced far to the south. To the north, on the contrary, the formations can not only be more readily differentiated but are divisible into additional units.

No paleontologic evidence for differentiating the formations of the Bristow quadrangle was found. The different species of fossils found have so wide a range in the Pennsylvanian series that they are of little or no use in determining age.

In the published report by D. W. Ohern on the Nowata quadrangle and the unpublished report by R. H. Wood on the Hominy quadrangle, both of which lie to the north of this area, tentative boundaries in the stratigraphic sections have been established, but of the stratigraphic units thus delimited only the Elgin sandstone and the Copan formation with its Dewey limestone member are recognizable in the Bristow quadrangle.

[3] Miser, H. D., Llanoria, the Paleozoic land area in Louisiana and eastern Texas: Am. Jour. Sci., 5th ser., vol. 2, pp. 61–89, 1921. An extensive bibliography is given.

QUATERNARY DEPOSITS.

RECENT ALLUVIUM

Since the development of the Tertiary peneplain, now represented by the uniformly elevated uplands, so far as the evidence shows, there has been but one cycle of erosion, the one which is exhibited by the development of the present stream system. The two main streams and their larger tributaries have well-developed flood plains covered with alluvium. These flood plains constitute the most valuable agricultural land in the quadrangle, their principal value lying in their greater moisture, for they not only hold a large part of the rain falling on them but also receive a considerable share of the run-off from the adjacent hills and uplands.

PENNSYLVANIAN ROCKS

BEDS ABOVE ELGIN SANDSTONE

Above the Elgin sandstone, which is the westernmost persistent sandstone bed in the quadrangle, is a series of shale, sandstone, and limestone that extend up to the base of the Permian, which appears 15 to 20 miles west of the quadrangle. Of this series only the lowermost 50 or 75 feet is present within the quadrangle.

According to Buttram[4] the Neva limestone, which is near the top of the Pennsylvanian series and crops out just west of the town of Cushing, in Payne County, lies 557 feet above the Pawhuska limestone of the Cushing field, and the top of the Pawhuska limestone lies 139 feet above the Elgin sandstone. The aggregate of these measurements indicates that the Pennsylvanian beds between the Elgin and the Neva have a thickness of 696 feet. The interval between the Elgin sandstone and the top of the Pawhuska limestone varies considerably, for measurements made by the writer in sec. 18, T. 17 N., R. 8 E., and sec. 12, T. 17 N., R. 7 E., show it to be 161 feet, or 22 feet more than the interval measured by Buttram in sec. 10, T. 17 N., R. 7 E., only 2 miles distant. In the following section the first two measurements were made by the Oklahoma Geological Survey in sec. 12, T. 17 N., R. 8 E.

Composite section of rocks above the Elgin sandstone as exposed in secs. 7 and 18, T. 17 N., R. 8 E., and sec. 12, T. 17 N., R. 8 E.

	Ft.	in.
Pawhuska limestone:		
Limestone, carrying the following fossils: Plant remains, also *Deltopecten occidentalis*, *Deltopecten* aff. *D. vanvleeti*, *Myalina swallowi*, *Schizodus?* sp., *Pleurophorus* sp., fish plate or tooth		5

[4] Buttram, Frank, The Cushing oil and gas field, Okla.: Oklahoma Geol. Survey Bull. 18, pp. 8–10, 1914.

	Ft.	in.
Pawhuska limestone—Continued.		
Shale	8	
Sandstone, gray	4	
Concealed	8	
Limestone, arenaceous, gray; weathers reddish brown	2	
Shale, greenish gray except for lower part, which is red; probably contains sandy layers	36	
Sandstone, gray, cross-bedded; thickness varies	4–8	
Concealed, probably all shale	20	
Sandstone, light gray	4	
Shale, red	1	6
Sandstone, greenish gray, thin bedded	1	6
Shale, red	14	
Sandstone, gray, spotted with dark brown	2	
Shale	4	
Sandstone	1	
Shale, red	7	
Sandstone, gray, cross-bedded	2	
Shale	10	
Sandstone, cross-bedded, in places spotted with dark brown	6	
Shale, varicolored, gray to red	17	
Elgin sandstone.		

ELGIN SANDSTONE

The Elgin sandstone, according to Haworth,[5] was first suggested as a stratigraphic unit by G. I. Adams, because of its extraordinary development near Elgin, Kans. The southward extension of this sandstone has been traced across the Pawhuska and Hominy quadrangles at the north by Carl D. Smith and R. H. Wood, to whose unpublished maps the writer has had access, and hence the Elgin of the Bristow quadrangle is the equivalent of the Elgin at its type locality.

In the Bristow quadrangle the Elgin is a friable gray to yellowish-brown sandstone that ranges in thickness from 50 to about 80 feet. It is exposed near the west margin of the quadrangle and represents the highest sandstone of considerable thickness in the stratigraphic section. (See Pls. II and III.) Lithologically it is like the sandstones of the underlying formations, and in the west-central part of the quadrangle it is differentiated only with difficulty from the Bristow formation below. Its upper surface is distinct throughout its course across the quadrangle and is a good stratigraphic boundary. The same may be said of its base in the northern part of the quadrangle, but to the south the base becomes obscure because of the increasing development of sandstone in the upper part of the underlying Bristow formation. Here and there lenses of red shale occur in the sandstone. So far as observed the Elgin is barren of fossils in the Bristow area.

[5] Haworth, Erasmus, Stratigraphy of the Kansas Coal Measures: Kansas Univ. Geol. Survey, vol. 3, p. 64, 1898.

BRISTOW FORMATION

The Bristow formation, named after the town of Bristow, is here defined as including all the strata below the Elgin sandstone to the base of the Tiger Creek sandstone member. The top of the Tiger Creek sandstone, which was differentiated in the preliminary report on the northern part of the quadrangle,[6] can not be certainly identified in all parts of the quadrangle, but its base is a distinct horizon separating the series of alternating sandstone and shale of the Bristow formation from the underlying thick shale bed forming the upper part of the Copan formation as herein delimited.

Lithologically the Bristow formation is an interbedded series of sandstone and shale, aggregating about 600 feet in thickness. The sandstones are generally gray to yellowish brown and are friable, and therefore their outcrop is commonly covered with sand or soil. There is no apparent difference between these sandstones and the Elgin sandstone above. In the northern part of the quadrangle some of the shales of the Bristow formation are gray and have considerable thickness. Here and to the north beyond the quadrangle it would be possible to divide the formation into stratigraphic units, but to the south the shales become thinner, change from gray to red, and lose their identity as mappable units, making the formation a monotonous series of interbedded sandstone and shale throughout its thickness.

The upper boundary of the formation is distinguished with no great difficulty over most of its extent in the northern part of the quadrangle, where the shale at the top is in contact with the Elgin sandstone. Near the middle of the quadrangle, however, sandstones appear near the top of the formation and make its upper boundary obscure. From sec. 20 to the northern part of sec. 32, T. 16 N., R. 8 E., these sandstones practically and in a few places actually merge into the Elgin sandstone above. In the southern part of secs. 31 and 32, T. 16 N., R. 8 E., the sandstones disappear and the top of the formation is again rather clearly exposed.

Across the northern part of the quadrangle the base of the Bristow formation is represented by what seems to be a single bed (the Tiger Creek sandstone), which at several places contains innumerable remains of the fossil *Fusulina inconspicua* in its lower few feet. Farther south this *Fusulina*-bearing bed loses its identity as a distinct bed by merging into the overlying sandstones. It continues to carry *Fusulina*, however, although the *Fusulina*-bearing portion is restricted to a thickness which at no place was observed to exceed 5 feet. The Tiger Creek sandstone is well developed in the southeastward-facing escarpment in sec. 9, T. 15 N., R. 9 E., on the southeast

[6] Fath, A. E., U. S. Geol. Survey Bull. 661, pp. 73–74, 1917.

side of the valley in the NE. ¼ sec. 27, T. 16 N., R. 9 E., on the west side of sec. 7, T. 16 N., R. 10 E., and at numerous other places to the north.

Associated with the *Fusulina*-bearing bed, especially in the northern part of the quadrangle, where this bed is differentiated from the

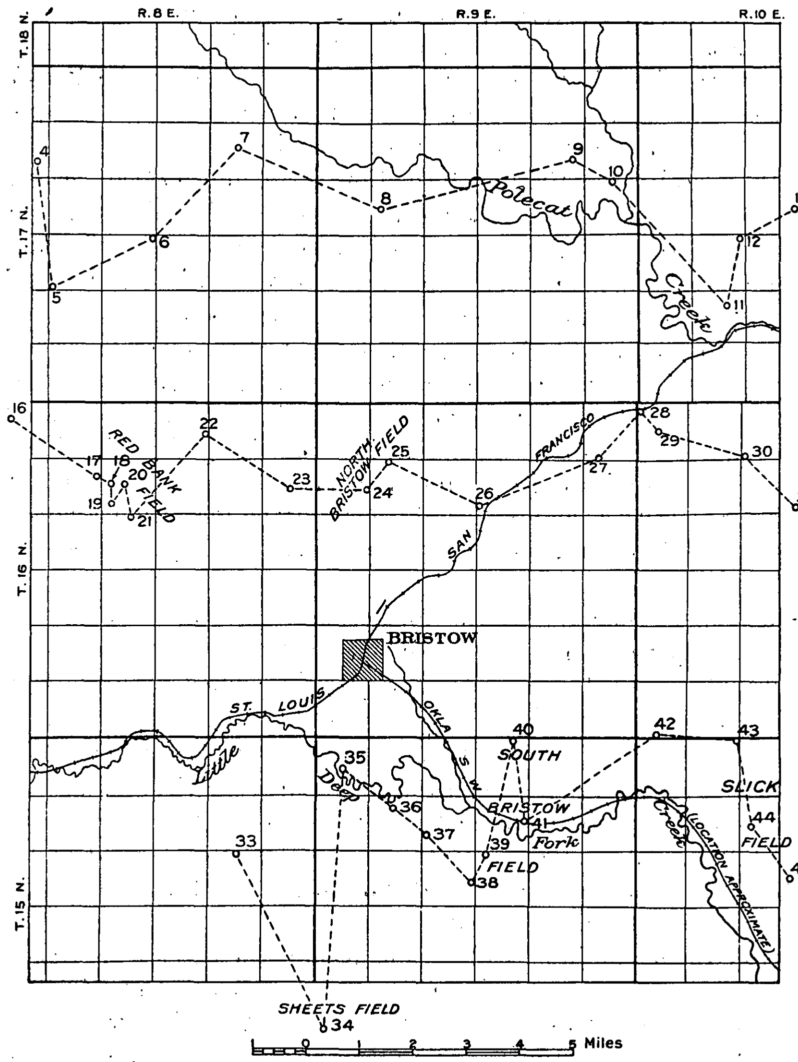


FIGURE 1.—Index map of Bristow quadrangle showing location of wells represented by sections on Plates IV, V, and VI

remainder of the formation, is a very noteworthy development of limy material. In some places the rock is a slightly sandy limestone; in others there are all gradations between good limestone and ordinary sandstone. The greatest observed development of this limestone phase is on the northeast side of the valley in the SW. ¼ sec. 5, T. 17

N., R. 10 E., where this bed shows a thickness of 22 feet, the upper half of which is limestone. This limestone phase is also well represented over most of secs. 5, 6, 7, 8, and 18, T. 17 N., R. 10 E., and secs. 1, 12, and 24, T. 17 N., R. 9 E., and it occurs locally at several places to the south of this area. In the escarpment in the SE. ¼ sec. 9, T. 15 N., R. 9 E., it is fairly well developed, but here it occurs in the lower or *Fusulina*-bearing part of the bed.

The thickness and sequence of the individual beds are graphically represented in Plate II. Where penetrated by the drill the principal distinguishing character of the Bristow formation is the presence of red shale in contrast to the general absence of red colors in the rocks beneath. The red shale is generally recorded by drillers as "red rock," "red mud," or "red shale." The upper shale member of the underlying Copan formation, because of its gray color, assists in distinguishing the lower limit of the Bristow formation in drilling.

In the North Bristow oil field, in secs. 7, 8, 17, and 18, T. 16 N., R. 9 E., the base of the Bristow formation is found at depths of about 300 to 375 feet, and in the Red Bank field it is found at depths of 500 to 600 feet. (See Pls. IV, V, and VI.) In the Cushing field, west of this quadrangle, the base of the formation is found usually about 500 feet above the Layton sand. In the small Sheetz field, in secs. 30 and 31, T. 15 N., R. 9 E., just south of the quadrangle, the base of the red shale-bearing Bristow formation lies about 400 feet below the surface. The subsurface conditions as represented by well logs are shown in Plates IV, V, and VI. (See also fig. 1.)

The fauna of the Bristow formation is scanty. *Fusulina inconspicua* has been mentioned. Associated with this form *Acanthopecten carbonifer* was found in the SE. ¼ sec. 18, T. 17 N., R. 10 E., and *Productus insinuatus* in the hill near the east quarter corner of sec. 13, T. 17 N., R. 9 E. One other collection was gathered and identified by George H. Girty as follows:

Lot 70, in the SW. ¼ SE. ¼ sec. 16, T. 17 N., R. 9 E., about 280 feet above the base of the Bristow formation:

Edmondia? sp.
Deltopecten occidentalis.
Aviculipecten sp.
Myalina meliniformis.
Myalina wyomingensis.
Leda arata.
Leda? sp.
Yoldia sp.
Schizodus sp.
Pleurophorus taffi?
Pleurophorus tropidophorus.
Pleurophorus sp.
Murchisonia sp.

COPAN FORMATION

The term Copan was first applied to a stratigraphic unit in the Nowata quadrangle by Ohern,[7] who defined it as including the beds between the base of the Stanton limestone above and the top of the Hogshooter limestone below. The Stanton limestone, however, thins out a few miles south of the Kansas line, and the next logical formation boundary is the base of the Tiger Creek sandstone member, a sandstone that persists from the Nowata quadrangle through the Bristow quadrangle. The adoption of that boundary line, however, throws into the Bristow formation some rocks included in the Copan formation as originally defined by Ohern, but this slight restriction of the Copan is believed to be justified, as it will make the Copan a map unit over a large area and prevent the introduction of a new name for rocks equivalent to the major part of Ohern's Copan. The base of Ohern's Copan was, as stated, the top of the Hogshooter limestone, which is thought by the present writer to be the same as the "Layton lime" of the Bristow quadrangle.

Of the subdivisions recognized by Ohern only one, the Dewey limestone member, is found in the northern part of the outcrop of the Copan across the Bristow quadrangle. Ohern recognized another limestone member in the upper part of the Copan, and to this he applied the name Avant. This Avant limestone member has some significance with regard to the upper boundary of the formation in the Bristow quadrangle. In its type locality this limestone is separated by a shale from the Stanton limestone above. Both the Avant limestone and the overlying shale cross the Pawhuska and Hominy quadrangles. Along Arkansas River the Avant is separated from the northward extension of the *Fusulina*-bearing sandstone that marks the base of the Bristow formation by 60 feet of shale, but farther south both the Avant and the overlying shale decrease in thickness, and near the south boundary of the Hominy quadrangle the Avant is only a foot or two thick and the overlying shale is only 3 to 5 feet thick.[8] Still farther south the Avant probably thins out before reaching the Bristow quadrangle.

In the Bristow area the Copan formation measures about 600 to 700 feet in thickness. Five general lithologic subdivisions can be recognized, as follows:

---

[7] Ohern, D. W., The stratigraphy of the older Pennsylvanian rocks of northeastern Oklahoma: Oklahoma Univ. Research Bull. 4, pp. 29–34, 1910.

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

Section of Copan formation in Bristow quadrangle

	Feet
Bristow formation.	
Copan formation:	
Upper shale	150
Upper sandstone and interbedded shale, including a lenticular sandy limestone and the Dewey limestone member	85–250
Middle shale	100–125
Lower sandstone with interbedded shale	100–150
Lower shale	100–200
"Layton lime."	

The upper shale crosses the Bristow quadrangle from sec. 4, T. 17 N., R. 10 E., to sec. 27, T. 15 N., R. 9 E., and is generally distinguished by a more or less continuous belt of prairie land east of and adjacent to the base of the Bristow formation. The top of this shale, which is also the top of the Copan formation, as here delimited, is a fairly well marked horizon. (See discussion about base of Bristow formation, pp. 13–15.) It is nearly all gray, being only locally part red. Natural exposures are few. It contains a few thin sandy beds, but they are rarely found in outcrop. The upper part of the shale is fairly well exposed in the narrow banks of the valley near the east quarter corner of sec. 6, T. 17 N., R. 10 E. At this place the shale contains at 30 feet below its top the following invertebrate fauna identified by George H. Girty:

Polypora sp.
Polypora sp.
Derbya crassa.
Chonetes verneuilianus.
Productus cora.
Productus pertenuis.
Pustula nebraskensis.
Spirifer triplicatus.
Squamularia perplexa.
Edmondia reflexa?
Edmondia sp.
Leda meekana.
Parallelodon tenuistriatus.
Acanthopecten carboniferus.
Aviculipecten pellucidus.
Euchondria neglecta?
Pseudomonotis kansasensis.
Placunopsis carbonaria?
Orestes sp.
Cytherella sp.

Near the center of sec. 10, T. 15 N., R. 9 E., a thin sandstone in this upper shale forms a ford across Little Deep Fork Creek, and it carries the following fauna:

Lot 86, about 100 feet below top of Copan formation:
Rhombopora lepidodendroides?
Polypora sp.
Deltopecten occidentalis.

The upper sandstone division of the Copan formation forms a well-timbered strip across the quadrangle from sec. 9, T. 17 N., R. 10 E., to sec. 25, T. 15 N., R. 10 E. This division varies greatly in thickness and character from place to place. At the east side of sec.

9, T. 17 N., R. 8 E., it consists of the Dewey limestone, 1 foot 6 inches thick, at its base, about 33 feet of sandstone at its top, and 53 feet of shale between. In sec. 21 of the same township the shale has decreased in thickness to about 40 feet, and a limy sandstone, in places 20 feet thick, appears about 20 feet below the Dewey limestone. In sec. 33, T. 17 N., R. 10 E., the limy sandstone has practically disappeared. In sec. 4, T. 16 N., R. 10 E., a sandstone appears below the Dewey limestone, and its top rises in the stratigraphic section until in sec. 17 of the same township it has replaced not only the Dewey limestone but also the shale bed which to the north lies between the Dewey and the overlying sandstone. (See Pls. I and II.) In sec. 17 and the northern part of sec. 20, T. 16 N., R. 10 E., the total thickness of sandstone in this division may be more than 150 feet. In secs. 19, 20, and 21, T. 16 N., R. 10 E., all but the upper 20 or 30 feet of the sandstone begins to break up, and shale beds appear. As the quantity of sandstone diminishes the shale increases, and of the lower part of this sandstone only a few stringers persist south of Little Deep Fork Creek. The upper 20 or 30 feet of the sandstone persists, however, and crops out across secs. 25 and 36, T. 16 N., R. 9 E.; secs. 1, 11, 14, 23, 24, and 25, T. 15 N., R. 9 E.; and secs. 19 and 30, T. 15 N., R. 10 E. In secs. 24 and 25, T. 15 N., R. 9 E., and secs. 19 and 30, T. 15 N., R. 10 E., higher sandstone beds come in, and the general effect appears as a thickening of the upper persistent bed. Nowhere in the quadrangle was the Dewey limestone observed to be over 1½ feet in thickness, and at several places it measures less than 9 inches. 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 remains of *Fusulina inconspicua* and segments of crinoid stems. *Spirifer triplicatus* was also found in the SE. ¼ sec. 8, T. 16 N., R. 10 E. Because of the thinness of the Dewey 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. Other scattered exposures are indicated on Plate II. Its southernmost exposure is probably the one about a quarter of a mile west of the east line of sec. 8, T. 16 N., R. 10 E., on the north side of the valley in the southeastern part of the section. Here it lies directly on top of the sandstone lentil which displaces it to the south.

Besides the meager fauna of the Dewey limestone a brackish-water fauna was found in one of the lower sandstone beds of the middle part of the Copan formation about 400 feet below the top. This fauna occurs at various places in secs. 17, 18, 19, 20, and 30, T. 15 N., R. 10 E.

Lot 90, at east side of sec. 19, T. 15 N., R. 10 E.:

Derbya sp.
Productus cora?
Solenopsis solenoides.
Allerisma aff. A. maxvillense.
Allerisma? n. sp.
Edmondia reflexa?
Leda aff. L. nasuta.
Deltopecten occidentalis.
Myalina meliniformis.
Myalina recurvirostris.
Modiola n. sp.
Pteria ohioensis.
Pinna peracuta.
Schizodus insignis?
Schizodus alpinus.
Schizodus affinis.
Schizodus curtus.
Schizodus wheeleri.
Schizodus aff. S. compressus.
Pleurophorus subcostatus.
Patellostium ellipticum?
Bucanopsis meekana?
Euphemus carbonarius.
Pleurotomaria n. sp. aff. P. broadheadi.
Pleurotomaria sp.
Goniospira lasallensis.
Goniospira? sp.
Aclisina? sp.
Platyceras? sp.
Naticopsis sp.
Nautilus sp.

Lot 91, in SE. ¼ sec. 18, T. 15 N., R. 10 E.:

Rhombopora lepidodendroides?
Productus cora?
Leda aff. L. nasuta.
Deltopecten occidentalis.
Pteria ohioensis.
Pinna peracuta.
Pseudomonotis sp.
Pleurophorus subcostatus.
Pleurophorus aff. P. mexicanus.
Schizodus n. sp.
Goniospira lasallensis.
Bulimorpha chrysalis?
Bulimorpha? sp.
Zygopleura sp.

From a sandstone bed about 330 feet below the top of the formation, exposed near the south quarter corner of sec. 18, T. 15 N., R. 10 E., the following forms were collected:

Lingula carbonaria?
Productus cora?
Allerisma aff. A. maxvillense.
Aviculipecten sp.
Myalina meliniformis.
Schizodus curtus?
Schizodus affinis.
Schizodus pandatus.

In material from about the same horizon about 2½ miles to the northeast, in the SE. ¼ sec. 5, T. 15 N., R. 10 E., the following forms were found:

Lot 83, talus that probably comes from a zone about 320 to 360 feet below top of formation:

Chonetes sp.
Deltopecten occidentalis.
Pleurophorus? sp.
Astartella concentrica.
Bucanopsis meekana?

The outcrop of the middle shale division of the Copan formation is indicated by the prairie that lies east of Chicken Creek and in secs. 20 and 29, T. 15 N., R. 10 E. Its exposures are small and few. It is probably gray, and logs of wells penetrating it have so recorded it. At no place was it found to contain fossils. Its lower part is broken by thin sandstones, through a series of which it grades into the underlying lower sandstone division.

The lower sandstone division of the Copan formation crops out in the southeast corner of the quadrangle. It consists of several sandstone beds interbedded with shale. One of the sandstones attains a thickness of 50 feet or more. This division is persistent north-northeastward across the Kiefer quadrangle and probably persists also to the south-southwest.

In the central part of the quadrangle the upper shale and upper sandstone divisions are more readily recognized in the logs. In the North Bristow oil field the top of the upper shale is found at depths of about 300 to 375 feet. In this field the lower sandstone division is a single sandstone bed about 30 to 50 feet thick lying about 900 feet below the surface. The base of the formation lies at a depth of about 950 to 1,050 feet. Farther west, in the Red Bank oil field, the top of the upper shale is found at depths of 500 to 600 feet. The upper sandstone division is well represented here, but the lower sandstone division appears to have thinned and disappeared, making it impossible to differentiate the middle and lower shales. The base of the formation lies at about 1,150 to 1,250 feet. The lower sandstone division appears to be missing also in the Cushing field, farther west. In the southern part of the Bristow quadrangle the lower sandy division consists of several thin beds of sandstone (recorded as "limes" by some drillers) separated by shales, which together occupy an interval nearly 200 feet thick in the South Bristow field. The top of this lower sandstone division lies at a depth of 300 to 500 feet, the depth depending on the altitude of the surface at the point where the drilling started. The base of the formation lies at a depth of 550 to 750 feet.

ROCKS NOT EXPOSED

GENERAL FEATURES

Interest in the rocks lying beneath the surface in the Bristow quadrangle is due principally to their economic importance. From these rocks the oil and gas produced in the quadrangle are obtained, and they are the source of possible additional oil production.

Knowledge concerning the underground rocks may be obtained in two ways—either by studying them at their outcrops east of the quadrangle or by studying the records of the wells that have penetrated them. Neither of these methods is wholly satisfactory, for the strata change between their outcrops and the Bristow quadrangle, and the well records as a whole are not sufficiently accurate and detailed to be relied upon except in their larger features. The well records are nevertheless valuable, for their information is obtained directly from the beds that underlie the quadrangle.

Only the upper portion of the lower sandstone division of the Copan formation is exposed in the Bristow quadrangle. The logs of wells in the quadrangle drilled through this division indicate that it occupies an interval of 100 to 150 feet and that it is underlain by shale, between 100 and 200 feet in thickness, which is considered to form the lower shale division of the Copan formation. (See Pls. IV, V, and VI.) Most of the well logs record beneath this shale a limestone bed that is persistent as far west as the Cushing field, where it is known as the "Layton lime." The upper surface of this limestone is here considered to mark the base of the Copan formation, as it is believed to be the same as the Hogshooter limestone, to the north, which is the base of the Copan in that region.

West of its outcrop the Copan formation is penetrated by many wells, and its presence can be recognized in the logs. To the southwest, in the direction of the Sheetz pool, in secs. 30 and 31, T. 15 N., R. 9 E., just south of the quadrangle, the top of the formation is found at a depth of about 400 feet. The upper sandstone division appears to be thin in this pool, and the top of the lower sandstone division lies about 700 feet beneath the surface.

The strata below the Copan formation that have been reached by the drill include a thickness of more than 3,200 feet. The lowermost rocks encountered are certainly as old as Mississippian and according to some writers may be of Devonian or even of Ordovician age. These strata contain four persistent limestone zones spaced at such intervals that they can be conveniently discussed separately. The positions and thicknesses of these beds, as given in well logs, are graphically shown in Plates IV, V, and VI.

The uppermost of these limestones lies immediately beneath the Copan formation and is correlated with the "Layton lime" of the Cushing field. It is also believed to be at the horizon of the Hogshooter limestone as recognized to the northeast, in Osage County. The second limestone lies at or near the horizon of the Checkerboard lime of the Glenn pool, to the east. The third persistent limy zone is not a single bed but a zone of interbedded thin layers of limestone and shale occupying an interval of about 100 to 200 feet, which is believed to be the counterpart of the Fort Scott limestone of southeastern Kansas and northeastern Oklahoma (the "Oswego lime" of drillers), which in the Cushing field, to the west, is thought to be represented by the Wheeler sand, a producing bed. The fourth of these persistent limestones is several hundred feet thick and is the westward extension of the Boone formation ("Mississippi lime" or Boone chert of drillers).

PENNSYLVANIAN ROCKS

"LAYTON LIME"

The first bed beneath the Copan formation that is generally recorded as a resistant rock is a limestone (a few drillers have recorded it as "sand"), usually 10 to 40 feet thick, which has considerable persistence and can be recognized throughout the quadrangle. To the west it can be traced into the Cushing field, where it is associated with or lies above the Layton sand, a rich oil-bearing reservoir. Because of this association the limestone bed in the Cushing field and neighboring localities is generally referred to by drillers as the "Layton lime." The limestone and sandstone in some places seem to be in juxtaposition, but more generally they are separated by a thin shale. In a few localities the sandstone appears to be missing. (See Pls. IV, V, and VI.)

In sec. 7, T. 17 N., R. 8 E., the "Layton lime" is present at a depth of about 1,400 to 1,500 feet. In the Red Bank field the depth is generally between 1,150 and 1,250 feet, and in the North Bristow field about 950 to 1,050 feet. In sec. 20, T. 17 N., R. 10 E., it lies about 600 feet beneath the surface.

The "Layton lime" lies immediately above the gas-bearing zone at a depth of about 1,000 feet in the Sheetz field, just beyond the south border of the quadrangle. In the South Bristow field it lies about 500 to 750 feet beneath the surface in secs. 5 and 9, T. 15 N., R. 10 E., and in the Slick field it is encountered at a depth of 200 to 300 feet. It apparently is at about the same stratigraphic position as the Hogshooter limestone as recognized to the northeast, in Osage County.[9]

INTERVAL BETWEEN "LAYTON LIME" AND CHECKERBOARD (?) LIME

The strata found beneath the "Layton lime" and above the next persistent limestone, the Checkerboard (?) lime, occupy an interval of about 300 to 450 feet and consist principally of shale with one or two beds of sandstone in the upper part. The interval is thinnest in the northeastern part of the quadrangle and thickens to the south and southwest. The productive Layton sand of the Cushing field lies at or near the top of this interval and is generally present in the Bristow quadrangle. It is the gas-producing bed in the small Sheetz field, just south of the quadrangle, but from the information at hand it has thus far been found to contain no indications of oil. In some localities the logs seem to indicate this sand to be missing. In others a second sand lies below the Layton sand. Shale apparently constitutes the remainder of this interval. These sandstones approach the surface east of the quadrangle and probably crop out in the timbered escarpment and hills west of the Glenn pool, in the vicinity of Kiefer.

The logs of a few scattered wells in the Bristow quadrangle record other thin beds of lime and sand within this interval, but because these beds are not recorded in most of the logs they are

[9] Lloyd, E. R., and Mather, K. F., Structure and oil and gas resources of the Osage Reservation, Okla.—T. 20 N., R. 11 E.: U. S. Geol. Survey Bull. 686, pp. 119–127, 1918.

considered to be nonpersistent, or, what is more probable, such records are errors of the drillers.

In the Cushing field the locally productive Jones sand lies in the lower part of this interval.

CHECKERBOARD (?) LIME

From 300 to 450 feet below the "Layton lime," according to the location in the quadrangle, is a fairly persistent thin limestone bed, which lies at about the same horizon as the Checkerboard lime of the Glenn pool.[10] (See Pls. IV, V, and VI.) The evidence for the correlation is very meager, but this bed will be tentatively referred to by the same name. In the eastern part of the quadrangle the drillers have recorded several thin limestones at this general horizon, and these limestones should perhaps be referred to as a limy zone rather than a limestone bed.

In the Slick field, east of Bristow, this limestone zone lies at a depth of 600 to 750 feet. In the South Bristow field it is found at a depth of about 1,000 to 1,150 feet, the depth depending largely on the altitude of the surface. In sec. 2, T. 15 N., R. 8 E., it lies at about 1,400 feet; in sec. 20, T. 17 N., R. 10 E., at about 1,000 feet; in sec. 6, T. 16 N., R. 10 E., at about 900 feet; in the North Bristow field at 1,300 to 1,400 feet; and in the Red Bank field at 1,500 to 1,625 feet. In the Cushing field it probably lies below the locally productive Jones sand and above the Cleveland sand.

INTERVAL BETWEEN CHECKERBOARD (?) LIME AND FORT SCOTT LIMESTONE

The interval between the Checkerboard (?) lime and the Fort Scott limestone, the third of the persistent limestone beds, measures about 550 to 900 feet, and in most of the quadrangle shale constitutes more than 80 per cent of it. (See Pls. IV, V, and VI.) There is an appreciable thinning of this interval in a northwesterly direction. In T. 15 N., Rs. 8 to 10 E., it measures about 800 feet, but in T. 17 N., R. 10 E., it is only 700 feet thick, in T. 17 N., R. 9 E., about 600 feet, and in T. 17 N., R. 8 E., about 550 feet.

The sandstones present in this interval lie almost altogether 100 feet or so beneath the Checkerboard (?) lime. Thin limestones are recorded in many of the well logs, but these do not show any general persistence either in extent or in position within the interval, and the records may therefore be erroneous identifications by the drillers.

The sandstones are noteworthy because they are the shallowest productive beds thus far discovered in the Bristow quadrangle, being the source of the gas in the South Bristow field and in the few wells in sec. 6, T. 17 N., R. 10 E., and the adjacent sections.

---

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

FORT SCOTT LIMESTONE

Above the sandstone-bearing Cherokee formation and below the thick shale just described is a 100 to 200 foot zone of thin limestones and interbedded shale. The available logs do not permit the individual limestones to be readily differentiated throughout the quadrangle, but the zone itself is persistent and is clearly indicated in most of the logs. (See Pls. IV, V, and VI.)

In the Glenn pool this zone is occupied by two limestones separated by about 100 to 150 feet of shale. The upper of these limestones was correlated by Smith with the Big lime and the lower with the "Oswego lime,"[11] but White and Greene[12] show that these two beds and the intervening shale probably represent the Fort Scott limestone of Kansas. The upper of these limestones in the Glenn region is generally recorded as the Big lime by drillers, and the lower as the "Oswego lime." Both the upper and lower of these Fort Scott limestones can be recognized with some assurance in the logs of many of the wells drilled in the eastern part of the Bristow quadrangle, especially in T. 15 N., R. 10 E., and Tps. 16 and 17 N., Rs. 9 and 10 E. In the western and southwestern parts of the quadrangle the differentiation becomes increasingly obscure, although the zone as a whole retains its individuality. To the west, in the direction of the Cushing field, the zone merges into the Wheeler sand, but to the southwest it is represented by three to five thin limestones with interbedded shale occupying an interval of about 200 feet.

The top of the Fort Scott limestone as here delimited is found at a depth of about 1,500 to 1,600 feet in the Slick field. In the South Bristow field it lies at about 1,900 to 2,100 feet, and in the Sheetz field at about 2,100 to 2,200 feet. In the northeastern part of the quadrangle, in and around sec. 6, T. 17 N., R. 10 E., it lies about 1,700 feet beneath the surface, and in the North Bristow field at about 2,100 feet. Farther west, in the Red Bank field, it is found at 2,200 to 2,300 feet. In secs. 7 and 8, T. 17 N., R. 8 E., it is about 2,400 feet below the surface. A few logs report showings of oil in these limestones, but commercial quantities had not been obtained from them prior to June 1, 1920.

CHEROKEE SHALE

The interval below the Fort Scott limestone and above the thick Boone formation ("Mississippi lime") measures roughly about 900 feet and according to well logs is occupied principally by interbedded

[11] Smith, C. D., The Glenn oil and gas pool and vicinity, Okla.: U. S. Geol. Survey Bull. 541, p. 33, 1914.

[12] White, L. H., and Greene, F. C., Correlation of the "Wilcox" sand in the Okmulgee district with the Osage, Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 3, pp. 401–402, 1921.

shale and sandstone and a few beds of thin and apparently nonpersistent limestone. (See Pls. IV, V, and VI.) The rocks in this interval in Osage County, to the north, have been referred to the Cherokee shale, but whether or not this interval in the Bristow quadrangle represents the same time equivalent can not yet be definitely stated. The writer is of the opinion that the lower part of this interval, comprising the Dutcher sand and underlying shales, is separated from the overlying portion by an unconformity and therefore that this sand may be older than the true Cherokee and may perhaps be even of Mississippian age. This opinion, however, is based on inconclusive evidence from well logs, and therefore in this report the Dutcher sand and underlying shales will be considered a part of the Cherokee.

In the Red Bank field, according to well logs, the Cherokee shale is represented by shale and sandstone in about equal proportions, but elsewhere shale predominates and the sandstone beds occur principally in the lower part of the formation. In the Glenn and Beggs regions, to the east, the sandstones of the lower part of this interval include in descending order the Red Fork, Glenn, Taneha, and Dutcher (Rhodes and Scott) sands, and in the Cushing field, to the west, the Bartlesville and Tucker sands.

The Red Fork sand is probably represented in T. 17 N., R. 10 E., where it gave good oil showings in a number of wells and yielded oil in commercial quantity in a few wells near the northeast corner of sec. 20. The sand that supplies small amounts of gas in sec. 9, T. 15 N., R. 9 E., at a depth about 200 feet below the top of the Fort Scott limestone, may perhaps be considered a near equivalent to the Red Fork.

The Glenn and Taneha sands, or a zone of sands at the general position of these two, persists throughout the quadrangle and at the west merges into the zone that contains the Bartlesville and Tucker sands of the Cushing field. Whether any single sandy body like the Glenn or the Taneha is persistent and is the same as the Bartlesville or the Tucker of Cushing can not be determined with certainty from the drillers' logs, but there is no question that the sand zone that includes the Glenn and Taneha of the Glenn and Beggs regions includes also the sands differentiated at Cushing as the Bartlesville and Tucker. This sandy zone will be referred to in this report as the Bartlesville (Glenn) sand zone. It contains showings of oil and gas in many parts of the Bristow quadrangle, and it supplies oil in commercial quantity in the North Bristow field and in a few wells in secs. 8 and 16, T. 15 N., R. 9 E. It also supplies the gas of the wells in sec. 34, T. 16 N., R. 9 E., and secs. 2, 3, and 9, T. 15 N., R. 9 E., and it contains the productive bed, locally called the Tucker sand, found at depths between 2,750 and 2,900 feet in the

Red Bank field and in the few wells in secs. 7 and 18, T. 17 N., R. 8 E.

Near the base of the Cherokee formation is the Dutcher sand, which since 1920 has yielded large quantities of oil in this quadrangle, principally in the Slick field. Since 1921 drillers in the Continental pool, a mile or two east of Bristow, and the Poor Farm pool, in and around sec. 2, T. 15 N., R. 8 E., have discovered rich accumulations of oil in the Dutcher sand. Prior to 1920 it was found slightly productive by two wells near the east quarter corner of sec. 10, T. 15 N., R. 9 E. The main exploitation of the Dutcher sand came with the northwestward extension of the development in the Beggs field, which reached the Bristow quadrangle late in 1919 or early in 1920. In June, 1920, this sand was tapped by a few wells in secs. 4, 5, and 9, T. 15 N., R. 10 E., and secs. 28 and 33, T. 16 N., R. 10 E.

North and northwest from the Slick field the Dutcher sand decreases in thickness and in T. 17 N., R. 10 E., and T. 16 N., R. 9 E., apparently thins out. (See Pls. IV, V, and VI.) In this direction it seems to follow roughly a line running diagonally across T. 17 N., R. 10 E., from northeast to southwest. For T. 16 N., R. 9 E., the available information is not so definite, but the northwestward limit of the sand seems to follow a line running west-southwestward from the northeast corner. The sand is present in most if not all of T. 15 N., R. 9 E., and in one small locality near the east quarter corner of sec. 10 it has been found productive by a few wells. It generally supplies showings of oil or gas wherever reached by the drill.

Oil is found in the Dutcher sand in several localities where there is no favorable structure in the surface rocks. Clark and Bauer [13] state that west of R. 13 E. in the Okmulgee County district, which lies east of the Bristow quadrangle, "no east dip in the surface rocks is known * * * except in connection with faulting." The distribution of the oil in these localities is controlled in part either by folding or an arched upper surface which is limited to the sand itself or else by locally more porous areas in the sand or by a local source of the oil. In the Slick field, as is shown on page 54, the upper surface of the sand shows many minor irregularities. The features above set forth indicate though they do not conclusively prove that either there is an unconformity at the top of the Dutcher sand or else the edging out of the sand is the result of overlapping sediments. If an unconformity is present, then the Dutcher sand is probably not a part of the Cherokee shale but belongs to some older formation, which may be of Mississippian age.

[13] Clark, R. W., and Bauer, C. M., Notes on the geology of the Okmulgee district: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 2, p. 289, 1921.

The wide areal extent in northeastern Oklahoma of the Dutcher sand and especially of the Boone limestone and the underlying black shale and "Wilcox" sand, all probably separated from one another by unconformities, indicates a long period of little or no deformation except elevation or subsidence. The unconformities have practically no angular relations, and during the long period when the different formations were subject to subaerial erosion they must have lain very close to sea level, or else the conditions must have produced a floor of nearly perfect peneplanation.

MISSISSIPPIAN ROCKS

BOONE FORMATION

Lying beneath the surface of the Bristow quadrangle at a depth which ranges from 2,650 feet in the eastern part to 3,200 feet in the Red Bank field is a series of limestone beds that measure about 350 to 450 feet in thickness and are considered to be of Mississippian age. This limestone series is found between the Dutcher and Mounds sands in the Glenn pool, where Smith [14] tentatively correlated it with the Morrow formation and Pitkin limestone. The later and more abundant evidence presented by Aurin, Clark, and Trager [15] and by White and Greene [16] has without question proved that this limestone series belongs to the Boone formation (the Boone chert or "Mississippi lime" of the drillers). It is generally conceded that a stratigraphic hiatus exists both above and below this formation.

Some of the logs of wells in the Bristow quadrangle indicate the Boone to be solid limestone; others indicate the presence of several sandy and shaly partings. It may be that the presence of partings in the limestone is a development which takes place in increasing amount toward the west. (See Pls. IV, V, and VI.)

In and around sec. 7, T. 17 N., R. 10 E., in the northeastern part of the quadrangle, the top of the Boone is found at a depth of 2,600 to 2,700 feet. Farther south, in the Slick field, the Boone lies at a depth of about 2,800 feet. In the South Bristow field it had not been reached prior to June 1, 1920, but it should be found at a depth of about 3,000 to 3,200 feet. In sec. 31, T. 15 N., R. 9 E., just south of the quadrangle, a well was drilled to 3,700 feet before encountering the lime, and it is possible that the "lime shell" and "water

[14] Smith, C. D., The Glenn oil and gas pool and vicinity, Okla.: U. S. Geol. Survey Bull. 541, pp. 14–28, 1913.

[15] Aurin, F. L., Clark, G. C., and Trager, E. A., Notes on the subsurface pre-Pennsylvanian stratigraphy of the northern Mid-Continent oil fields: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 2, pp. 117–153, 1921.

[16] White, L. H., and Greene, F. C., Correlation of the "Wilcox" sand in the Okmulgee district with the Osage, Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 3, pp. 399–407, 1921.

sand" recorded between 3,700 and 3,750 feet in the log of this well (No. 34, Pl. VI) may not represent the Boone. The findings of this well seem to indicate a southwestward dip which carries the Boone to considerable depth in this direction.

In the North Bristow field the Boone probably lies about 3,000 feet beneath the surface, and in the Red Bank field it has been found at depths ranging between 3,100 and 3,200 feet.

PRE-MISSISSIPPIAN ROCKS

"WILCOX" OIL SAND

The Boone formation is underlain by black shale[17] (possibly of Devonian age) and a hard white limestone, which together generally measure less than 100 feet in thickness, and below these is a rich oil sand to which the term "Wilcox" is generally applied. This sand, which was first extensively developed near Beggs, in Okmulgee County, 9 miles east of the southeast corner of the Bristow quadrangle, has proved to be productive only in more or less isolated localities. The region in which it has been found productive has been extended rapidly to the north and west and reached the Bristow quadrangle early in 1920.

According to Aurin, Clark, and Trager[18] the "Wilcox" oil sand lies at the top of a series of sandstones with interbedded green and red shales that together probably constitute the Tyner formation, of Ordovician age. This sandstone series, according to White and Greene,[19] contains oil at several horizons, and the term "Wilcox" is applied to all of them. These writers suggest that the first or true "Wilcox" sand is possibly the equivalent of the Sylamore sandstone, of Devonian age, and that the lower ones are of Tyner (Ordovician) age. The age of the first "Wilcox" sand has probably not been conclusively determined, although the paleontologic evidence presented by Aurin, Clark, and Trager is more suggestive of Ordovician than of Devonian age.

The first oil produced from the "Wilcox" sand in the Bristow quadrangle was obtained at a depth of about 3,500 feet in the Red Bank field, and the initial daily production was 300 barrels. Later wells obtained even greater quantities, up to maximum of 1,350 barrels a day.

---

[17] For a discussion of this shale see Aurin, F. L., Clark, G. C., and Trager, E. A., Notes on the subsurface pre-Pennsylvanian stratigraphy of the northern Mid-Continent fields: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 2, pp. 122, 127, 1921.

[18] Idem, p. 128.

[19] White, L. H., and Greene, F. C., Correlation of the "Wilcox" sand in the Okmulgee district with the Osage, Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 3, pp. 405–406, 1921.

BEDS BELOW "WILCOX" SAND

The beds underlying the first or true "Wilcox" sand, according to the reports by Aurin, Clark, and Trager and by White and Greene already cited, include other sands, some of them locally productive, and interbedded red and green shales which all these authors consider to be the local representatives of the Tyner formation, of Ordovician age. Prior to June, 1920, this series had been deeply penetrated by only one well in the Bristow quadrangle. The log of this well (No. 8, Pl. IV), does not show the characteristics of these beds as described by Aurin, Clark, and Trager, but this may be due to inaccuracy of the drillers in making the record.

Underlying the Tyner formation in the region east of Moskogee is a siliceous limestone which Aurin, Clark, and Trager[20] designate simply "Ordovician siliceous limestone." Their correlations indicate that this limestone is present east, west, and north of the Bristow quadrangle, and hence it should probably be present within the quadrangle. It seems probable that this is the limestone at a depth of 3,705 to 3,953 feet recorded in log 8 (Pl. IV).

STRUCTURE

DEFINITION

The term "structure" as used in geologic reports indicates the position or lay of the rock beds and has no reference to their composition or to the materials which they contain. Sedimentary rocks, such as those of the Bristow quadrangle, lie in layers one upon another in a manner somewhat similar to the leaves of a book. Individual rock layers, however, are not of uniform thickness, like the leaves of a book; they thicken and thin and may even pinch out.

The successive layers were originally deposited on practically level surfaces and hence lay in horizontal positions. In some regions they still lie horizontal, but at most places throughout the earth they have been subjected to earth movements which have deformed them, so that most of them are inclined or tilted, folded, broken, or upturned, 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 rocks of a single formation 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 structural features as a rule do not correspond with the surface features, for anticlines may occur beneath valleys as well as beneath hills and ridges, or on the slopes

[20] Op. cit., p. 121.

between hills and valleys, or they may even cross from the highlands into the lowlands, and in like manner synclines may occur beneath either hills or valleys or may extend across both hills and valleys.

By structure, then, is meant the general attitude of the rock layers, and the term is not restricted to beds that have been deformed, for beds that lie in their original horizontal position are said to have flat-lying or horizontal structure. Some petroleum geologists use the term in a different sense, speaking of "a structure" in some particular locality when in reality they mean an anticline or structural feature of some other type that they consider favorable for the accumulation of oil and gas.

REGIONAL STRUCTURE

Throughout northeastern Oklahoma, southeastern Kansas, and adjacent regions the rocks that crop out have characteristically a gentle westward to northwestward dip, generally measuring less than 1°. This westward-sloping attitude of the rocks is usually classified as a regional monocline. The extensive tilting of the beds that produced this attitude was brought about by an uplift that centered in the Ozark Mountains. Similar deformations occurred at about the same time in the Ouachita and Arbuckle mountains of southeastern and south-central Oklahoma. The territory affected by these earth movements was large. This extensive regional deformation probably took place late in Permian time or at its end.

Since the development of this extensive monocline the beds have been beveled by erosion, so that the oldest, or lowest stratigraphically, are exposed in belts at the east side of the monocline, and the successively younger beds appear farther and farther west and northwest.

STRUCTURE OF THE BRISTOW QUADRANGLE

GENERAL FEATURES

The Bristow quadrangle lies on the regional monocline of northeastern Oklahoma. The general strike of the rocks in the quadrangle is about N. 15° E. and the dip N. 75° W. (See Pls. II, VII, and VIII.) The dip averages about 75 feet to a mile. The highest structural point is in the southeast corner of the quadrangle, and the lowest in the northwest corner. As on the regional monocline, so here the rocks that are stratigraphically the lowest 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. Plate II gives the surface distribution of the formations, and Plates IV, V, and VI, show graphically in exaggerated form the westward inclination of the strata.

The westward monoclinal slope of the rock beds is not uniform: it is modified by variations in the rate of dip, local folds, and small faults, reflected in the surface rocks, shown on Plates II, VII, and VIII.

The most prominent structural features of the quadrangle are a series of faults, which are grouped in four distinct lines crossing the quadrangle in a direction that closely parallels the strike of the rock beds. The individual faults, however, trend in a northwesterly direction at an angle of about 45° from that of the groups. The parallel trend of the individual faults and of the groups of faults is a noteworthy feature that receives special treatment elsewhere in this report (pp. 35–38).

Associated with the faults are several minor folds, which appear to be intimately related to the faults, but a notable exception is to be found in a larger fold in the northwestern part of T. 16 N., R. 8 E., which can be subdivided and is treated in this report as two folds, the North Catfish and South Catfish anticlines. These folds, even though geographically associated with faults, present some evidence which suggests that they were formed independently of the faults. These features also are treated in more detail in the discussion of the oil and gas developments.

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 beds, among them the Elgin, the *Fusulina*-bearing bed at the base of the Bristow formation, and the Dewey limestone, all 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 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. Some of the more prominent of such outcrops are mapped on Plate II. Local stratigraphic sections were measured wherever several successive beds were exposed, and these were helpful as a check to the tracing of the several beds.

The determinations of altitude of rock outcrops used in present-day petroleum investigations in the Mid-Continent region are fairly accurate. Permissible maximum errors ranging from 2 to 5 feet are common, and such a degree of accuracy usually 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 precluded the taking of 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. The altitudes so determined were checked by hand leveling 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. (In addition to the numerous altitudes given on the published topographic map, the writer probably had half as many more for less important points, which were obtained by copying from the topographers' original plane-table sheets.) 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 that 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 from less than half an hour to two hours. If the atmospheric pressure has been constant or has been changing at a uniform rate, the altitudes thus determined may be considered 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 were 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 was particularly careful in the areas of the anticlines and faults.

METHODS OF REPRESENTING STRUCTURE

The most practicable method of representing simple 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 850-foot contour on Plate VIII shows the line along which the base of the *Fusulina*-bearing bed at the bottom of the Bristow formation is 850 feet above sea level. In like manner the 860-foot contour indicates an altitude of 860 feet, and the 840-foot contour an altitude of 840 feet. The "contour interval" (the vertical distance between the altitudes represented by adjacent contours) used on Plate VIII is 10 feet. It is possible to determine from the spacing of the contours the approximate altitude 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 *Fusulina*-bearing bed of the Bristow formation crops out in a relatively narrow belt across the region its altitude in localities outside 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 horizons which were traced and whose altitude was determined. In thus computing the altitude of the base of this bed over the region it must necessarily be assumed, in the absence of evidence to the contrary, that the intervals between the base of the *Fusulina*-bearing sandstone and each succeeding bed above or below are the same underground as they are where the beds crop out at the surface and the intervals can be measured. It is known, however, from the way in which these intervals thicken and thin and even disappear on the outcrop that they are not constant. Well logs, if they accurately recorded the base of the Bristow formation, would be a great help in determining the accuracy of the computed altitudes on this bed. This bed, however, is not one in which drillers are specially interested, and hence its depth is not accurately measured. In many well logs its presence is not even recorded. For these reasons well-log data were not used in drawing the structure-contour map (Pl. VIII).

Most of the sandstones and shales vary in thickness from place to place along their outcrops, as is well illustrated by Plate III. If the thickness of individual beds is not constant at the surface it is presumably also not constant where the beds are concealed beneath the surface, and hence the distances between the several beds and the base of the Bristow formation are doubtless variable from place to place. For this reason the structure of the *Fusulina*-bearing bed can not be accurately determined at any considerable distance from its outcrop, and the structure shown on Plate VIII must be considered approximate only, a compromise between data on strike, dip, and stratigraphic interval obtained in the field and the judgment of the writer.

The field observations resulted only in ascertaining the altitudes of the outcropping beds and measuring where possible the intervals between them. The change in altitude of any single bed supplied information for determining the dip, and from the dip it was possible to project one bed beneath the outcrop of an adjacent one, and in this way to determine intervals between beds even though their outcrops were some distance apart. The compiled results of this work are given on a separate map (Pl. VII), which shows by means of lines the strike of the rock beds whose lines of outcrop were mapped and whose altitudes were determined. In localities where the intervals between adjacent rock beds are constant these strike lines were so spaced that for practical purposes they are structure contours with intervals of 10 feet. In localities where the beds thicken or thin so that the intervals between adjacent mapped beds varies the strike lines on such beds run at angles to each other. In such localities the converging or diverging strike lines were either abruptly terminated or abruptly added, but always with the attempt to make the interval between adjacent lines represent as closely as possible structure intervals of 10 feet.

The difference between this strike-line map and the structure-contour map (Pl. VIII) is that this map represents facts as determined in the field instead of a compromise between data of different kinds and the judgment of the writer. It shows the localities where the intervals between outcropping beds vary, also the strike of the exposed ledges. The structure-contour map, on the other hand, is merely an attempt (the word "attempt" is used advisedly) to show the attitude of the base of the Bristow formation by structure contours at 10-foot intervals, based on data which may be in error as much as 100 feet at a distance of 5 miles or more from the outcrop.

No two geologists using the evidence on the strike-line map (Pl. VII) as a basis to draw up a structure-contour map would obtain the same results. The map here given (Pl. VIII) must be considered merely the writer's interpretation of the evidence. The two maps show but little difference within a belt 3 miles wide on each side of the outcrop of the base of the Bristow formation, but this similarity is due to the constancy of intervals between the beds that crop out in this belt. If in places at a greater distance from the outcrop of the key horizon the structure contours approximately agree with the strike lines, this must be considered a coincidence rather than an expected result. On the other hand, it is probable that the structure-contour map gives a good general picture of the structure, for the local irregularities should compensate one another, because the beds in the aggregate are more or less 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.

The strike-line map is of especial value for determining local structure in detail and is far preferable for use in choosing sites for test wells, especially in localities at a distance from the outcrop of the base of the Bristow formation.

FAULTS

The most noteworthy feature of the faults in this quadrangle is their approximate parallel trend and their grouping into series that are also parallel. (See Pls. II, VII, and VIII.) They trend about N. 30° W. and lie en échelon in linear groups or series that trend about N. 15° E., or nearly parallel with the strike of the strata. The individual faults are of minor magnitude, both in vertical displacement and in areal extent. The largest stratigraphic displacement is about 130 feet, and the greatest length about 3¼ miles.

Within the quadrangle there are four groups or series of faults, two of which are much more prominent than the others. The two main groups extend from the north-central part of the quadrangle to the southwest corner and from the northeast corner to the south-central part.

As the rock outcrops in this region 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 consists in slickensided faces of sandstone outcrops. Plate IX shows the most prominent of such slickensided fault planes observed in the region, in the north-central part of sec. 5, T. 16 N., R. 8 E. 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. Such exposures are exceptional, however, and 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.

In the displacement of the rocks caused by the fault movements the rocks adjacent to the fault planes were sheared in a zone several feet thick. The fractures in these shear zones have subsequently been filled by veinlets of siliceous material, and these veined shear zones (Pl. X) 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 criterion for detecting faults is the discordance of beds on the two sides of the fault, but this criterion is difficult of application where there are no good horizon markers, as in areas where shale is the surface rock. Still another criterion, the discrepancy in the position of contour lines as determined from the evidence available, 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.

As there is no direct evidence that thrusting has taken place along any of the faults, and as none of the structural features suggest thrust faulting, all the faults are 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°—the measured dips at the localities mentioned above. It is also probable that the individual fault planes change in dip from place to place. The faults whose traces are not altogether straight but are more or less curved or bowed as shown on the maps may have these irregular courses because of variation in dip.

Besides the faults shown on the maps (Pls. II, VII, and VIII), there may be others in the quadrangle, for which, however, the writer was unable to find positive field evidence. One locality where a fault may be present is between the knoll represented by the two round contours near the center of sec. 19, T. 15 N., R. 10 E., and the ridge to the southwest. If a fault exists here it would be in line with two others to the north and east. Another possible locality for a fault is the northeastern part of sec. 26, T. 16 N., R. 9 E. If one exists here it must be comparatively small. Faults may also occur in other localities where the outcrops are poor, as shown on Plates VII and VIII by the dashed contours.

Similar linear series of faults are rather extensive in northeastern Oklahoma. The writer has found them near Paden[21] and east and northeast of Okemah.[22] They also occur in the Hominy and Pawhuska quadrangles,[23] to the north, and in the Cushing region,[24] to the northwest.

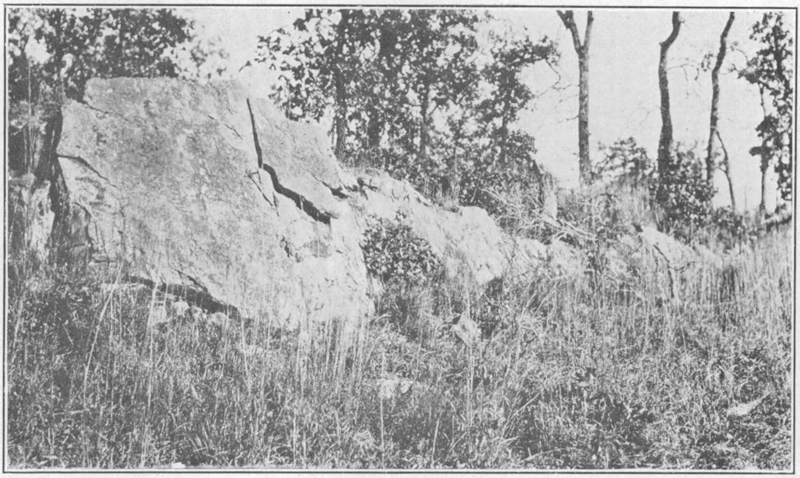
---

[21] Fath, A. E., and Heald, K. C., Faulted structure in the vicinity of the recent oil and gas development near Paden, Okfuskee County, Okla.: Oklahoma Geol. Survey Bull. 19, pl. 2, pp. 353–360, 1917.

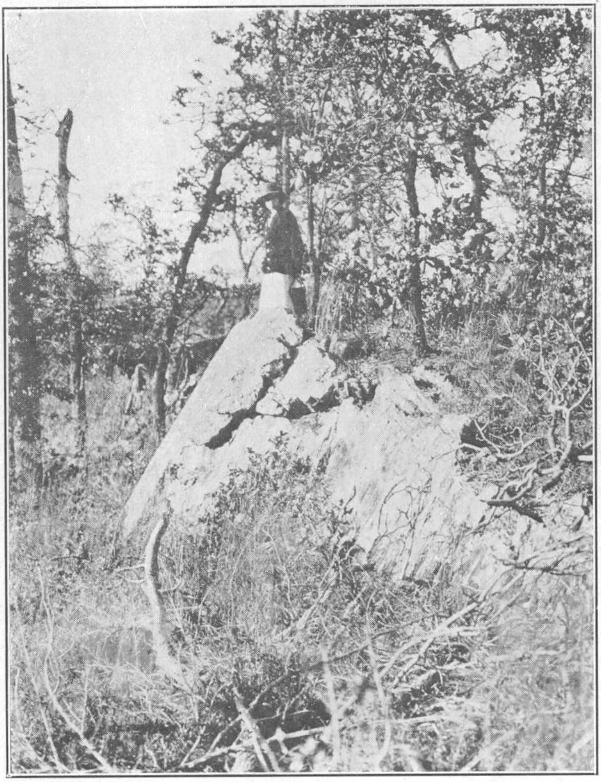
[22] Fath, A. E., Emery, W. B., and Heald, K. C., unpublished report in U. S. Geol. Survey.

[23] White, David, and others, Structure and oil and gas resources of Osage Reservation, Okla.: U. S. Geol. Survey Bull. 686, 1922; personal communication from R. H. Wood.

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

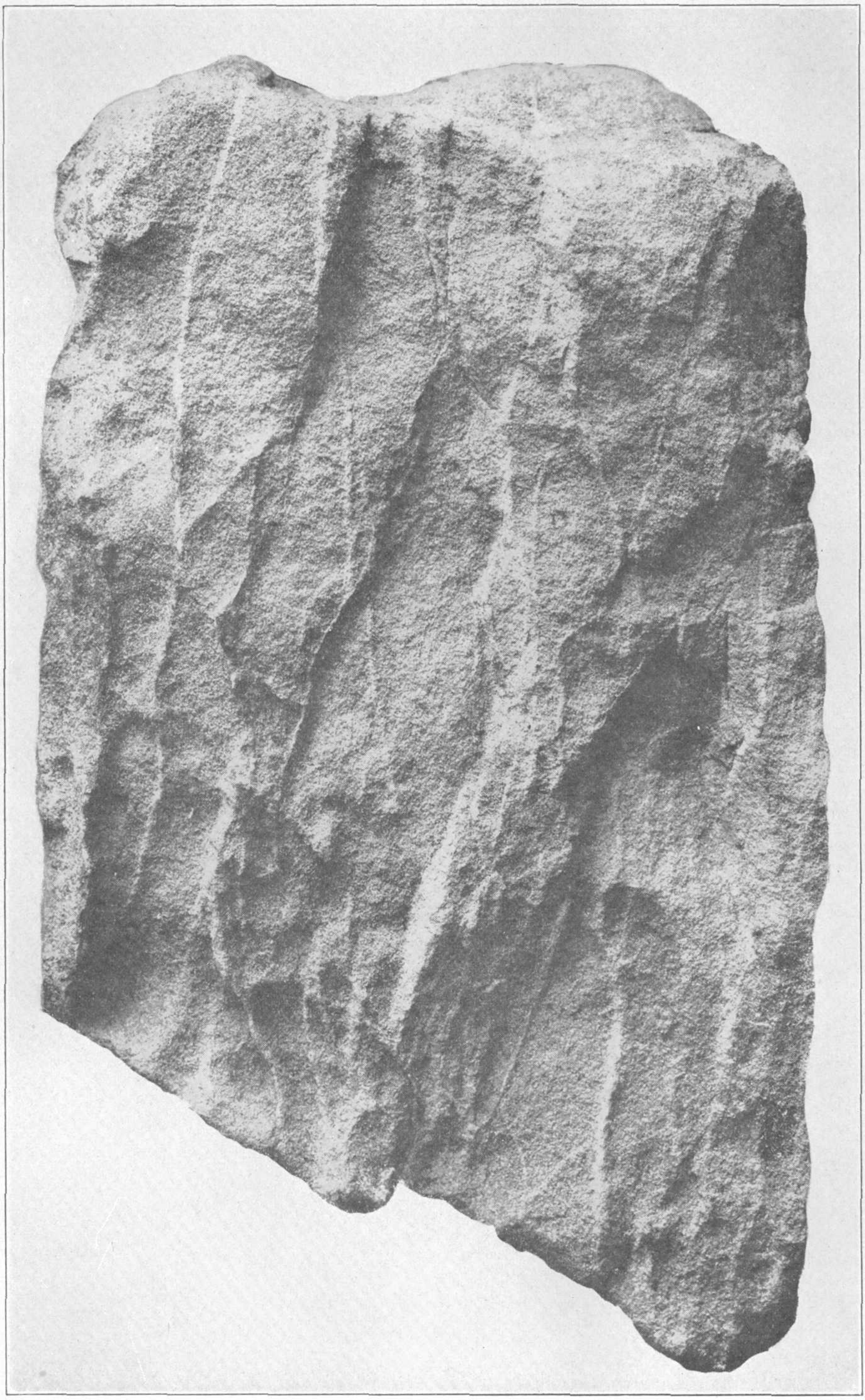


A



B

FAULT SCARP SHOWING SLICKENSIDED SURFACE OF SANDSTONE PRODUCED BY FAULT MOVEMENT



VEINED SANDSTONE FROM SHATTERED AND RECEMENTED ZONE ADJACENT TO A FAULT

The origin of the faults has been discussed at considerable length by the writer in two previous publications[25] and hence will be treated only briefly in this respect.

The faults are normal—that is, the downthrow is in the direction of the hade—and therefore the immediate forces that caused the individual fractures were probably tensional in nature and operated horizontally in a direction normal to their trend, or about N. 60° E. On the other hand, the linear grouping of these fractures into belts and their general uniform development throughout each belt suggest, as the most simple explanation, that the faults of any one series were formed simultaneously by a horizontal force that operated in a direction parallel to the trend of the series, or about N. 15° E.

The Pennsylvanian rocks that form the upper thousand feet of strata in this region are probably too weak and incompetent to transmit horizontal forces through the distances—50 miles or more—over which some of these fault belts extend. It is therefore assumed that the massive pre-Cambrian crystalline rocks lying at an unknown depth and the overlying massive and strong lower Paleozoic strata are the rocks in which these forces were transmitted.

The deformation of the weak and yielding strata near the surface would differ from that of the deep-seated strong and competent beds. Instead of breaking or shearing sharply along a nearly vertical plane or zone parallel to the fracture or shear zone in the underlying strong rocks along which a horizontal displacement had occurred, the weak strata would be bent and the parts would tend to be dragged apart, so that tension would be produced diagonal to the direction of movement. Under this explanation the fractures produced in the rocks immediately overlying the harder rocks in which the horizontal displacement occurred would be tears, which would remain open if it were not for the adjustment that would immediately take place in these overlying formations. According to this explanation the fracture would be closed up by the slumping or giving way of the soft rocks on one side or the other, which would result in a small vertical displacement of the beds on opposite sides of the fissure—that is, there would be a normal fault. The fissuring due to lateral movement would not cause displacement of the strata at the surface, but the later adjustment would. Although the deep-lying fractures may have been irregular tears, their upward extensions into the overlying, less loaded material caused by the slumping would be straighter, and at the surface they would be represented by regular normal faults.

---

[25] Fath, A. E., The origin of the faults, anticlines, and buried "granite ridge" of the northern part of the Mid-Continent oil and gas field; U. S. Geol. Survey Prof. Paper 128, pp. 75–84, 1920; Geology of the Eldorado oil and gas field, Butler County, Kans.: Kansas Geol. Survey Bull. 7, pp. 150–155, 1921.

In applying this explanation to the faults in the Mid-Continent field, it becomes evident that the direction of the shearing movement in the hard, competent deep-lying rocks must have been along the belts of faults, the territory on the east side of each fault belt having moved northward relative to that on the west side. For the faulted region as a whole the movement may be likened to a regional shearing, in which the belts of faults in the weak surface beds mark the location of the fault planes in the granite basement.

If the soft and yielding beds were sufficiently thick faulting of this type would be gradually dissipated upward and would not reach the surface. It is therefore probable that in addition to the faults found at the surface others exist beneath the surface along the same belts. There is also a possibility that additional belts of diagonal faults may be present in the deeper rocks and not reach the surface because the movements which initiated them were not as great as those which produced the faults that now show at the surface. Some inconclusive evidence of the subsurface conditions along these fault belts is discussed in connection with the Slick field (pp. 52–54).

ANTICLINES IN SURFACE ROCKS AND SUBSURFACE STRUCTURE

The anticlines and other features of the structure are described in detail in connection with the account of the oil and gas fields on pages 44–59.

OIL AND GAS DEVELOPMENT

HISTORY OF DRILLING IN THE BRISTOW QUADRANGLE

Drilling for oil and gas in the Bristow quadrangle began before Indian and Oklahoma territories were combined to make the State of Oklahoma and even preceded the opening of the Glenn pool, in 1906. J. J. Curl, of Bartlesville, drilled the first hole, in 1905, in the northwest corner of sec. 29, T. 16 N., R. 9 E., at the present site of the refinery. When the drill had reached a depth of about 1,000 feet the driller experienced considerable trouble, and the hole was plugged and abandoned. The rig was skidded a few feet, and a second hole was started, but at the same depth similar trouble was experienced, and in the summer of 1906 this hole also was abandoned. So far as could be ascertained, no logs of these holes were kept, and as the sites are now covered by the refinery buildings they are not indicated on the maps.

In November, 1906, the second attempt to find oil and gas was started by Messrs. Mattson, Barnes, and Freeland, and the results were more encouraging. The well was put down in the same quarter section as the earlier unsuccessful holes but farther southeast, on the southwest bank of Sand Creek. The drilling of this well progressed intermittently. At a depth of 1,395 feet a small flow of gas (about 100,000 cubic feet a day) was found, but drilling continued to 2,030 feet, where a good showing of oil was encountered. Drilling was suspended at this depth for about 40 days. When it was found that no commercial production could be obtained at this depth the hole was continued to 2,250 or 2,275 feet, again shut down for a short time, and then drilled to 2,500 feet, when operations were once more stopped, this time for more than a year. When drilling again started it continued to a depth of 2,680 feet. No more favorable showings were encountered and nothing more was done until 1909, when the hole was plugged back to the gas sand, which was then shot and the gas turned into the Bristow town supply and used for about 60 days during the cotton-ginning season. The well was then completely plugged.

In 1921 deep drilling in this vicinity found the Dutcher sand to be a rich producer of oil. Information pertaining to the extent and other details of this field, known as the Continental pool, was not available for inclusion in this report.

During the intermittent drilling of the well in sec. 29, T. 16 N., R. 9 E., several other wells had been drilled east and southeast of Bristow. In the winter and spring of 1907 Dabney & Duff drilled a well with a Star rig in the NE. ¼ sec. 25, T. 16 N., R. 9 E., which reached a depth of 2,460 feet. Oil and gas showings were encountered between 1,700 and 1,800 feet and again at about 2,400 feet. No other information concerning this well could be obtained.

In the summer of 1907 Frank Barnes and Claude Freeland started a well in the NW. ¼ sec. 2, T. 15 N., R. 9 E. On December 20 of that year a flow of gas, amounting to a scant million cubic feet daily under a pressure of about 1,000 pounds, was encountered in a 15-foot sand found at a depth of 2,485 feet. After being shut down for a few days the well was deepened to 2,562 feet, but then it was plugged back to the gas sand, and its supply was used by the town of Bristow. This represents the first successful well to be completed in the Bristow quadrangle. The well was still being used in 1917, when its flow was practically undiminished, even after nine years of service.

After the completion of this small gas well a well was started by the Allen Oil Co. at the south side of sec. 8, T. 15 N., R. 9 E., on the Abraham Allen farm. At a depth of 818 feet a 12-foot oil sand was encountered. Drilling continued, however, and reached a depth of about 2,300 feet by the summer of 1908 without finding any other noteworthy showings. The well was then plugged back to the oil sand at 818 feet, and after shooting the sand the oil was bailed and gaged for a daily production of about 15 barrels. Nothing more was done with the well, and on the writer's last visit, in 1917, the oil stood within a few feet of the top of the casing. So far as known no log was kept of the drilling.

After this discovery of oil three attempts were made in the immediate vicinity to find a greater production in the same sand. These attempts were all unsuccessful. The first was made half a mile northeast of the Allen well. The sand was found, but it showed only a little gas. The second attempt was made a few hundred yards west of the original well. In this hole the sand was dry. The third attempt was made in the spring of 1909 a few hundred yards north of the original well, and here the sand was found to be broken. All these holes were drilled during the intermittent drilling of the well in sec. 29, T. 16 N., R. 9 E., the gas from which was not used until the fall of 1909.

The work above outlined marks what may be called the first stage in the oil and gas development in the Bristow quadrangle. It was contemporaneous with the great development of the Glenn pool. The results were discouraging, and no other attempt was made to find oil and gas until December, 1910, when the Oklahoma Natural Gas Co. drilled a dry hole in the NW. ¼ sec. 6, T. 16 N., R. 10 E.[26] On the completion of this hole the same company drilled another in March and April, 1911, one-third of a mile to the northwest, in sec. 36, T. 17 N., R. 9 E., where at a depth of 990 to 1,010 feet gas was encountered with an initial flow of 7,000,000 cubic feet a day. The supply was turned into the 12-inch pipe line of this company, which at that time carried gas to Oklahoma City, until the pressure decreased to a point at which it would no longer force gas into the pipe line. The well was again connected to the pipe line in February, 1917, when its open-flow capacity registered 350,000 cubic feet a day with a rock pressure of 375 pounds. This was the second successful well in the quadrangle.

At about the time the well just described was being drilled the Nina Oil Co. drilled a well in the SW. ¼ sec. 2, T. 15 N., R. 9 E., about two-thirds of a mile south of Barnes & Freeland's gas well. At a depth of 2,486 feet the gas sand of the Barnes & Freeland well was reached, but drilling continued to a depth of 2,570 feet. The well was then plugged back to the gas sand and tubed with a packer, and all the casing was pulled. The gas was turned into the Bristow supply and used for two weeks, when the well began to make oil with the gas. On being blown off the oil flowed over the derrick through the 2-inch tubing. A short time afterward water began to appear, probably because of a defect in the packer, and spoiled the well for either gas or oil. Because the casing had been pulled, the well had to be abandoned.

---

[26] U. S. Geol. Survey Bull. 661, p. 98, 1918.

Another well was being drilled at about this time by the Selby Oil Co. and Frank Barnes in the SW. ¼ sec. 10, T. 16 N., R. 9 E. It encountered several showings of gas and at a depth of 2,565 to 2,577 feet a showing of oil.[27] The well was drilled to 3,010 feet and then plugged back to the sand at 2,565 feet, which was shot with a small charge. The result was unsatisfactory, and the hole was abandoned.

In the summer of the same year (1911) the Oklahoma Natural Gas Co. drilled a hole in sec. 30, T. 17 N., R. 10 E.,[28] which proved unsuccessful. Some gas showings were encountered, for small bubbles were coming up through the water-filled casing when the site was visited in the summer of 1915.

In 1912 seven wells were started. A gas well with a capacity of about 3,000,000 cubic feet a day was completed on June 1 by Joe Abraham, Frank Barnes, and James Stout. This, the third successful gas well in the quadrangle, is near the center of the south line of the NW. ¼ sec. 9, T. 15 N., R. 9 E. The other wells being drilled in this year were in sec. 20, T. 17 N., R. 10 E.; sec. 32, T. 17 N., R. 10 E.; the NW. ¼ sec. 8, T. 15 N., R. 9 E.; sec. 5, T. 17 N., R. 8 E.; sec. 20, T. 17 N., R. 8 E.; and sec. 2, T. 15 N., R. 8 E. All were unsuccessful. The Carman No 1 well, in the northeast corner of the NW. ¼ NW. ¼ sec. 8, T. 15 N., R. 9 E., found a showing of 30 barrels of oil in a sand at 1,295 feet but was abandoned because of a bad hole.

The year 1913 saw seven wells started, but only one of them, the George Barr No. 1 well, in the SW. ¼ NW. ¼ sec. 8, T. 15 N., R. 9 E., was successful. It was drilled to about 2,250 feet but was plugged back to a gas sand at 1,262 feet, from which a flow was obtained amounting to about 1,000,000 cubic feet a day. This well was connected with the Bristow supply and was still being used in 1917 but was abandoned prior to May, 1920. After the good showing in the Carman No. 1 well, drilled in the fall of 1912, well No. 2 was started a quarter of a mile to the south. It was dry at 1,400 feet and abandoned. Other unsuccessful wells drilled in this year were in sec. 26, T. 17 N., R. 8 E.; sec. 3, T. 16 N., R. 8 E.; sec. 30, T. 16 N., R. 8 E. (just west of the quadrangle boundary); sec. 29, T. 17 N., R. 9 E.; and sec 33, T. 17 N., R. 9 E. The well near the center of the E. ½ NE. ¼ sec. 20, T. 15 N., R. 10 E., was probably also drilled in 1913, although not certainly.

[27] An incomplete log of this well is published in U. S. Geol. Survey Bull. 661, p. 97. The following items should be added to make the log complete: Black slate 2,510 to 2,555 feet; sand 2,555 to 2,580, with show of oil from 2,565 to 2,577; not recorded 2,580 to 2,585; sand 2,585 to 2,710, with a hole full of water at 2,610; white slate, 2,710 to 2,950; lime 2,950 to 3,010 (this is probably the Boone as defined in the present report).

[28] U. S. Geol. Survey Bull. 661, p. 98, 1918.

In 1914 well No. 3 on the Carman farm was drilled in the southeast corner of the SE. ¼ NE. ¼ sec. 8, T. 15 N., R. 9 E. It encountered the same gas sand that was found in well No. 1 and the Barr well but was drilled deeper, and at 2,625 to 2,660 feet it encountered an oil sand which, when pumped, furnished an initial daily production of 20 barrels. This represents the first successful production of oil in the quadrangle. The well was still being pumped in 1920. Four other wells were started during this year, all of which were unsuccessful. They were in sec. 36, T. 16 N., R. 9 E.; sec. 5, T. 15 N., R. 9 E.; the southeast corner of sec. 9, T. 15 N., R. 9 E.; and sec. 19, T. 16 N., R. 10 E.

In 1915 five wells were started in the quadrangle, in the following order: Sec. 26, T. 15 N., R. 9 E.; sec. 20, T. 17 N., R. 8 E.; the NW. ¼ SW. ¼ sec. 9, T. 15 N., R. 9 E.; sec. 14, T. 15 N., R. 8 E.; and sec. 1, T. 16 N., R. 9 E. The well in the NW. ¼ SW. ¼ sec. 9, T. 15 N., R. 9 E., developed gas at 2,540 feet, with a daily capacity of 6,000,000 cubic feet. It was connected with the Bristow supply. In the spring of 1917 oil appeared with the gas, and the supply of oil finally became so great as to be detrimental to the use of the well as a gas well and hence it was shut in. This was the state of affairs in May, 1917. At some later time the oil was allowed to flow, and in May, 1920, it was reported to be producing about 7½ barrels daily. The well in sec. 1, T. 16 N., R. 9 E., developed an aggregate of several million cubic feet of gas from several sands, but this was not deemed sufficient to make it a paying gas well and hence it was plugged and abandoned. The other three wells drilled in 1915 were failures.

Intermittent wildcatting continued in 1916, and this year saw the development of the first gas field of real importance, which may be called the South Bristow field. The Cosden Oil & Gas Co. drilled the initial well in this field, which was brought in on August 3. It was in the southwest corner of the NW. ¼ sec. 22, T. 15 N., R. 9 E., and after 36 hours of continuous flow its daily capacity was measured to be 41,664,000 cubic feet, with a rock pressure of 420 pounds. After seven days of continuous open flow its daily capacity had declined to 39,600,000 cubic feet. With the completion of this gas well drilling became active in its vicinity, and by May, 1917, thirteen additional wells had been drilled, of which two were dry and two very small wells were abandoned. At this time another well was being drilled and two new rigs were in place. Most of the gas from this field was sold to the Oklahoma Natural Gas Co., which connected the field to its 12-inch line by an 8-inch line.

In 1916 another oil well was drilled in the northeast corner of the SE. ¼ SE. ¼ sec. 8, T. 15 N., R. 9 E. It produced about 20 barrels a day by pumping, from the same sand as the oil well in the NW. ¼ of this section. Its productivity lasted for a few years only, and in 1919 the well was abandoned.

The history of developments in 1917 and later—that is, since the completion of the field work—has not been ascertained with as much detail as that of the earlier years. In the middle of the South Bristow gas field oil was discovered in October, 1917, in the Bartlesville (Glenn) sand zone. Three additional producing oil wells were completed in this vicinity in sec. 16, T. 15 N., R. 9 E., prior to 1920. In December, 1917, a well in sec. 18, T. 17 N., R. 8 E., a few hundred yards west of the quadrangle, obtained oil in the lower part of this zone. The production of this well was so small that it stimulated but little additional drilling. Within the quadrangle two wells in the NE. ¼ of the same section obtained a small production, probably in the same sand. One was principally a gas well with a showing of oil, and the other a small oil well with considerable gas.

Another small field, generally spoken of as the Sheetz field, lies just beyond the quadrangle boundary, in and around the northeast corner of sec. 36, T. 15 N., R. 8 E. A well with a good showing of gas in the Layton sand and small quantities of oil in what probably is the Dutcher sand created some excitement in this vicinity in 1915 or 1916, but no commercial production was obtained. The Layton gas sand was further tested, and in November, 1917, a production of 6,000,000 cubic feet with a rock pressure of 400 pounds was obtained in the SW. ¼ sec. 25, T. 15 N., R. 9 E. In 1920 this well, which had a good showing of oil, was drilled a few feet deeper and yielded 30 barrels of oil daily. Up to June, 1920, three additional gas wells had been drilled in this general vicinity, each having an open flow of about 5,000,000 cubic feet daily.

After the publication of the writer's preliminary report on the northern part of the Bristow quadrangle,[20] in which the Catfish anticlines were described, the Red Bank Oil Co. leased a considerable area on these anticlines and started a test well in November, 1918. This well, which is in the northeast corner of the SW. ¼ SW. ¼ sec. 9, T. 16 N., R. 8 E., found several good showings of gas and one of oil before reaching the lower part of the Bartlesville (Glenn) sand zone, where, in a sand that is locally designated the Tucker, at a depth of 2,750 to 2,816 feet, an open-flow gas production of 22,800,000 cubic feet daily and a closed rock pressure of 970 pounds was found. This well marks the beginning of what has since developed into a good oil and gas field. All wells drilled in this field prior to March, 1920, went down only to the Tucker sand, but in that month one went to the "Wilcox"

[20] U. S. Geol. Survey Bull. 661, pp. 69-99, 1917.

sand at a depth of 3,531 to 3,564 feet and obtained a high-gravity oil (between 40° and 41° Baumé), which since then has been the principal goal of the operators. Developments were limited to the South Catfish anticline until late in 1920, when the first test hole on the North Catfish anticline was drilled. Gas and oil have since been found on this north fold.

In June, 1918, oil was found in a well being drilled in the NW. ¼ sec. 8, T. 16 N., R. 9 E., which was the beginning of the North Bristow field. This oil comes from the Bartlesville (Glenn) sand zone, and it has been found to be present in the adjacent secs. 5, 7, 8, 17, and 18. Later in 1918 small producing areas were developed near the east quarter corner of sec. 10, T. 15 N., R. 9 E., and in the SW. ¼ sec. 4, T. 16 N., R. 10 E.

The small gas area near the center of sec. 6, T. 16 N., R. 10 E., was discovered in March, 1919.

In 1920 the westward extension of the known producing area of the "Wilcox" and Dutcher sands, in which oil was first found near Beggs, reached the Bristow quadrangle, where it is known as the Slick field.

Since then the Continental field, a mile or two east of Bristow, and the Poor Farm field, in and around sec. 2, T. 15 N., R. 8 E., have been developed. No detailed information on these fields was available for inclusion in this report, and hence they will not be discussed.

RED BANK FIELD

SOUTH CATFISH ANTICLINE

The Red Bank field lies in an area of considerable folding and extensive faulting that extends from secs. 32 and 33, T. 17 N., R. 8 E., southward to sec. 21, T. 16 N., R. 8 E. In this area there are two distinct anticlines having northerly trends, one of which lies north of the other.

The more southerly one is called the South Catfish anticline and extends from the NW. ¼ sec. 9, T. 16 N., R. 8 E. The reverse (eastward) dips that mark one side of this fold in the surface rocks are seen between the valley of Catfish Creek and the fault that crosses secs. 9 and 15. (See Pls. VII and VIII.) 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 altitude 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 must be 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 across 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 crest line of the fold could not be accurately determined at the time of this investigation, but it was considered to cross the western part of sec. 9, and the first description of this fold recommended as the best location for a test well the SW. ¼ SW. ¼ of this section. The initial test hole was drilled as recommended and proved to be the discovery well of the field. The drilling developments since then have shown that the inferred location of the crest line was practically correct, for the structural high points in the underground rocks conform closely with those of the surface rocks.

The subsurface structure in the "Layton lime," Fort Scott and Boone limestones, and Tucker and "Wilcox" sands was worked out from well-log information, and the principal features of it are shown on Plate XI. The structure of the "Layton lime" as shown in Plate XI, *B*, conforms rather closely with that of the surface rocks, with one noteworthy modification—the beds are more intensely folded, a feature which the writer has discussed at some length in earlier publications.[30] The explanation advocated by the writer for this feature is that the movements which formed the folds acted intermittently over a long period and during the time that the rocks of the region were being deposited, so that the older rocks were subjected to more deformation than the younger rocks.

Along the west side of the NW. ¼ sec. 16 the westward dip in the "Layton lime" is rather steep, as shown by the closer spacing of the contours in Plate XI, *B*. This probably represents a fault, the downward extension of the one mapped in the surface rocks, as shown in Plate XI, *A*. In view of the uncertainty in placing a fault here, the possible displacement is shown by dashed contours.

The effect of the downward extension of the fault in the E. ½ sec. 9 on the "Layton lime" is not clear. The information from

[30] Fath, A. E., The origin of the faults, anticlines, and buried "granite ridge" of the northern part of the Mid-Continent oil and gas field: U. S. Geol. Survey Prof. Paper 128, pp. 75–84, 1920; Geology of the Eldorado oil and gas field, Butler County, Kans.: Kansas Geol. Survey Bull. 7, pp. 155–164, 1922.

102896—25——4

the two wells east of the fault is confusing, and hence no attempt was made to contour the structure in this locality.

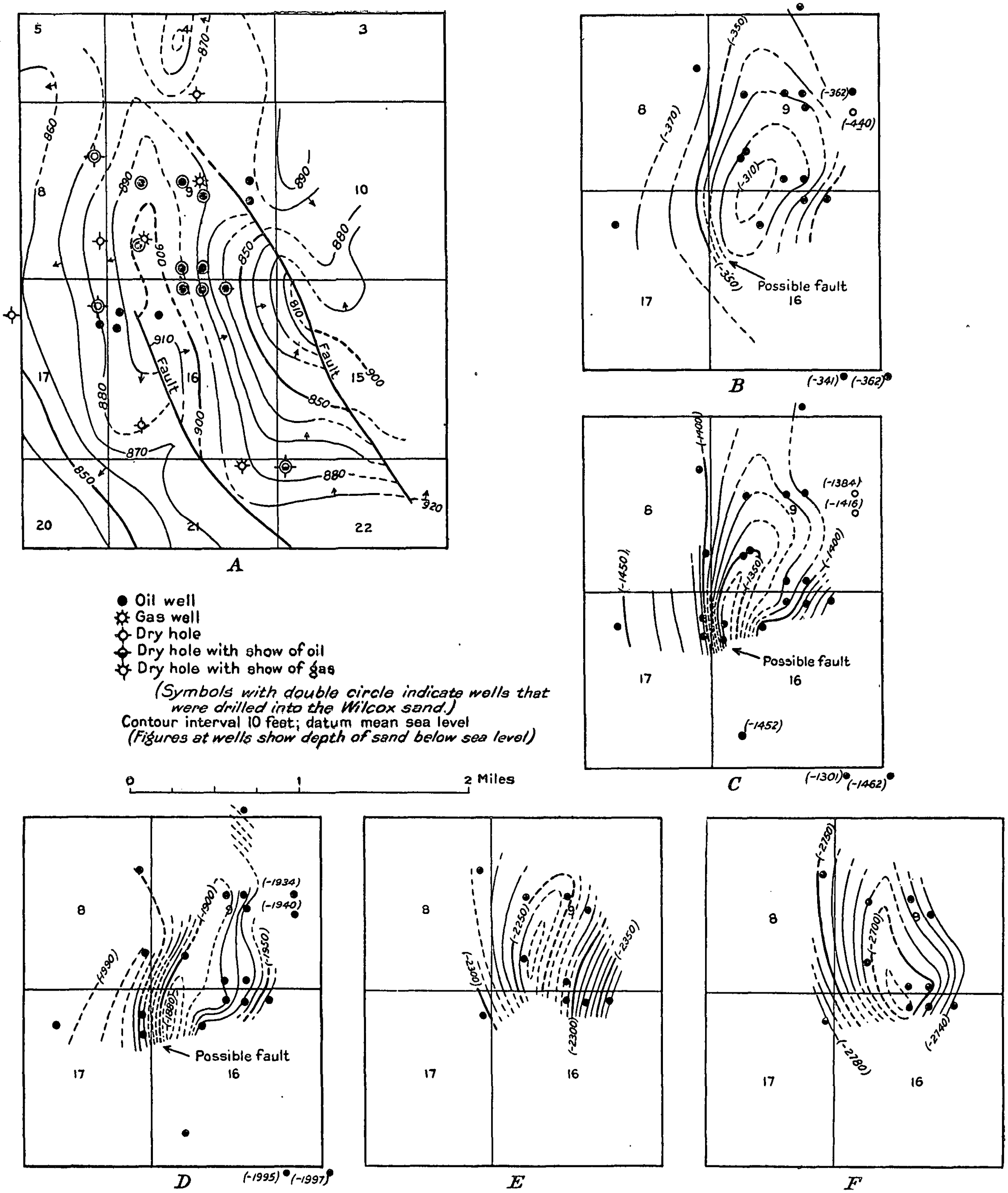
The more intensely folded attitude of the deeper rocks is still further emphasized in the Fort Scott limestone (Pl. XI, *C*). The crest is not as accurately located, but even so it is shown to lie almost directly beneath that of the "Layton lime." The "fault" along the west side of sec. 16 shows even greater displacement in this bed than in the "Layton lime." The displacement in this bed is also shown by dotted contours.

In the still deeper Tucker sand (Pl. XI, *D*) there is little if any greater folding, and the structure appears to differ somewhat from that in the higher beds. This difference, however, may be due partly to the inherent inaccuracies to be found in many drilling logs. Nevertheless, the resemblance of the structure to that in the higher beds is still noteworthy. The crest covers the same general area, and the "fault" is likewise presented along the west side of the NW. 1/4 sec. 16.

The wells that have gone below the Tucker sand to the Boone limestone (Pl. XI, *E*) and the "Wilcox" sand (Pl. XI, *F*) are much fewer, and the mapping of the structure in these formations, which lie at depths of more than 3,000 feet, is therefore based on relatively meager information. The structure as mapped, nevertheless, coincides rather closely with that of the higher beds. The most notable differences in the Boone are an apparent eastward shifting of the crest, the absence of the "fault" along the west side of the NW. 1/4 sec. 16, and a stronger development of the east flank. In the "Wilcox" sand the crest is shifted even farther eastward, but the east flank does not dip so steeply. The interpretation of the well logs, especially in regard to the "Wilcox" sand, is somewhat uncertain, and this may explain some of the differences.

The discovery well of this field found showings of gas and oil in several of the upper sands and an open-flow production of gas, estimated at 5,000,000 cubic feet daily, in a sand in the upper part of the Bartlesville (Glenn) sand zone, at a depth of 2,460 to 2,520 feet, locally called the Skinner sand. Drilling continued, and gas with an open-flow volume of 22,800,000 cubic feet daily and a closed rock pressure of 970 pounds to the square inch was found in a sand at a depth of 2,750 to 2,816 feet, in the lower part of the Bartlesville (Glenn) sand. This sand is locally known as the Tucker. Deeper drilling was not attempted, and the well was completed as a gas well. The location of this well is near the crest of the fold.

Later drilling lower on the flanks of the fold found the Tucker to carry oil. The yields obtained were not large, 20 to 150 barrels a day from the completed wells, and it was not long before salt water began to constitute a part of the fluid pumped.



STRUCTURE CONTOUR MAPS OF SEVERAL HORIZONS IN THE RED BANK FIELD

The oil from the Tucker sand has a specific gravity of 0.840 (36.7° Baumé). The detailed analysis is given on page 61.

Deeper drilling in the spring of 1920 resulted in the bringing in of a 300-barrel well (after being shot) in the northwest corner of the NE. ¼ sec. 16, T. 16 N., R. 8 E. The oil sand was found below the Boone formation or "Mississippi lime," at a depth of 3,531 feet. It is believed to be the "Wilcox" sand as known in the Beggs region of Okmulgee County. Later wells drilled to this sand obtained initial daily yields ranging from 30 to 1,350 barrels. The development of the "Wilcox" sand presents the greatest promise for future production.

The oil from the "Wilcox" sand is of higher rank than that from the Tucker sand, its specific gravity being 0.820 (40.7° Baumé). The detailed analysis is given on page 61.

NORTH CATFISH ANTICLINE

The North Catfish anticline extends southward from secs. 28 and 29, T. 17 N., R. 8 E., across secs. 32 and 33, and into sec. 5, T. 16 N., R. 8 E., where it terminates against a fault. The fold is not symmetrical, and its highest point lies against the fault, from which it pitches gradually northward. The eastward dip on this anticline is slight in sec. 28 and the northern part of secs. 32 and 33, but in the southern part of sec. 32 the upthrown side 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 (about 50 feet) 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.

In the discussion of this fold in the preliminary report already cited a location in the north-central part of sec. 5 was recommended. No test had been made of this fold prior to June, 1920, but since then several wells have been drilled in this vicinty, of which some were completed as gas wells and others as oil wells. The details of these wells were not available for inclusion in this report, and whether or not the attitude of the pay sands coincides with that of the surface structure has not been ascertained.

NORTH BRISTOW FIELD

The North Bristow field, about 3 miles north of Bristow, in and around sec. 8, T. 16 N., R. 9 E., lies in a region where the surface rocks have a fairly regular westerly dip with no indication of folding or faulting. It was discovered by chance drilling, and the oil sand is in the upper part of the Bartlesville (Glenn) sand zone of the Cherokee formation.

The data supplied by 17 wells indicate that the pay zone dips west in much the same way as that of the surface beds. (See fig. 2.) There is no definite indication of an anticline, although in the northwestern part of sec. 17 the altitudes of the pay sands as given on the map show a situation that is anomalous in connection with the above explanation. It is possible that the measurements were not accurately made, or that faults may be present. The wrinkle in the sand indicated by the contours around the dry hole in the southwest corner of the NE. ¼ NW. ¼ sec. 8 is due either to local thinning of the sand or to poor measurement.

Because no anticlinal or domal fold seems to be present in the pay sand of this field the accumulation of the oil here is probably due to some feature other than favorable geologic structure. The dry holes in the NW. ¼ sec. 8 do not show that the sand is absent, and it seems reasonable to suppose that the presence of oil is due to locally greater porosity of the sand. The presence of gas in the sand at a place where the altitude is higher than that of the adjacent oil-bearing part of the sand indicates that gravity is a probable cause of the segregation of the gas and oil.

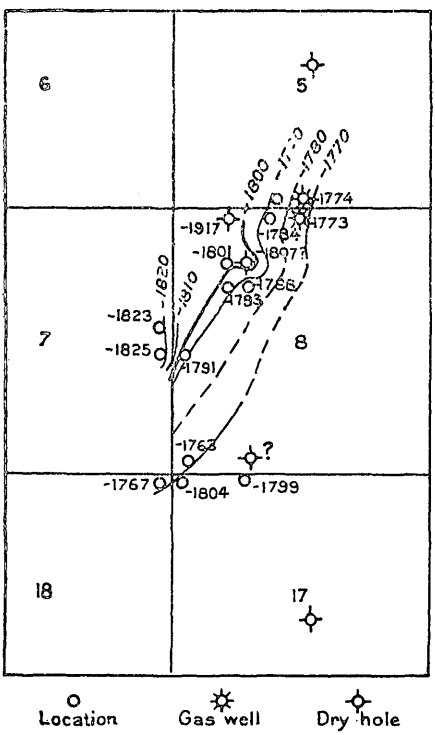


FIGURE 2.—Structure-contour map of the pay sand in the North Bristow field

The initial daily production of the discovery well was reported to have been 65 barrels, by pumping. Other wells ranged in yield from 20 to 135 barrels, and so far as the writer is aware only one well, that in the northwest corner of sec. 17, flowed after completion. Its initial flow amounted to 135 barrels daily, and after 2½ months its flow still amounted to 80 barrels.

The developments after June, 1920, extended the field about half a mile in a southwesterly direction, but no very encouraging results that would indicate a large and highly productive field were obtained.

The oil obtained in this field has a specific gravity of 0.835 (37.7° Baumé). The detailed analysis is given on page 61.

SOUTH BRISTOW FIELD

The South Bristow field lies south and southeast of the town of Bristow and includes several small and more or less isolated developments, of which the largest is the gas field in secs. 10, 15, 21, and 22, T. 15 N., R. 9 E.

The structure of the surface rocks in this general locality shows no features specially favorable to the accumulation of oil and gas. The normal westward-sloping monocline is modified by a few northwestward-trending faults with small displacements. These faults, however, show no close relation to the oil and gas accumulations, although it is possible that other faults that do not reach the surface may in part be the cause of the pools in the subsurface formations.

The sand supplying the gas in the gas field lies at a depth of about 1,200 feet, or about 75 feet below the Checkerboard (?). It is the shallowest and stratigraphically the highest producing bed in the quadrangle.

The development has shown the gas to be limited to a narrow northward-trending belt along the west line of sec. 22 and a small area around the northeast corner of the NW. ¼ NW. ¼ sec. 15. Deeper oil wells in the immediate vicinity encountered showings of gas but not gas in commercial quantity. Other wells a mile or more to the northwest, in secs. 8 and 9, also found showings of gas.

The gas sand shows no general anticlinal folding such as would be expected if the controlling feature of the accumulation were structure. (See fig. 3.) Minor folding is present, but the minor folds appear to bear no relation to the distribution of the gas.

When the well in the SE. ¼ SW. ¼ sec. 15 was drilled it was reported that the gas sand was found to be very hard, suggesting that the sand in this locality is more highly cemented. This probable variation in the cemented condition of the sand, together with the lack of pronounced structure and the irregular distribution of the wells, may indicate that the gas accumulation was due to the presence of local porous areas in the sand. If the sand were equally porous throughout its extent the other wells that penetrated it in the vicinity of the successful wells, especially those put down where the structure seems to be equally favorable, should have also encountered large quantities of gas. That they did not shows clearly that the porosity of the sand is the principal feature governing the accumulation of the gas.

That the sand between the different producing wells is rather open is attested by the close correspondence between the initial pressure of certain wells and the existing pressure of wells already producing—for example, wells 2, 6, and 7 (see Pl. XII) came in with initial pressure very similar to the pressure still existing in wells 1, 3, and 6. The apparent anomalous pressure of wells 4, 5, and 8 can be explained by the fact that they form a more or less isolated group around the northeast corner of the NW. ¼ NW. ¼ sec. 15, which does not seem to be connected with those along the west line of sec. 22.

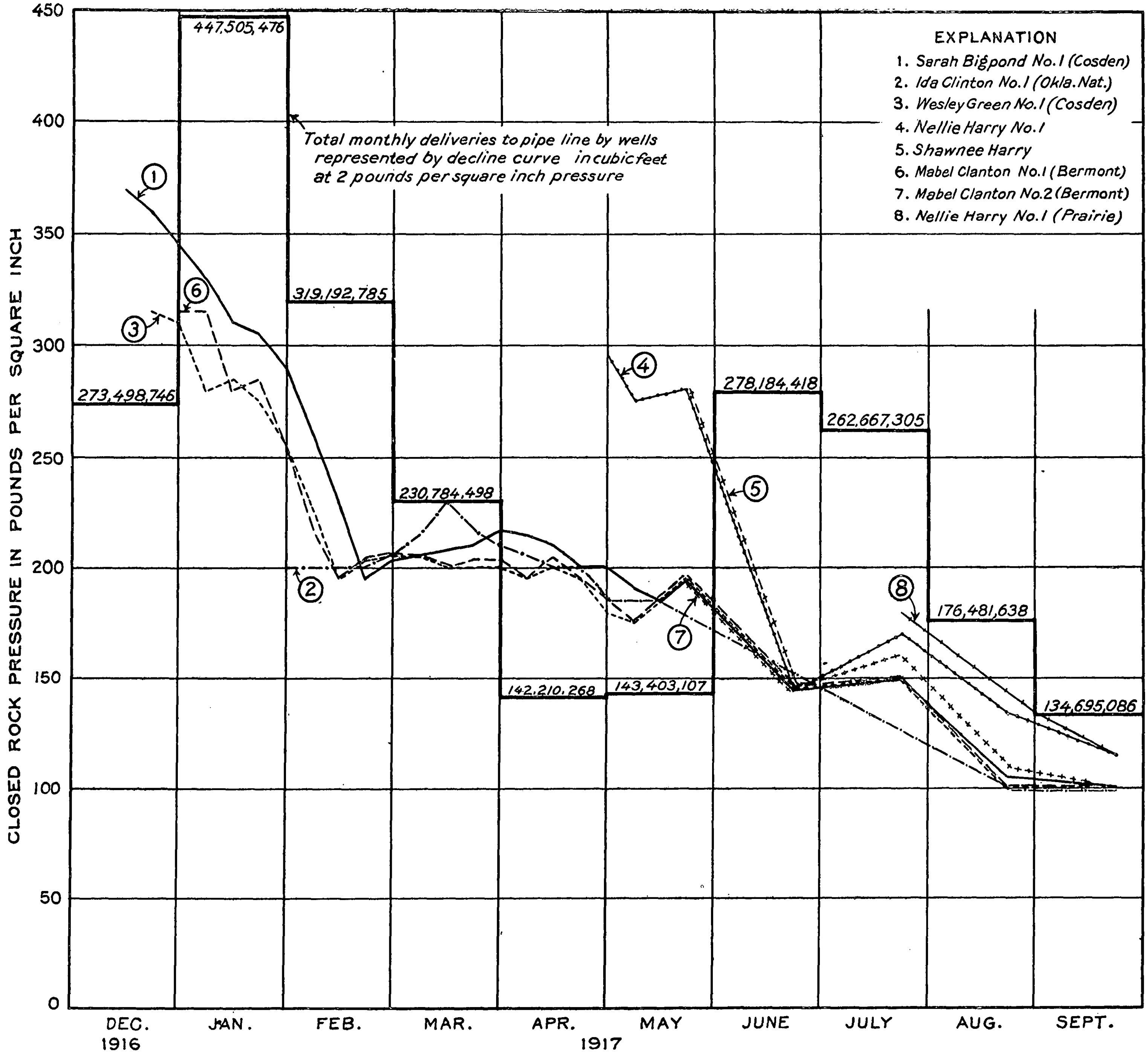
The original pressure of this gas reservoir, as indicated by the discovery well, was 420 pounds to the square inch (before connection with the pipe line as shown in Pl. XII). Its measured open-flow volume after 36 hours of continuous flow was 41,664,000 cubic feet daily and after 7 days of continuous open flow 39,600,000 cubic feet. The rock pressure declined rapidly as gas was withdrawn, indicating that the reservoir was of rather small extent. Early in the life of the field, when the production was small, however, the rock pressure corresponded by declining less rapidly. Although gas was discovered here on August 3, 1916, deliveries to the pipe line did not begin until the middle of December. By October of the following year the rock pressure of the gas had decreased to about 100 pounds, and at this pressure the wells could not deliver appreciable quantities of gas without assistance and hence were closed in. What developments have taken place since then are not known to the writer.

Almost directly between the two groups of gas wells are four oil wells producing from the upper part of the Bartlesville (Glenn) sand zone. The map showing the structure of the surface rocks (Pl. VII) suggests that a fault lies immediately to the west, and it may be that this fault has controlled the oil accumulation in this small area. The possible attitude of the pay sand in this vicinity is suggested in Figure 3, which shows gentle folding with a slight depression to the north. No special feature can be picked out to which can be certainly ascribed the cause for the oil accumulation in this vicinity.

The discovery well here, in the southeast corner of the NE. ¼ sec. 16, was completed in October, 1917, and had an initial daily production of 30 barrels. The yield of the other wells ranged from 10 to 40 barrels.

The few wells in sec. 8 and the western part of sec. 9 were some of the earliest successful wells in the quadrangle. The oil in these wells also comes from the upper part of the Bartlesville (Glenn) sand zone. No structural feature that may be credited with the formation of the pool can be determined in this locality from the information given in the well logs.

When the first of these wells, in the southeast corner of the NE. ¼ NW. ¼ sec. 8, was completed, in March, 1914, it was rated as a 20-barrel pumper. It was operated only intermittently, and in 1915 (?) an offset well to the south was drilled. In June, 1920, the combined daily production from these two wells amounted to but 2½ barrels. The oil from the first well has a specific gravity of 0.843 (36° Baumé). The detailed analysis is given on page 60.



GRAPHS SHOWING DECLINE IN CLOSED ROCK PRESSURE OF EIGHT GAS WELLS IN THE SOUTH BRISTOW FIELD

Near the east corner of sec. 10 are two wells producing from the Dutcher sand. The northern well came in with a daily production of 40 barrels, and the southern well with 30 barrels. An attempt to obtain oil in sec. 11 met with failure.

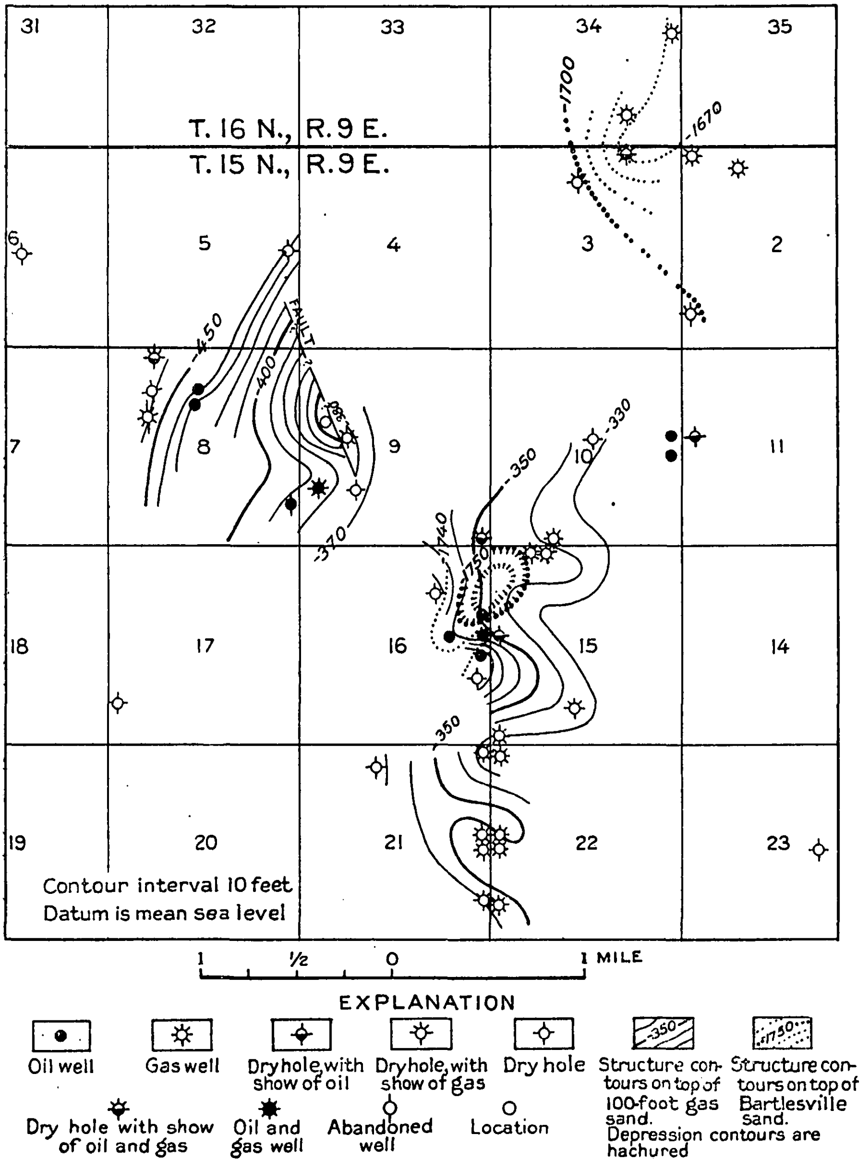


FIGURE 3.—Structure-contour map showing two horizons in the South Bristow field.

Around the northeast corner of sec. 3, T. 15 N., R. 9 E., are several gas wells producing from the upper part of the Bartlesville (Glenn) sand zone. The easternmost of these was the first commercial well in the quadrangle, having been completed in the winter of 1907–8. Its initial capacity was rated at 1,000,000 cubic feet daily, with a rock pressure of about 1,000 pounds to the square inch. Its output was used to supply the town of Bristow, and in 1917 it was reported to be as good a producer as when first completed. The other wells all have small open-flow capacities, none exceeding 5,000,000 cubic feet. The closed rock pressure, however, is high, as much as 1,200 pounds to the square inch. The well in the northwest corner of the NW. ¼ NE. ¼ sec. 10 was drilled to the Dutcher sand and obtained an oil flow that amounted to about 100 barrels daily. After a few weeks the flow changed to salt water, and then the well was plugged back to the gas sand.

The local structure of the gas sand as given in Figure 3 shows a minor southwestward-plunging fold similar to the one shown in the surface rocks (see Pl. VII) but more intense. Probably this feature was partly instrumental in causing the gas to accumulate in this locality.

SLICK FIELD

The completion during 1919 of wells having initial yields as high as 1,000 barrels daily stimulated intensive drilling in the Beggs district of Okmulgee County, east and southeast of the Bristow quadrangle. In the extension of this district the developments progressed principally westward and in 1920 reached the eastern part of the Bristow quadrangle. These developments led to the discovery of a highly productive Dutcher sand field extending as a broad belt in a general north-south direction across Tps. 15 and 16 N., R. 10 E. This field, known as the Slick field, after the new town of that name in sec. 17, T. 15 N., R. 10 E., reaches for a mile or so into the eastern part of the Bristow quadrangle and constitutes the quadrangle's most intensive and extensive oil-field development. The limits of this field had not been outlined by June, 1920, when the region was last visited by the writer, and the information obtained at first hand is therefore incomplete. This original information, however, has been greatly augmented by well logs obtained through the Oklahoma Geological Survey and by a development map with well elevations published by the Bartlesville Petroleum Experiment Station of the United States Bureau of Mines in the spring of 1922. (See Pl. XIII.) The information given below was compiled principally from these sources.

The structure of the surface rocks as given on Plate VII shows no features that would indicate the presence of an oil field along the eastern border of the quadrangle. Whether or not reverse dips are to be found along the east side of the Slick field is not known to the writer. It is his impression, however, that such reverse dips do not exist, and Clark and Bauer[31] confirm this impression. The minor faults of this region are inadequate to account for so extensive a field as the Slick field, and its explanation must be sought in features that are inherent in the Dutcher sand and not reflected in the surface rocks.

The Dutcher sand thins toward the north and northwest, but it has yielded showings of oil or gas in most wells reaching it over an area extending for several miles beyond the Slick pool, a result which precludes explaining the western limit of the Slick oil accumulation on the ground of lenticularity. The Dutcher sand is present east of the Slick pool, but whether or not it thins along the east margin of the field and whether or not this possible thinning controls the eastward limit of the oil is not clear from the available information. The information seems to indicate that the sand continues eastward, with little or no thinning, but a definite statement to this effect can not be made. Data pertaining to the porosity of the sand are not at hand, and whether or not the pool is limited to a more porous portion of the sand can not be demonstrated at present.

A preliminary contour map was made showing the attitude of the upper surface of the Dutcher sand as recorded in available well logs. This map (Pl. XIII) is based on incomplete information and therefore can not be considered final in its interpretation. Three features shown by this map are to be discussed—the general structure, the minor folding, and a disturbed belt crossing secs. 4 and 5, T. 15 N., R. 10 E., and sec. 33, T. 16 N., R. 10 E.

The available information indicates that the Dutcher sand as a whole dips westward, its altitude being in general 50 to 175 feet lower at the west side of the field than at the east side. High areas, which may be designated "domes" or "ridges," are found within the field and not on its east margin. A "dome" is present in the NW. 1/4 sec. 15, and a broad "ridge" covers parts of secs. 9, 10, 4, and 3, T. 15 N., R. 10 E., and sec. 34, T. 16 N., R. 10 E. Reverse or east dips occur east of the high areas, and it is probable that they had considerable influence in localizing the oil. It is to be noted, however, that these high areas apparently run into unproductive territory, and further that their trends, especially those of the one running from the center of sec. 9 into the NE. 1/4 sec. 3, T. 15 N., R. 10 E., and the one in sec. 34, T. 16 N., R. 10 E., and the northern part of sec. 3, T. 15 N., R. 10 E., lie diagonally to the elongated direction of the field. Another "ridge" crossing sec. 5, T. 15 N., R. 10 E., and secs. 32, 33, and 28, T. 16 N., R. 10 E., also trends northeast.

[31] Clark, R. W., and Bauer, C. M., Notes on geology of the Okmulgee district: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 2, p. 289, 1921.

The second feature to be noted is the great number of minor folds or wrinkles without any well-defined system or regular distribution. This irregularity does not seem to be of the type that is due wholly to deformation, and it may even suggest the possibility of an erosional surface—that is, an unconformity. The thinning of the sand in a northwesterly direction (see pp. 9–10) is additional evidence for such a possibility. As the contour map of this field is not based on complete nor intensively studied information no definite conclusion as to the cause of the minor irregular features of the sand surface will be offered.

The third feature to be noted is a belt several hundred yards wide extending in a diagonal direction across sec. 33, T. 16 N., R. 10 E., and secs. 4 and 5, T. 15 N., R. 10 E., which is shown without contours on the map. The contours for the area to the east show that the sand there stands more than 125 feet higher than on the west side of the blank belt. Within this belt are several dry holes, which are indicative of some unusual condition in the sand. These facts point toward the probability that the Dutcher sand along this belt is structurally disturbed, and it is so labeled on the map.

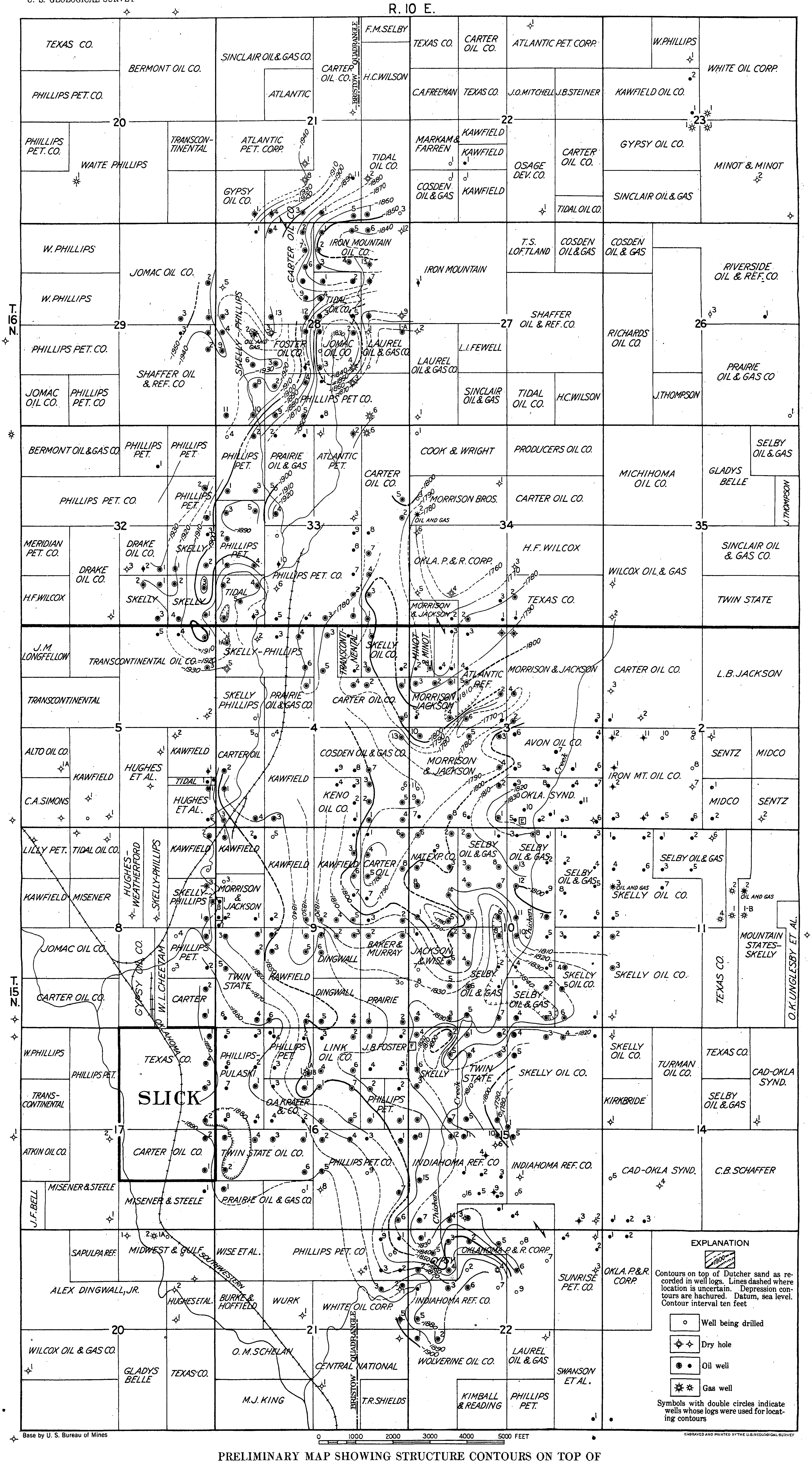
The structure map of the surface rocks of this neighborhood (Pl. XIII) shows that one of the series of fault belts nearly coincides with this disturbed belt in the Dutcher sand, and it therefore seems possible that the underground conditions in this belt may be the result of the more intense faulting and possibly even of a northeastward-trending master fault. Additional evidence in support of this possibility is to be found in the general northeasterly trend of the larger folds that cross secs. 9 and 3 and secs. 3 and 34 and of the "ridge" lying west of and parallel to the disturbed belt. Except for the line of en échelon surface faults overlying the disturbed belt, all these features are apparently confined to the subsurface rocks lying at or near the depth of the Dutcher sand.

Anticlinal folding in the Dutcher sand, which is not reflected in the surface rocks, probably had considerable influence in localizing the oil of the Slick field, but folding was not the only factor involved. How much influence should be ascribed to other factors, such as source of supply, variation in porosity, or lenticularity, has not been determined from the information available.

MISCELLANEOUS WELLS

In secs. 4, 5, and 6, T. 16 N., R. 10 E., are five gas wells and one oil well about which the writer has no information.

An oil well in the northeast corner of sec. 20, T. 17 N., R. 10 E., was reported to be a 50-barrel producer from the Red Fork sand,



PRELIMINARY MAP SHOWING STRUCTURE CONTOURS ON TOP OF DUTCHER SAND IN THE SLICK FIELD, CREEK COUNTY, OKLA.

Based on incomplete information

which lies above the Bartlesville (Glenn) sand. Additional wells, about which the writer has no information, have been reported in the immediately adjacent neighborhood.

A flowing well from the Dutcher sand in sec. 13, T. 17 N., R. 9 E., was completed in 1921.

In sec. 7, T. 17 N., R. 8 E., are an oil well and a gas well, both producing from the Tucker sand. A few other wells producing from the same sand are situated around the south quarter corner of sec. 7, just beyond the quadrangle boundary.

Just beyond the south line of the quadrangle, in secs. 25 and 36, T. 15 N., R. 8 E., and secs. 30 and 31, T. 15 N., R. 9 E., are several gas wells and one oil well, all of which produce from a sand that is probably the equivalent of the Layton sand in the Cushing field. It lies at a depth of about 1,000 feet, and the gas production amounts to about 5,000,000 cubic feet daily for each well. The one oil well gets its oil in the lower part of the same sand and came in with a production rated at 50 barrels. Several wells were drilled here, and it is probable that since the field was visited in 1920 other producers have been obtained.

UNTESTED AREAS WHOSE STRUCTURE MAY POSSIBLY BE FAVORABLE TO OIL AND GAS ACCUMULATION

MAJOR ANTICLINAL FOLDS

In the preliminary report[32] on the northern part of the quadrangle the two Catfish anticlines were recommended as possessing considerable promise for developing oil and gas fields. This recommendation was based entirely on the structural features, and in the subsequent development of the Red Bank field on these anticlines the validity of the recommendation has been demonstrated. No other anticlines of similar size are present in the quadrangle, and consequently no areas where similar fields may be expected can be pointed out.

Rich pools, such as the Slick, Continental, and Poor Farm, have been developed in localities where the surface rocks do not reflect the factors controlling the oil in the deep sands, and of course the surface geology gives no definite indication as to where other such pools will be found. The features that control these oil accumulations are apparently limited to the sand itself, and as the productive Dutcher sand of these fields may be separated from the overlying rocks by an unconformity, such accumulations may be present elsewhere, in localities where no favorable structure shows at the surface. The same holds true to an even greater degree for the "Wilcox" sand,

[32] U. S. Geol. Survey Bull. 661, pp. 89–90, 1917.

which is separated from the surface rocks by two or more unconformities. The apparent thinning out of the Dutcher sand in the northeastern part of the quadrangle does not preclude, especially if its upper surface is erosional, the presence of remnants of it in almost any locality.

The application of geology to the discovery of such fields as the Slick, Continental, and Poor Farm is rather uncertain. Once such a field is discovered, however, geology intelligently applied, especially in subsurface study to ascertain the trend of the hidden folds in the sand and its thickening, thinning, and changing porosity, should assist greatly in economically extending the field.

MINOR ANTICLINAL FOLDS

Scattered throughout the quadrangle and associated with the belts of faults are numerous minor anticlinal folds, most of which pitch northwestward. (See Pl. VII.) The possible importance of these folds in relation to oil and gas has not been adequately demonstrated. The one in secs. 1 and 12, T. 17 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 as No. 27 on Plate V, 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 to 1,083 feet, 1,000,000 cubic feet of gas at 1,145 feet, a showing of oil and gas at 2,040 to 2,074 feet, and a light showing of oil at 2,344 to 2,369 feet. The quantity of gas discovered was not considered sufficient to make it a paying gas well, and the hole was abandoned. This well penetrated the Boone formation about 250 feet but did not reach the "Wilcox" sand. It therefore can not be considered an adequate test, for if the "Wilcox" sand is folded in this area, as it is in the Red Bank field, it may be oil-bearing here. The attitude of the "Wilcox" sand on this minor fold, which is probably due entirely to the faulting in this vicinity, is still wholly problematic. How this fold changes in depth is unknown, but the writer hazards the guess that a test near the middle of the SW. ¼ sec. 1 would possibly find the "Wilcox" at a sufficient distance from the downward extension of the faults to the east to be beyond their immediate influence and still be on the fold—that is, the fold reaches to this depth. The top of the "Wilcox" should be found at a depth approximating 3,275 to 3,350 feet.

None of the other minor folds in the northern part of the quadrangle for which test locations were suggested in the preliminary report on this area[33] had been tested prior to June, 1920, and

[33] Op. cit., pp. 90–92.

whether or not they have been tested since then is not known to the writer. The suggestions given in that report will therefore be repeated here with but little modification, for the recent developments, as late as the spring of 1922, have shown no reason for suggesting locations radically different. The slight changes that will be made are due principally to the greater depths at which productive sands are now found.

A sharply flexed anticline occurs 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 in this vicinity. 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 Plates VII and VIII may be questioned. The structure in this northwest quarter 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 corner must be abruptly terminated. Because of these unknown factors, 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 southwest, a test well to avoid passing through the fault should be as distant from it as possible and still be near the crest of the anticline. Such a well would probably reach the Fort Scott limestone at about 1,000 feet below sea level, the Glenn sand at 1,640 feet, and the "Wilcox" sand between 3,150 and 3,250 feet.

A small northwestward-pitching anticline, which was probably caused by the fault to the east, occurs in sec. 30, T. 17 N., R. 9 E. The best locality for a test of this anticline is probably near the center of the section. In drilling at this locality the strata that were found in the well in sec. 17, T. 17 N., R. 9 E. (see log 8, Pl. IV), would probably be found at nearly the same depths. The Boone formation ("Mississippi lime") will be found at about 2,950 feet below the surface and the "Wilcox" sand at about 3,400 feet.

Sec. 14, T. 17 N., R. 8 E., is crossed by another small northwestward-pitching anticline which was almost certainly formed by the same movements that caused the fault to the east. The best locality for a test of this anticline is probably in the center of the southwest quarter of this section. The fault to the east of this locality also may have some influence in causing oil and gas to accumulate. A guide as to the strata to be encountered here is afforded by the log of the well in sec. 11, T. 17 N., R. 8 E. (log 7, Pl. IV). The "Wilcox" sand should be reached at a depth of about 3,600 feet.

The fold in sec. 21, T. 17 N., R. 8. E., would probably be best tested by a well in the center of the northwest quarter, and as the fault to the east is small its influence in causing oil and gas to accumulate is probably small also. The strata to be found here will be about the same as those encountered in the well in the southwest corner of sec. 20, T. 17 N., R. 8 E. (log 5, Pl. IV), but at this locality they will probably be about 50 feet higher with respect to sea level.

For testing the anticline in sec. 22, T. 16 N., R. 8 E., the NE. ¼ SW. ¼ appears to be the most favorable locality. The fault to the east is of small displacement, 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 in drilling is indicated in the logs of the wells of the Red Bank field (logs 17 to 21, Pl. V). The strata recorded in these logs should be found in this locality at approximately the same position with respect to sea level.

In the southern part of the quadrangle only a few minor folds were found of sufficient magnitude to warrant suggesting test locations. Like those described above, they are intimately related to faults, but they differ in that they occur only in the western part of the quadrangle.

In secs. 28 and 33, T. 16 N., R. 8 E., there is a northwestward-pitching fold, on which the most favorable location for a test seems to be near the north quarter corner of sec. 28. If the Dutcher sand is present here it probably lies at a depth of about 3,100 to 3,200 feet, and the "Wilcox" at about 3,650 to 3,750 feet.

A similar fold is present in secs. 8 and 9, T. 15 N., R. 8 E., and the most favorable point for testing it is in the northwest corner of the SW. ¼ sec. 9. The Dutcher sand should be present here and will probably be found at about 3,250 feet, and the "Wilcox" sand at about 3,800 feet.

Along the west line of sec. 16, T. 15 N., R. 8 E., is a small sharp closed fold with about 50 feet of easterly dip before it reaches the fault on that side, within a distance of about half a mile. The inclination of this fault plane is southwestward, and the nearness of the crest of the fold to the fault makes it seem that a test should preferably be made on the west flank. The northeast corner of the NE. ¼ SE. ¼ sec. 17 is suggested.

FAULTED AREAS

The territory southwest of some of the faults that have comparatively large displacements should be considered structurally favorable for oil and gas, especially if the formations on the southwest sides form the upthrown blocks, so that the fault planes dip toward the northeast. The best example of this type in the quadrangle is the area southwest of the fault that crosses sec. 34, T. 17 N., R. 8 E., where the beds dip to the north, west, and south. If an oil-bearing stratum in this block is sealed by the fault to the northeast the conditions would be excellent for the accumulation of oil or gas. A test of such an area should be made at the highest structural point or possibly a short distance across the fault, in the expectation that the fault plane would be penetrated and the upthrown block reached before the pay sand was struck. Drilling in features of this type is uncertain, for there always is the possibility that the sands will not be sealed and the further possibility that the beds at depth are highly disturbed, as has been brought out in discussing the origin of the faults. (See pp. 37–38.)

Similar conditions, which may demonstrate the ability of such features to control oil and gas accumulations, are found in the northwest corner of sec. 10, T. 16 N., R. 8 E. The easternmost wells of the Red Bank field in this vicinity certainly lie east of the large fault that crosses sec. 9, and it does not seem that the oil produced by these wells comes from the main South Catfish fold. This oil may perhaps be controlled by the upthrown block on the southwest of the fault to the east; if it is, these wells are not in the best locations, and better results would be obtained farther northeast. It may be that the oil in this locality is continuous from the anticline on the west to and into the upthrown block in the NW. 1/4 sec. 10 and the northeastern part of sec. 9.

Other structural features of this upthrown-block type are to be found adjacent to several of the faults in the quadrangle, the more important of which occur across the fault terminating the south end of the North Catfish anticline, near the center of sec. 5, T. 16 N., R. 8 E.; on the southwest sides of both faults that cross sec. 20, T. 15 N., R. 8 E.; in the northwestern part of sec. 3, T. 15 N., R. 9 E.; and in the area immediately east of the north quarter corner of sec. 24, T. 17 N., R. 9 E. Still another lies in and adjacent to the northwest corner of sec. 4, T. 15 N., R. 10 E., in the Slick field. The effect of this fault by itself is not apparent, as the oil is found on all sides, but there is a disturbed belt in this vicinity, which is described in the discussion of this field (pp. 52–54).

In the drilling of any test wells in the Bristow quadrangle an operator unfamiliar with the region will find the logs shown in Plates IV, V, and VI of assistance in indicating the rocks to be encountered. The detailed log of the well nearest to any point where a hole is to be drilled should in general be the best key for this purpose.

ANALYSES

The following analyses of oil and gas from the Bristow quadrangle were made by the Bureau of Mines:

Analyses of oil and gas from Bristow quadrangle

Prairie Oil & Gas Co.'s Carmen well No. 3, SE. ¼ NE. ¼ NW. ¼ sec. 8, T. 15 N., R. 9 E,

[Initial production, 20 barrels by pumping. Specific gravity, 0.8430 (36° Baumé). First drop 32° C.]

Temperature (° C.)	Fraction (per cent)	Specific gravity
Up to 50	1.5	
50 to 75	2.0	
75 to 100	5.0	0.7230
100 to 125	7.0	
125 to 150	5.0	
150 to 175	6.0	
175 to 200	5.0	
200 to 225	5.0	.8130
225 to 250	6.0	
250 to 275	5.5	
275 to 300	8.0	
Residuum	44.0	.9215
Asphalt	1.9	
Paraffin	2.25	

Atlantic Petroleum Co.'s Bloesch well No. 1, NW. ¼ NW. ¼ sec. 15, T. 15 N., R. 9 E.

[Gas taken from so-called Layton sand at a depth of 1,098 to 1,122 feet. Collected May 17, 1917, by A. E. Fath. Laboratory No. 9181]

	As received	Air free
CO_2	0.1	0.1
O_2	6.6	.0
CH_4	60.4	88.2
C_2H_6	3.2	5.1
N	29.4	6.6
Specific gravity (air=1)	0.73	0.61
British thermal units at 0° C. and 760 millimeters	707	1,034

Wallace Jack well No. 1, NE. ¼ sec. 5, T. 15 N., R. 10 E.

[Sample from flow line by A. E. Fath. Laboratory No. 00537. Specific gravity at 15° C., 0.880 (29.1° Baumé, modulus 140). Amount distilled, 300 cubic centimeters. First drop, 26°. Sulphur, 0.38 per cent. Water, none]

Temperature (° C.)	Air distillation, with fractionating column (barometer, 743 millimeters)			Vacuum distillation, without column (pressure, 40 millimeters)		
	Fraction (per cent by volume)	Total per cent (by volume)	Specific gravity	Fraction (per cent by volume)	Total per cent (by volume)	Specific gravity
Up to 50	1.4	1.4				
50 to 75	1.5	2.9	0.708	----------	----------	----------
75 to 100	3.8	6.7				
100 to 125	4.7	11.4	.752	----------	----------	----------
125 to 150	2.9	14.3	.777	----------	----------	----------
150 to 175	3.9	18.2		0.6	36.6	0.866
175 to 200	3.3	21.5	.805	3.3	39.9	
200 to 225	3.7	25.2	.823	5.6	45.5	.874
225 to 250	5.4	30.6	.836	5.3	50.8	.888
250 to 275	5.4	36.0	.849	5.9	56.7	.898
275 to 300	----------	----------	----------	5.9	62.6	.912

Analyses of oil and gas from Bristow quadrangle—Continued

Irene Roberts well No. 2, NW. ¼ sec. 8, T. 16 N., R. 9 E.

[Sampled from flow line by A. E. Fath. Laboratory No. 00538. Specific gravity at 15° C., 0.835 (37.7° Baumé). Amount distilled, 300 cubic centimeters. First drop, 25° C. Sulphur, 0.36 per cent. Water, none]

Temperature (° C.)	Air distillation, with fractionating column (barometer, 735 millimeters)			Vacuum distillation, without column (pressure, 40 millimeters)		
	Fraction (per cent by volume)	Total per cent (by volume)	Specific gravity	Fraction (per cent by volume)	Total per cent (by volume)	Specific gravity
Up to 50	3.2	3.2	} 0.667			
50 to 75	3.3	6.5				
75 to 100	6.7	13.2	.727			
100 to 125	6.4	19.6	.747			
125 to 150	6.7	26.3	.761			
150 to 175	6.7	33.0	.782	0.7	55.6	} 0.858
175 to 200	5.2	38.2	.800	4.7	60.3	
200 to 225	5.1	43.3	.815	5.0	65.3	.872
225 to 250	5.6	48.9	.828	5.8	71.1	.880
250 to 275	6.0	54.9	.840	3.4	74.5	.898
275 to 300				3.7	78.2	.907

Mayes well No. 2, in the northwest corner of the NE. ¼ sec. 16, T. 16 N., R. 8 E.

[Sampled from flow line by A. E. Fath. Laboratory No. 00539. Specific gravity at 15° C., 0.820 (40.7° Baumé). Amount distilled, 300 cubic centimeters. First drop, 24° C. Sulphur, 0.22 per cent. Water, none]

Temperature (° C.)	Air distillation, with fractionating column (barometer, 747 millimeters)			Vacuum distillation, without column (pressure, 40 millimeters)		
	Fraction (per cent by volume)	Total per cent (by volume)	Specific gravity	Fraction (per cent by volume)	Total per cent (by volume)	Specific gravity
Up to 50	3.1	3.1	} 0.670			
50 to 75	3.3	6.4				
75 to 100	6.9	13.3	.714			
100 to 125	6.8	20.1	.740			
125 to 150	7.0	27.1	.758			
150 to 175	7.8	34.9	.777	0.7	61.3	} 0.854
175 to 200	5.4	40.3	.797	4.5	65.8	
200 to 225	7.1	47.4	.810	5.0	70.8	.861
225 to 250	5.4	52.8	.825	4.7	75.5	.875
250 to 275	7.8	60.6	.837	4.5	80.0	.891
275 to 300				4.5	84.5	.901

Hettie Yardy well No. 1, SE. ¼ sec. 9, T. 16 N., R. 8 E.

[Sampled from flow line by A. E. Fath. Laboratory No. 00536. Specific gravity at 15° C., 0.840 (36.7° Baumé). Amount distilled, 200 cubic centimeters. First drop, 68° C. Sulphur, 0.43 per cent. Sample can one-third full of water]

Temperature (° C.)	Air distillation, with fractionating column (barometer, 737 millimeters)			Vacuum distillation, without column (pressure, 40 millimeters)		
	Fraction (per cent by volume)	Total per cent (by volume)	Specific gravity	Fraction (per cent by volume)	Total per cent (by volume)	Specific gravity
100 to 125	2.5	2.5	} 0.770			
125 to 150	4.0	6.5				
150 to 175	2.8	9.3	} .790	0.3	38.8	} 0.883
175 to 200	4.3	13.6		.6	39.4	
200 to 225	3.1	16.7	} .820	4.0	43.4	
225 to 250	4.7	21.4		3.2	46.6	.893
250 to 275	17.1	38.5	.846	4.9	51.5	.907

INDEX