STRUCTURE OF THE FORT SMITH-POTEAU GAS FIELD, ARKANSAS AND OKLAHOMA.

By Carl D. Smith.

INTRODUCTION.

The region described herein lies south of Arkansas River in Arkansas and Oklahoma and embraces an area about 40 miles square extending across the outcrops of the main coal-bearing formations of Oklahoma and Arkansas. As shown on the map, the area is traversed by several railway systems, all of which pass through or have connections with Fort Smith.

Natural gas was discovered in Massard Prairie 5 miles southeast of Fort Smith and also about 2 miles southeast of Mansfield, Ark., a number of years ago, and more recently it has been found 4 miles east of Poteau, Okla. This particular area has been selected because it has been more extensively prospected for gas than any other part of the Arkansas Valley trough, and because geologic structures here are typical of a great deal of untested territory in Arkansas and Oklahoma. Further details of structure in a part of this general region are given in other publications.[1]

In the construction of the map accompanying this report free use has been made of reports on the coal fields of Oklahoma and Arkansas by J. A. Taff and A. J. Collier, whose formational boundaries and descriptions of strata have been copied with but little change.

As the purpose of this report is to outline in a general way the region in which geologic structures and formations are similar to those in the smaller area shown on the map, little attention has been given to the depth and thickness of possibly productive sands, well logs, and other detailed information usually contained in such a report.

TOPOGRAPHY.

The character of the topography in the field is determined largely by the attitude and varying degrees of hardness of the strata which make up the geologic section. The geology and topography are so

[1] Collier, A. J., The Arkansas coal field: U. S. Geol. Survey Bull. 326, 1907. Taff, J. A., and Adams, G. I., Geology of the eastern Choctaw coal field, Indian Territory: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, 1900.

closely related that reference from one to the other is necessary to an understanding of either.

The most conspicuous topographic features in the area are Cavanal, Sugarloaf, and Poteau mountains, which reach altitudes ranging between 2,000 and 2,300 feet and are separated by broad valleys, where the general level of the country ranges between 450 and 750 feet. Cavanal, the highest of the three mountains, lies wholly in Oklahoma, 3 to 4 miles west of the town of Poteau. Sugarloaf is crossed by the Arkansas-Oklahoma State line and has its greatest length in a northeast-southwest direction. Poteau Mountain lies near the southern border of the area shown and extends from the vicinity of Heavener, Okla., eastward for a distance of 25 miles, into Arkansas.

The mountains occupy structural basins in which the alternating layers of hard and soft strata lie much like a stack of dishes, gradually diminishing in circumference upward.

GEOLOGY.

STRATIGRAPHY.

The formations which make up the geologic section discussed in this report belong to the Pennsylvanian series of the Carboniferous system, as proved by both fossil shells and plants. That part of the section lying above the top of the Hartshorne sandstone contains a number of coal beds 1 to 7 feet thick; below the Hartshorne no coal of economic importance has yet been found.

The section of rocks exposed in the area shown on the map (Pl. II) is about 12,700 feet in thickness and is made up of shale, sandstone, and beds of coal. This mass of sedimentary rocks has been subdivided and each formation given a name. The composition and character of the formations, named in order from lowest to highest, are described below, and the areal distribution of each is shown by appropriate symbols on the map.

Atoka formation.—The thickness of the Atoka formation, measured across the upturned edges of the formation in an anticline a few miles northwest of Heavener, ranges between 6,000 and 7,000 feet, and its base is not exposed. So far as shown, the whole thickness is made up of shale and sandstone, the sandstone constituting but a small part of the formation and lying in zones about 100 feet thick separated by beds of shale 1,000 to 1,200 feet thick. However, sandstone in more or less abundance is interbedded with the shale; likewise beds of shale occur in the zones prevailingly sandy.

The sandstone beds are medium to fine grained in texture and brown to light gray in color. The shale beds are rarely exposed naturally, but wherever seen they are bluish in color and contain a few ironstone concretions.

Study of the Atoka formation for many miles along its outcrop indicates that the inclosed sandstone beds are somewhat variable in thickness and lateral extent. There are areas in which the formation consists almost entirely of shale, whereas in other areas the beds of sandstone are abnormally thick and massive. The irregularity of the sandstones has an important economic bearing because they form the reservoirs in which gas is found in Massard Prairie near Fort Smith and in the area southeast of Mansfield. The gas obtained east of Poteau seems to come from the Hartshorne sandstone, described below.

Hartshorne sandstone.—The Hartshorne sandstone varies in thickness from 100 to 200 feet and is made up generally of massive beds at the top and thinner beds below, with layers of shale between, gradually giving place to shale of the Atoka formation at the base. The Hartshorne as a rule makes a low ridge and is one of the most easily recognizable and economically important formations in the field, important because of its value as an index to the position of two extensive coal beds, one of which lies just above the sandstone and the other from 50 to 100 feet higher.

McAlester shale.—In areal extent the McAlester shale far surpasses any of the other formations. On account of the relative softness of its constituent materials the McAlester forms the surface rock of most of the lowlands and prairies, which are interrupted here and there by local developments of ridge-making sandstone beds occurring in the shale. The thickness of the McAlester has been estimated at 2,000 to 2,500 feet.

In Arkansas the McAlester shale has been subdivided into several formations, but in order not to complicate the map these subdivisions have been omitted.

Savanna formation.—Three prominent zones of sandstone, each ranging in thickness between 100 and 200 feet, separated by masses of shale, constitute the Savanna formation. Its total thickness is estimated at 1,200 to 1,500 feet.

Boggy shale.—To the casual observer the term " shale " as applied to the Boggy would seem inappropriate, but close investigation reveals the fact that out of a total of about 2,300 feet of the formation exposed in Cavanal Mountain not more than 400 feet is made up of sandstone. The sandstone in relatively thin beds is so interspersed throughout the shale that, on weathering, the superior hardness of the sandstone leaves it in the form of talus, covering the slopes and concealing the shale. In areal distribution the Boggy is confined to the crests of Cavanal, Sugarloaf, and Poteau mountains.

Lack of definite information as to the position of the contact of the Savanna formation and the Boggy shale in Sugarloaf and Poteau mountains has made it undesirable to attempt to represent the Boggy on the map, all strata above the McAlester being shown as Savanna, though remnants of the Boggy 500 to 600 feet thick outcrop in narrow bands along the crests of these mountains.

STRUCTURE.

GENERAL CHARACTER.

The area herein described is a part of a large region occupied by the same or similar formations lying between the intensely folded and faulted rocks of the Ouachita Mountains to the south and the slightly disturbed rocks of the Ozark uplift to the north, and extending from the latitude of Atoka in southern Oklahoma, northeastward and eastward to the vicinity of Little Rock, Ark.

The structure of the region, broadly speaking, is unsymmetrical, in that the folding south of the central part of the trough or basin has been more intense than to the north. Between the latitudes of Atoka and McAlester in Oklahoma the trend of the folds is northeast-southwest; from the vicinity of McAlester eastward the folds trend generally east-west. Some of the anticlinal folds, especially near the south side of the area, have comparatively steep dips on their north sides, and are in places overturned in that direction.

In Oklahoma the area is bounded sharply on the south by the great Choctaw fault, which extends from the vicinity of Atoka northeastward and eastward into Arkansas. Toward the northwest, in Oklahoma, Canadian and Arkansas rivers may be taken as marking approximately the northern limit of the Arkansas Valley type of structure. Northward the folds die out into a monocline with a gentle westward dip.

In Arkansas the belt of folded rock extends approximately 50 miles in width to the vicinity of Little Rock, across which Arkansas River flows diagonally southeast.

At places the compressive force or forces which caused the rumpling of the strata has been more than the strength of the rocks could withstand, and as a result they have been broken, especially along or near the axes of upward folds, thus allowing one limb to override the other, producing what is known as a thrust fault. The axes of anticlines and synclines and the positions of faults are shown by appropriate symbols on the map.

FOLDS.

Backbone anticline.—One of the best-known structural features in the field is Backbone anticline, so named because of its association with a prominent ridge formed by the outcropping edge of an upturned stratum of sandstone, known as Backbone Ridge. This upward fold of the strata extends from the vicinity of Greenwood, Ark., to a point about 1½ miles southeast of Bokoshe, Okla., a distance of about 30 miles. Along the greater part of this fold is a fault, south of which the southward-dipping beds have been thrust to the north, overriding and concealing corresponding beds north of the fault. The outcrop of the Hartshorne coal bed surrounds the anticline.

Biswell Hill anticline.—Biswell Hill, an elliptical domelike eminence northeast of Greenwood, which is mantled over by the Hartshorne sandstone, is the topographic expression of a broad anticline whose axis lies parallel to and a short distance northeast of the east end of the faulted Backbone anticline. The fold is slightly unsymmetrical, the dips to the north being steeper than those to the south. Like the Backbone anticline, of which it is an irregular continuation, the Biswell Hill anticline marks an area without coal surrounded by the outcrop of the Hartshorne coal bed, which dips away from it to the north and to the south. The structure of Biswell Hill, though not so pronounced as that from which gas is obtained southeast of Mansfield, seems to be as good as if not better than that southeast of Fort Smith for the accumulation of gas. What effect the Backbone fault, which ends against the west side of the anticline, may have had on the reservoir-forming, deeply buried strata is problematic; it is possible that this break may have disturbed the rocks in such a way as to form an outlet to the surface, thus allowing any gas that may have collected to escape.

Massard Prairie anticline.—The axis of the Massard Prairie anticline trends northeast-southwest through Massard Prairie about 5 miles southeast of Fort Smith. The surface indications here suggest a broad elliptical uplift with low dips both to the north and to the south. Many wells that have been sunk in and near the summit of the dome furnish the natural gas used in Fort Smith.

Poteau anticline.—The axis of the Poteau anticline trends northeast between Cavanal and Sugarloaf mountains from the vicinity of Howe to the Arkansas-Oklahoma line, thence east for a distance of 6 or 8 miles, where its identity is lost in a broad upward fold lying between Greenwood and Huntington. The productive gas wells east of the town of Poteau are located near the axis of this fold. The part of the anticline which lies in Arkansas has been described by Collier in United States Geological Survey Bulletin 326 as the Montreal anticline. It has been considered advisable to change the name of the anticline, however, because it is more pronounced near the town of Poteau, Okla., than at Montreal, a small town in Arkansas near the east end of the fold.

Hartford anticline.—The axis of the Hartford anticline trends east-northeast and west-southwest through the town of Hartford, Ark. The lowest rocks brought to the surface by the upward fold are exposed in Coops Prairie, a flat area almost completely surrounded by elongated or elliptical encircling ridges made by sandstones of the Atoka formation. In this prairie are located the productive gas wells which furnish fuel for Mansfield and vicinity. From the crest of the axis the strata dip away in all directions. To the west the plunge of the axis of the fold continues for a longer distance than toward the east, hence rocks successively higher in the geologic column appear at about the same level. A few miles northeast of Howe the axis of this fold seems to join with the Poteau anticline in rising toward the Heavener anticline.

Heavener anticline.—The upward fold of the Heavener anticline is peculiar both in its form of development and its trend. From a point near the big bend of Poteau River in the north-central part of T. 5 N., R. 24 E., the axis of the fold rises steeply southeastward to a high arch and descends as abruptly within a mile northwest of Heavener. Should the beds of sandstone which have been worn away and whose edges now crop out in the plain around the elliptical border of this domelike fold be restored, they would form a mountain more than a mile high, 6 miles long, and 3 miles wide. The trend of the axis of the Heavener anticline is slightly south of east and almost directly in line with that of the Poteau syncline, against which it abuts.

Milton anticline.—Only part of the Milton anticline is included in the area here described. It is comparatively narrow and bears a little east of northeast. The axis rises from the vicinity of the southward bend of Arkansas River north of Spiro to the neighborhood of Bokoshe and again descends toward the southwest. The anticline is surrounded by the outcrop of the Hartshorne coal bed, which, however, is concealed by alluvium near the river. It is understood that some wells have been sunk on or near the crest of the fold northwest of Spiro, but with what success is not known.

Cavanal syncline.—The axis of the Cavanal syncline trends east-northeast through Cavanal Mountain, just south of Cameron, Hackett, Excelsior, and Greenwood across the area shown on the map. The deepest part of the basin lies beneath Cavanal Mountain, where the Hartshorne coal bed, a convenient datum plane for comparison of elevations, is probably 4,000 feet below sea level or 6,400 feet below the highest peak of the mountain.

Sugarloaf syncline.—The Sugarloaf syncline is a comparatively shallow structural basin lying between the Poteau anticline and the Hartford anticline. The deepest part of the basin is probably near the point where the Arkansas-Oklahoma line crosses the mountain. From this point its rising axis trends east-northeast just north of the town of Huntington. In the deepest part of the basin the Hartshorne coal is probably 1,700 feet below sea level, or 3,700 feet below the highest peak of the mountain.

Poteau syncline.—The Poteau syncline is a long synclinal trough, which stretches more than 100 miles along the south side of the Arkansas coal field and extends into Oklahoma to a point a few miles northeast of Heavener, where its axis is deflected and swings to the southwest around the south limb of the Heavener anticline. This basin is occupied for the most part by Poteau Mountain, beneath which the Hartshorne coal bed reaches an unestimated depth, possibly almost as great as beneath Cavanal Mountain.

Bokoshe syncline.—The position of the axis of the Bokoshe syncline is not well known except between Spiro and Bokoshe. From the vicinity of Spiro the axis of the fold may trend northeast through Fort Smith or east and join the basin between Massard Prairie and the Backbone anticline.

FAULTS.

Choctaw fault.—The Choctaw fault extends from the vicinity of Atoka, in southern Oklahoma, northeast and east along the south side of the coal field, passing into Arkansas just south of Poteau Mountain, and continuing eastward for an undetermined distance. It separates the coal-bearing rocks on the north from the older rocks of the Ouachita Mountains on the south. Prior to the faulting the rocks lying south of the Choctaw fault were closely folded and in many places the folds were overturned toward the north. Then, as the pressure which produced the folding continued, the strata broke along lines parallel to the axes of the folds and the rocks on the south side of the fracture were pushed upward and over those on the north side. The vertical displacement increases from a few hundred feet at the Arkansas line to several thousand feet farther west.

Backbone fault.—The Backbone fault extends from a point about 2 miles northwest of Greenwood, in a west-southwest direction, paralleling and lying just south of the north outcrop of the Hartshorne coal bed, to a point somewhere between Panama and Bokoshe, where it dies out in the westward-plunging end of the Backbone anticline. This fault represents an overthrust of the strata from the south and shows a displacement of about 5,000 feet at the Arkansas-Oklahoma line. The rocks brought to the surface by the fault consist mainly of sandstone and shale of the Atoka formation, so that the beds of sandstone which produce gas in the various parts of this field probably here come to the surface.

STRUCTURAL RELATIONS.

A prominent theory as to the source of oil and gas is the one which ascribes its origin to the slow distillation of organic matter buried with shale and sandstone at the time of their deposition. If this be the origin of these fuels they must have been disseminated in small quantities throughout the containing sediments, and in order to be concentrated into "pools" as they are now found they must have been transported and collected by some agent. The agent most likely to have accomplished such transportation is water, driven either by capillary attraction or by hydraulic pressure, moving through the formations containing the oil or gas in small particles. When once a reservoir of sufficient porosity, like a sandstone, is reached, where interchange of position is least hindered, the oil, gas, and water would separate by difference in weight, the water occupying the lowest point available, overlain successively by oil and gas, if all three be present. It thus appears that gas would occupy the highest available part of a given reservoir, and would be underlain by oil, if present; if not, by water.

It is evident that bodies of gas under great pressure, unless effectually sealed in by some means, would disseminate throughout the containing porous reservoir until no appreciable pressure would be perceptible. We must conclude, then, that the gas is prevented from escaping upward by some impervious medium—for instance, fine-grained shale—and that it is prevented from spreading laterally along the containing bed of sandstone either by impervious material or by some other means, if impervious material should not be present. Among other means may be mentioned the termination of the porous sandstone bed, the sealing of the porous medium by asphaltic material, and by oil, water, or both, occupying different parts of the sandstone.

In order that the oil or water may be effective, certain structures in the reservoir stratum are necessary. The simplest structure favorable for the accumulation of oil or gas is the anticline or upward fold of the porous reservoir and an overlying impervious layer, which is in effect a dome or elongated fold under which the gas collects and is prevented from escaping or disseminating through the reservoir by the presence of bodies of oil or water occupying lower levels in the same stratum. There are, of course, a number of factors that would and do modify these ideal conditions, but a consideration of them can not be undertaken in this paper.

Anticlinal structures are present in all three of the gas-bearing areas shown on the map of the Fort Smith-Poteau gas field. The best-defined upward fold or anticline produces gas in the region southeast of Mansfield. Here the outcropping edges of the upturned upper part of the Atoka and higher formations encircle the gas-producing area in concentric elliptical ridges, which slope or dip away from the central point in every direction.

Although the Massard Prairie anticline southeast of Fort Smith is not so pronounced as the one near Mansfield, it is fairly well defined, and the gas-producing area there is located at the summit of the dome.

The gas obtained from the area east of the town of Poteau, according to the interpretation of the records of two wells, seems to be derived from the Hartshorne sandstone, as a bed of coal, supposedly the Hartshorne, is penetrated from 100 to 200 feet above the gas-producing sand. It will be noted on the map that these wells lie on or near the axis of the Poteau anticline, along or near which further prospecting in the vicinity will reach the same sand at the shallowest possible depth. To the northeast and southwest the Hartshorne sandstone comes to the surface, hence the areal extent over which it may be gas bearing is rather small. However, it should be remembered that a number of sands occur in the Atoka formation at varying depths below the Hartshorne, and these may contain gas in some part of the fold.

The question as to the probability of striking oil at some point down the dip of the strata below the gas has been asked. It is not known, of course, whether the gas is underlain down the slope of the sand by oil or water, nor how far down the slope the contact of the water and gas or the oil and gas would be found, but toward Sugarloaf and Cavanal mountains the strata dip at the rate of 200 to 300 feet to the mile; hence to reach a given bed it would be necessary to drill deeper and deeper as either of these mountains is approached. It is estimated that the top of the Hartshorne sandstone lies at a depth of 3,000 to 3,500 feet below the town of Poteau.

The production of the wells east of Poteau is reported to be 12,000,000 cubic feet per day, with a gas pressure averaging about 400 pounds to the square inch.

Log of gas well, 3½ miles east of Poteau, Okla.

	Thickness.	Depth.	Remarks.
	Feet.	*Feet.*	
Conductor	6	6	
Hard shell	18	24	
Shale	136	160	Water at 60 feet.
Shell	30	190	
Black slate	80	270	
Hard shell	5	275	
Black slate	60	335	
Shell	20	355	
Black slate	290	645	Small "showing" of water.
Sandy shale	60	705	
Black slate	145	845	
Sandy shale	15	860	
Black shale	210	1,070	
Lime	7	1,077	
Black shale	553	1,630	
Black sandy shell	25	1,655	
Black shale	42	1,697	
Coal	3	1,700	Small "showing" of gas in coal.
Hard shell	2	1,702	
Black shale	94	1,796	
Black hard shell	4	1,800	
Black sand shell	20	1,820	
Gray sand	15	1,835	
Black and gray sand	33	1,868	
Gray sand, gas	32	1,900	

According to well records now in hand, gas wells in Massard Prairie, about 5 miles southeast of Fort Smith, range in depth between 1,312 and 2,845 feet. The log of the deepest of these wells shows that 17 different sands, ranging in thickness from 9 to 263 feet, were encountered in drilling to a depth of 2,845 feet. By no means all of these sands are productive. In some of the wells as many as four sands produce gas, but usually the greatest volume of gas is obtained from one sand in each well. The most productive sands are found between 1,000 feet and 2,100 feet below the surface. The initial closed pressure of the gas varies between 145 and 280 pounds to the square inch, and the daily volume of gas obtained from each well varies between 140,000 and 4,250,000 cubic feet.

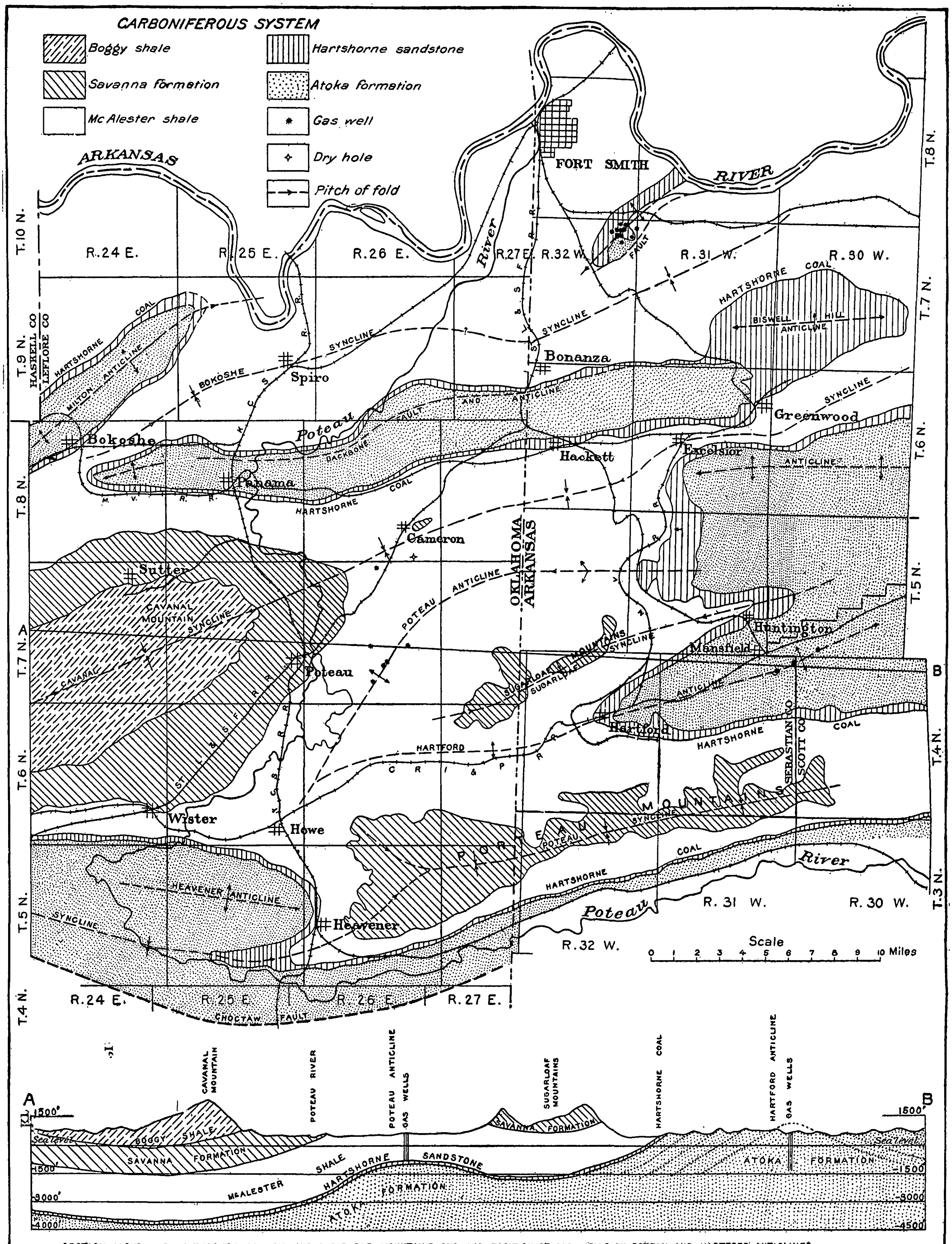
All of the wells in Massard Prairie start in or near the Hartshorne sandstone, hence all the gas is obtained from sands in the Atoka formation.

Log of well in Massard Prairie, 5 miles southeast of Fort Smith, Ark.

	Thickness.	Depth.
	Feet.	*Feet.*
Top and shale	150	150
Sand	19	169
Shale	221	390
Sand	15	405
Shale	20	425
Sand	25	450
Shale	245	695
Sand	40	735
Shale	10	745
Sand	25	770
Shale	235	1,005
Sand	15	1,020
Shale	95	1,115
Sand	253	1,378
Shale	122	1,500
Sand	52	1,552
Shale	393	1,945
Sand	30	1,975
Shale	45	2,020
Sand	185	2,205
Shale	47	2,252
Sand	28	2,280
Shale	90	2,370
Sand	15	2,385
Shale	150	2,535
Sand	25	2,550
Shale	5	2,555
Sand	8	2,563
Shale	44	2,607
Sand	30	2,637
Shale	16	2,653
Sand	20	2,673
Shale	172	2,845

The fault in the Backbone anticline makes prospecting there rather precarious, because the fracturing of the strata may have furnished an outlet to the surface, thus preventing any large accumulation of gas.

No detailed information concerning the number, thickness, and depths of producing sands in the Hartford anticline southeast of Mansfield is at hand. It is known from geologic evidence, however,



SECTION ALONG LINE A-B THROUGH CAVANAL AND SUGARLOAF MOUNTAINS SHOWING POSITION OF GAS WELLS ON POTEAU AND HARTFORD ANTICLINES

MAP OF FORT SMITH-POTEAU GAS FIELD, ARKANSAS AND OKLAHOMA.

By Carl D. Smith.

that the wells start in the Atoka formation 3,000 feet or more below the Hartshorne sandstone. If gas there is obtained at approximately the same depth as in the Massard Prairie field, a thickness of nearly 6,000 feet of the Atoka formation is to be regarded as containing good prospective gas strata.

As explained under the heading "Stratigraphy," the sandstone beds of the Atoka formation as seen in outcrop are variable in thickness, texture, and lateral extent. This condition undoubtedly holds true where the deeply buried sands in the Atoka are penetrated by the drill. A study of the records in hand indicates considerable variability even in near-by wells. But when the number of sands is taken into account it is thought that, in areas of favorable geologic structure, deep drilling may be resorted to with good chances of successful outcome.

It seems that, if other things are equal, the chances of striking gas are better in the upward folds or anticlines than in other localities. Of course, if a porous medium be not present in the anticline, then the chances there are no better than elsewhere; but as the presence or absence of the porous medium can not be foretold, that chance must be taken as a part of the risk of drilling.

THE GLENN OIL AND GAS POOL AND VICINITY, OKLAHOMA.

By Carl D. Smith.

INTRODUCTION.

On account of its phenomenal production the Glenn oil pool in Oklahoma is well known, but so far as the writer is aware no detailed report of the geology of the pool has ever been published. To determine, if possible, the reason for the accumulation of this wonderful body of oil and gas, one week in December, 1912, was spent by the writer in studying the geologic structure of the field as shown by outcropping formations. This work was supplemental to the investigations that have been carried on in adjacent regions for several years.

The unpublished results of investigations by the writer and others in contiguous territory have been drawn upon freely, as a study of the small area shown on the map would throw but little light on the geology or the conditions governing the accumulation of oil in this pool.

The Glenn pool area as here described is located in Creek and Tulsa counties, Okla., near the towns of Sapulpa and Tulsa, and includes several minor pools known as the Taneha, Red Fork, and Perryman. (See map, Pl. III.) Glenn pool proper was discovered in 1906 and since its discovery its boundaries have been gradually extended until at present it merges with the other pools and no lines can be drawn between them.

It is not the purpose of this report to give any opinion as to the probable future extension of the Glenn pool, but to point out the relation existing between accumulations of oil and gas and the geologic structure as shown by the attitude of surface strata, with a view to ascertaining some general relations that may be applicable to fields yet untouched or only partly developed.

TOPOGRAPHY.

The topography of the Glenn pool area is determined by the attitude and varying degrees of hardness of the strata which make up the geologic section. The most conspicuous features of relief are roughly parallel zones of comparatively rugged sandstone highlands trending northeast-southwest, separated by belts of smoother lowlands developed in softer strata. As a general rule the irregular escarpments have steep slopes facing east and gentle slopes stretching westward from the crests to the base of the next belt of highland. One of these belts of rugged country, trending slightly west of south, lies about 6 miles west of Sapulpa; another passes just west of Sapulpa; still another, which first makes its appearance about 2 miles southwest of Red Fork, passes 2 to 3½ miles east of Sapulpa, and continues to the southwest, passing just west of Kiefer and Mounds. Another highland zone of more or less continuity passes 2 to 3 miles east of the town of Glenpool, and probably should be considered the southern continuation of the hilly country east of Arkansas River and southeast of Tulsa. The regularity of the areas of low relief is interrupted in places by the presence of hard, hill-making sandstone beds in the soft shale which underlies the lowlands. Turkey Mountain, northwest of Jenks, and the hilly country east of Arkansas River and southeast of Tulsa are examples of the local development of sandstone beds in zones which are usually characterized by soft material and marked by comparatively small differences of altitude. Altitudes in the Glenn pool area range between about 600 and 950 feet.

GEOLOGY.

STRATIGRAPHY.

GENERAL RELATIONS OF THE FORMATIONS.

In order to understand conditions that probably prevail beneath the surface in the Glenn pool, it is necessary to consider the character and attitude of formations 35 to 40 miles to the east, where the deeply buried strata of the Gleen pool area come to the surface and can be studied in outcrops. (See cross section, Pl. III.) The section of rocks exposed in the area represented by the map is about 850 feet in thickness and comprises alternating beds of shale, sandstone, limestone, and coal, named in the order of their relative thicknesses. These formations are Carboniferous in age and constitute a part of the Pennsylvanian or middle series of the Carboniferous, which outcrops in northeastern Oklahoma, on the west flank of the Ozark uplift, extends as a broad northeast-to-southwest trending belt from Kansas into Oklahoma, and dips gently westward beneath the Permian series ("Red Beds"). (See fig. 1, p. 43.)

The contact of the Pennsylvanian series with the Mississippian series below, which lies near and roughly parallels Grand River, is unconformable, but the angle of unconformity between the two series is so slight that the discordance in strike and dip of the strata is scarcely perceptible. It is probable that the Pennsylvanian sediments were deposited upon a slightly eroded and gradually sinking land surface composed of the Mississippian series, and were derived, in part at least, from the Mississippian and older rocks which form the core of the Ozark dome. No unconformities of more than local development have been noted in the Pennsylvanian series above the base of the Cherokee formation, which is described below.

Section showing relations, character, and thickness of formations exposed in and to the east of the Glenn pool area, Okla.

	Feet.
Carboniferous system:	
Pennsylvanian series:	
Limestone, bluish gray; locally known as the "Lost City limestone"	1–40
Shale and sandstone	350
Limestone, bluish, hard; checkerboard lime of the drillers	$2\frac{1}{2}$
Shale, with variable beds of sandstone	215
Coal, Dawson	$1\frac{2}{3}$–$2\frac{1}{2}$
Shale, with irregular beds of sandstone	210–350
Limestone, massive gray; big lime of drillers	0–40
Shale, with irregular beds of sandstone	200±
Limestone, Fort Scott, Oswego lime of drillers; bluish-gray limestone with 3 to 5 feet of shale near middle	10–30
Shale, sandstone, limestone, and coal; Cherokee formation	1,000±
Unconformity.	
Blue to white limestone, with some shale and thin sandstone; Morrow formation	100–120
Unconformity.	
Mississippian series:	
Limestone, blue and brown, locally sandy and shaly; Pitkin	60±
Black shale with thin beds of limestone and sandstone; Fayetteville formation	20–60
Unconformity.	
Limestone, Boone; flinty limestone and flint	200±

On account of their greater hardness the sandstone and limestone beds are much more conspicuous in their outcrops than the shale, but probably the shale constitutes four-fifths to nine-tenths of the geologic column. The shale is generally soft and friable and disintegrates rapidly on exposure, thus giving rise to valleys or lowlands where unprotected by caps of harder material. The sandstone varies greatly in hardness. Many beds are so loosely cemented that they weather as easily as shale, thus giving the impression that they are extremely variable or lenslike in development, whereas others are of sufficient hardness to form bold escarpments many miles in length.

FORMATIONS NOT EXPOSED IN THE GLENN POOL AREA.

Information regarding strata that underlie the Glenn pool area but are not exposed in it has been obtained from well logs, from geologic reports on adjacent areas, and from personal study of regions to the northeast, east, and southeast, where the formations penetrated by the drill in the Glenn pool area come to the surface. The thickness of these formations is about 2,000 feet and is described in some detail below.

PRE-CARBONIFEROUS FORMATIONS.

The strata below the Boone limestone, the lowest formation of the Carboniferous system, belong to the Devonian, Silurian, and Ordovician systems, which outcrop in the central part of the Ozark uplift to the east. They consist mainly of limestone, and some sandstone and shale, and are so deeply buried in the Glenn pool area that they probably have not been reached by the drill.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

Boone limestone.—The lowest formation considered in detail in this report is the Boone limestone, which outcrops mainly east of Grand River and is known to drillers as the "Mississippi lime." It ranges in thickness from 100 to 350 feet and is made up of limestone, cherty limestone, and layers of chert or flint. The outcrop of the Boone forms a flint-covered surface in which the purer beds of limestone are in few places exposed. It is usually easy of recognition in drilling because of its great hardness, thickness, and cutting action on the drill bit. The Boone is usually regarded as the formation in or below which oil and gas do not occur in paying quantities, but whether or not this conclusion is correct remains to be proved.

After the deposition of the Boone and its consolidation into hard rock there was a period of uplift and erosion. That is, the present surface of the Boone shows evidence of having been a land area at some time in its former history and of having undergone partial destruction prior to the submergence which permitted the deposition of later sediments now found upon its irregular surface.

Fayetteville formation.—Above the Boone is a blue-black shale 20 to 60 feet thick, which generally contains two thin bluish-white limestone members, one near the base and the other near the top. Lenticular beds of dark ferruginous sandstone are present locally in the shale. The Fayetteville formation as a whole is comparatively soft and its base in contact with the Boone below is usually easy to recognize in drilling because of the difference in character and hardness of the two formations.

It is of course practically impossible to recognize in drill records the exact positions of the contacts of formations whose outcrops are so far removed from the point where they are penetrated by the drill as those are in this area. However, after a close study of records of wells in the Glenn pool area and to the east, it is believed that the Fayetteville formation thickens from about 60 feet near Grand River to 275 feet at Glenn pool and that two comparatively thick sandstone beds are present in the formation under cover that do not reach the surface in outcrop.

Pitkin limestone.—Conformably on the Fayetteville formation lies the Pitkin limestone. As described in the Muskogee folio,[1] the Pitkin varies but little from 50 feet in thickness and consists of layers of light-blue to brown granular limestone interbedded with fine-textured harder limestone and some thin layers of shale.

The Pitkin is considered the uppermost formation of the Mississippian series and is separated from the overlying Morrow formation of the Pennsylvanian series by an unconformity similar to the one between the Boone limestone and the Fayetteville formation. But for fossil evidence and detailed study of the formations elsewhere the existence of these unconformities would scarcely be detected in regions contiguous to the Glenn pool area. It is only when large areas are studied that the discordance in strike and dip can be ascertained. North of the Muskogee quadrangle and northeast of the Glenn pool area the Pitkin limestone is thin, and in the southeast corner of Kansas it is absent.

PENNSYLVANIAN SERIES.

In the general region of northeastern Oklahoma a notable change takes place in the character and thickness of the Pennsylvanian formations. In Kansas the Pennsylvanian consists mainly of shale and limestone, sandstone constituting but a minor part of the section, whereas to the south, in Oklahoma, most of the limestones are thin and disappear from the section, very few reaching as far south as Arkansas River. On the other hand, sandstones appear, growing thicker and more regular in development toward the south. Notwithstanding the disappearance of the limestones, the Pennsylvanian section as a whole is thicker to the south.

Morrow formation.—As described in the Muskogee folio, the Morrow formation, the basal formation of the Pennsylvanian series, consists chiefly of limestone, with a lesser amount of shale, and in places thin beds of sandstone. The thickness of the Morrow ranges between 100 and 120 feet and at the top of the formation is an unconformity similar to the one at the top of the Boone. Eastward from the Muskogee quadrangle the limestone in the Morrow is

[1] U. S. Geol. Survey Geol. Atlas U. S., Muskogee folio (No. 132), 1906.

gradually displaced by shale and sandstone. What changes may take place in its composition under cover west and northwest of its outcrop in the Muskogee quadrangle are of course problematical and can be inferred only from the logs of deep wells. North of the Muskogee quadrangle and northeast of the Glenn pool area the Morrow formation is thin, and in the southeast corner of Kansas it has not been recognized as a separate formation in the geologic section.

Cherokee formation.—For purposes of discussion in this report the upper contact of the Morrow formation is assumed as the base of the Cherokee formation, although in southeast Kansas the Cherokee as described probably includes the Morrow or its representative. The base of the Fort Scott limestone forms the upper boundary of the Cherokee. According to the interpretation of well logs, the Cherokee thickens from 850 feet near Tulsa to 1,080 feet near Mounds. In outcrop the lower 500 feet of the Cherokee consists mainly of shale, with interbedded thin sandstone, limestone, and coal, whereas the upper part contains a greater proportion of sandstone. According to the interpretation of well logs, a number of oil and gas sands, which do not appear to reach the surface in outcrop, are penetrated between the middle and the base of the Cherokee in the Glenn pool area. Several sands are productive below the Cherokee, but as that formation contains the sands from which the bulk of the oil and gas is obtained a detailed description of the sandstone beds of the Cherokee, as observed in outcrop, may be of interest.

Study of the outcropping edges of the beds of sandstone in the Cherokee formation east and northeast of the Glenn pool area has thrown much light on their probable character under cover in the oil and gas area. Of course the conclusions are based on the observation of a narrow strip of outcrop, at some distance from the Glenn pool, but without positive evidence to the contrary it may be inferred that similar conditions hold true to the westward, where the sandstones are deeply buried. The sandstones have been described as lenslike masses completely inclosed in shale, or as irregular bodies giving place horizontally to shaly sandstone and finally to shale. In the outcrops of the sandstones the correctness of this conclusion is borne out to a certain extent, but it has also been found that a number of sandstones have comparatively wide distribution, one particular layer having been followed continuously for 50 miles or more along its outcrop. This bed is, however, not regular in texture, being thin or shaly or indurated at some places, and at others thick and massive. Other beds, though not so prominent as the one above referred to, show evidence of considerable lateral extent. Another factor that has probably led to the idea of small lenses and extreme local variability is the influence of an irregular system of folds of the strata.

The result of such folds is that the same sand may be found at different levels in near-by wells. It is believed that the sands are not so lenticular as they have been represented, and that their apparent lenticularity is due to local variations in texture and to structure.

Fort Scott limestone.—In its outcrop east and northeast of the Glenn pool area the Fort Scott limestone is made up typically of two members separated by 3 to 5 feet of shale, the whole ranging in thickness between 10 and 30 feet. Just below the lower limestone, and separated from it by a foot or so of shale, there is generally a bed of coal 12 to 20 inches thick, though between the town of Broken Arrow and Arkansas River the coal bed pinches out. In this locality also the Fort Scott limestone is thin and inconspicuous in outcrop.

The Fort Scott limestone is known to drillers as the Oswego lime, and is one of the most constant and extensive formations in the developed oil and gas region of northern Oklahoma. The top of the Fort Scott has been used as a datum surface for the construction of a structure contour map of the Glenn pool region, which is shown on Plate III and discussed below.

Formations above the Fort Scott limestone.—Between the top of the Fort Scott limestone and the top of a limestone exposed and quarried in the bluff just south of Arkansas River, southeast of Sand Springs, there are between 1,030 and 1,130 feet of beds made up of shale, sandstone, limestone, and coal.

Near Tulsa a limestone known to drillers as the Big lime occupies a position in the geologic section from about 200 to 240 feet above the top of the Fort Scott limestone. To the north and northeast of the Glenn pool area this limestone is extensive and conspicuous, both in outcrop and in the logs of wells. About the latitude of Broken Arrow the limestone disappears in outcrop and, judging by the logs of wells in the Glenn pool area, it is believed that the deeply buried edge of the limestone extends in a southwest direction across the field somewhere between Red Fork and Mounds, and that the limestone noted in well logs in the southern part of the field as Big lime is really the Fort Scott limestone or Oswego lime. In the vicinity of Tulsa the presence of a thin bed of coal just below the Fort Scott serves to distinguish it from the Big lime, but this coal does not seem to extend as far south as the southern part of the Glenn pool area.

FORMATIONS EXPOSED IN THE GLENN POOL AREA.

From 210 to 350 feet above the Big lime is a coal bed 20 to 30 inches thick, whose outcrop passes through Dawson, thence southeast of Tulsa, 3 miles northwest of Jenks, just west of the town of Glenpool, thence southwestward to a point a mile or so east of Mounds. For convenience of discussion it is called in this paper the Dawson coal. This coal is an excellent datum surface for working out details of structure but is noted in only a few well logs. In the neighborhood of Tulsa the coal bed lies about 465 feet above the Fort Scott limestone. Near Mounds it should be found about 550 to 570 feet above the Fort Scott limestone.

About 215 feet above the Dawson coal and 680 to 780 feet above the top of the Fort Scott is a thin hard limestone of remarkable persistence and uniformity, which outcrops in a number of places in the Glenn pool area. This bed is exposed in Tulsa at the junction of the St. Louis & San Francisco and Missouri, Kansas & Texas and Midland Valley railroads, near the north end of the St. Louis & San Francisco Railroad bridge over Arkansas River, at a number of places between Red Fork and Jenks, at many places in Glenn pool proper, and a short distance northeast of Mounds. It varies little from 2 feet 6 inches in thickness and is an excellent datum surface for working out details of structure. It is known to drillers as the Checkerboard lime.

Another recognizable bed in the Glenn pool area is a limestone which outcrops at Lost City and is locally known as the "Lost City limestone." It lies stratigraphically about 350 feet above the Checkerboard lime and 1,030 to 1,130 feet above the top of the Fort Scott limestone. Its maximum measured thickness is about 40 feet, where it is exposed at the site of a proposed cement plant near the northeast corner of sec. 18, T. 19 N., R. 12 E. From this point, both northeast and southwest, the thickness of the limestone diminishes in short distances to a foot or so. It is quarried northeast of Sand Springs and at Lost City, in the south bluff of Arkansas River southeast of Sand Springs. From this latter point the outcrop of the limestone trends south and southwest, passing west of Sapulpa. Above this limestone, in the area shown on the map, is an unmeasured thickness of shale and sandstone that has not been examined in detail and will receive no further consideration in this report.

DEPTH OF THE BOONE LIMESTONE IN THE GLENN POOL.

About the latitude of Tulsa the Boone limestone or Mississippi lime, which is a widespread and easily recognizable formation in drill holes to the north, either changes greatly in character or plunges steeply to the south, causing more or less confusion in well logs. A thickness of about 250 feet of strata variously interpreted by drillers as "very hard black lime and black sand," "mixed ground," and the like, at a depth of 950 to 1,200 feet below the top of the Fort Scott, has been taken by many drillers to be the Boone, but when the known divergence of the various recognizable beds and the probable thickening of the Morrow and Pitkin to the south are taken into account, it is believed that the interpretation is erroneous, and that the Boone lies still deeper, say at a depth of about 1,300 feet below the Fort Scott at Tulsa or about 2,000 feet below the Checkerboard lime, which outcrops in Tulsa. It is believed that the formation usually interpreted in the Glenn pool area as the Mississippi lime is really the combined Morrow and Pitkin.

As nearly as can be ascertained from study of the logs of wells drilled in the Glenn pool area the thickness of the section between the base of the Cherokee and the top of the Boone limestone (Mississippi lime), in which interval three unconformities exist, is about 550 feet. This interval includes the Fayetteville formation, the Pitkin limestone, and the Morrow formation, and no attempt is here made to differentiate them in the columnar section shown on the map.

STRUCTURE.

DEFINITIONS.

By structure is meant the "lay" or attitude of the strata composing the geologic section with reference to a given level. An upward fold or arch is called an anticline and a downward fold a syncline. Where strata have been tilted so as to dip in only one direction the structure is called a monocline. The axis of a fold is a line passing through the highest points along the crest of an anticline or through the lowest points along the trough of a syncline. If some particular stratum of rock be taken as a datum surface, a line representing this surface will rarely be level but will plunge and rise or curve in various directions.

STRUCTURE OF THE REGION.

The Glenn pool area lies in the region known as the Prairie Plains monocline, which extends as a broad belt from Iowa across northwestern Missouri, eastern Kansas, and central Oklahoma. To the east of this monocline in Oklahoma lies the Ozark dome of older rocks toward which the strata rise and outcrop in roughly parallel zones; to the west strata successively higher in the geologic section are exposed in northeast-southwest trending belts. The westward dip of these formations is variable in amount, increasing from 15 feet to the mile in southern Kansas to nearly 50 feet to the mile in the Glenn pool area. The westward inclination of the strata is neither constant nor constantly variable, but is interrupted by areas in which the formations lie flat or nearly so, whereas in other areas the dip is greater than normal. The structure is further complicated by a system of disconnected folds whose axes parallel roughly the direction of general dip—slightly north of west. These folds are not well defined, but seem to be elongated, westward-plunging rumples, which merge both to the east and west with the prevailing westward dip.

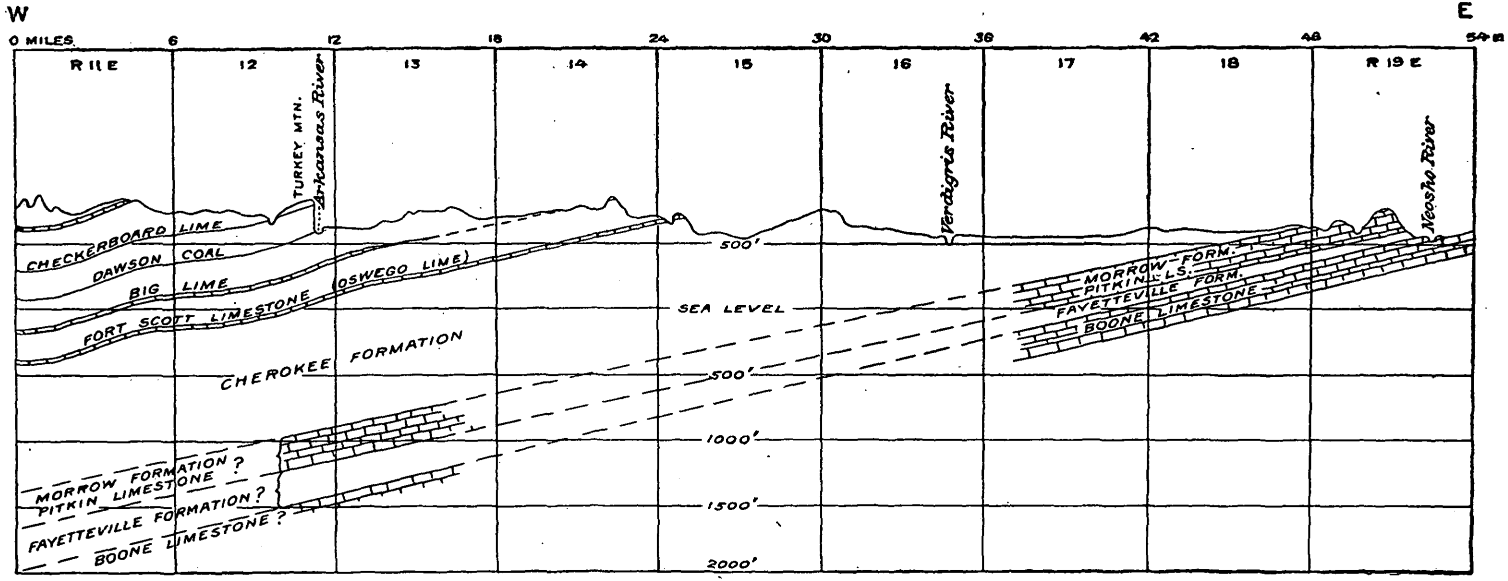


FIGURE 1.—Cross section along line between Tps. 18 and 19 N., Oklahoma, showing westward dip of strata and probable correlation of the Morrow formation, Pitkin limestone, Fayetteville formation, and Boone limestone from their outcrop near Grand River, with formation penetrated by the drill in the Glenn pool area.

Investigation of the strata between the top of the Morrow and the top of the Boone, where they outcrop northward from the Muskogee quadrangle, indicates that the three unconformities embraced in that section converge toward the north, finally merging into one in the southeast corner of Kansas, thus eliminating the Fayetteville, the Pitkin, and possibly the Morrow from the section, and allowing the Cherokee to rest on the eroded surface of the Boone. This seems to be the case also under cover along the ninety-sixth meridian, where, from a study of well logs, nothing that can be interpreted as representing these three formations can be recognized more than a few miles north of the latitude of Tulsa. Southward from Tulsa the limestone beds in the Morrow and Pitkin probably become thicker, and, as discussed above, are likely to be mistaken for the Boone limestone. As a number of sandstone beds occur between the top of the Morrow and the top of the Boone it is believed that a great many wells that are productive at comparatively shallow depths in the Glenn pool area might be deepened with good chances of reaching still lower productive sands.

STRUCTURE CONTOUR MAP.

On the map (Pl. III) an attempt has been made to represent by contour lines on the top of the Fort Scott limestone (Oswego lime) the various structural features involving the oil and gas sands and associated strata in the Glenn pool area. The Fort Scott overlies the most productive sands of the area, hence its value as a datum surface for the construction of a structure contour map depends upon its known relation to the formations below and to the formations exposed at the surface. The projection of the structure of surface formations to underlying strata necessarily presupposes that no unconformity or break in the regular sequence of formations exists within the geologic section under consideration and that they are all parallel or nearly so. A study of the logs of wells that penetrate formations above and below the Fort Scott, and investigation of the same formations in outcrop, indicate that, although the strata are not exactly parallel, there is a more or less regular convergence toward the north and possibly a slight convergence of the formations above the Fort Scott toward the west. In other words, the thickness of the investigated rock section as a whole is less toward the north, although individual members may vary irregularly.

In the construction of a contour map with the top of the Fort Scott as a datum surface all available information, such as the known relation of the limestone to other outcropping formations, the depths at which it was penetrated in wells, and the known convergence of strata toward the north, has been taken into consideration. The accuracy of the map depends, therefore, on the accuracy with which the structure of the area has been worked out, using the outcrops of associated formations as criteria, and on whether or not the logs of wells have been correctly interpreted. As stated in the introduction, the work in the Glenn pool area was done hurriedly, with a view to ascertaining the general conditions, and it is expected that detailed work in the area would doubtless bring out inaccuracies in the map, but it is believed that in the main the features shown are correct.

A contour interval of 25 feet has been taken as best adapted for showing the structure, and the elevations on the top of the Fort Scott are given with reference to sea level. To arrive at the depth of a certain sand at a given place, its distance from the Fort Scott must be known, also the altitude of the surface of the ground at the desired locality.

Below the top of the Fort Scott for a depth of 800 feet at Tulsa to a depth of 1,200 feet near Mounds it is believed that the underlying formations conform to the Fort Scott in structure, though with increasing depth there seems to be an increase in the rate of divergence of the strata toward the south. Below the depths named a number of factors of undetermined value may enter and completely negative any conclusions that might be drawn from a study of the surface formations. Among the most potent of these factors are the great thickening and change in the character of the formations from north to south; the presence of three unconformities or breaks in the natural sequence of rocks between the top of the Morrow and the top of the Boone limestone ("Mississippi lime"); the thinning of the Pitkin and Morrow formations toward the north; and the possible existence of a complex system of faults and folds which involved the Mississippian and the lower part of the Pennsylvanian prior to the deposition of the main mass of the Pennsylvanian.

RELATION OF OIL AND GAS ACCUMULATIONS TO FOLDS IN THE STRATA.

Study of the Glenn pool area, as well as numerous other localities in the same general region, has served to strengthen the writer's belief that in this area geologic structure controls, to a large extent, the accumulations of oil and gas. Where gas, oil, and water, which have different specific gravities, occur in a porous medium like a sandstone, where interchange of position is but slightly hindered, the tendency is that the gas should be forced to the highest available point, whereas the oil would lie below the gas and the water below the oil. This relationship would obtain, provided the containing medium was uniformly porous, but in fact it is not, hence a number of modifying factors, some of undeterminable importance, enter into the list of possibilities that must be considered.

As the presence or absence of sands and their degree of porosity can not be foretold by a study of surface formations, all that remains for the geologist is to work out the geologic structure and to say that, provided a porous medium is present at a certain structurally favorable point, the chances of obtaining oil and gas at that point are far superior to the chances of obtaining oil and gas at some structurally unfavorable point. In the oil and gas region of northern Oklahoma it is unsafe to say positively that oil or gas will not be found at any particular place, but it can be said positively that certain localities are much more favorable than others.

By reference to the map (Pl. III) it will be noted from the deformation contours on the top of the Fort Scott limestone that the axis of a syncline trends approximately east-west through the town of Sapulpa, rising and dying out toward the east until finally it merges with the general rise of the formations in that direction. To the south of this basin the Fort Scott rises to a broad area lying mainly between and to the south of the towns of Kiefer and Glenpool.

From the vicinity of Kiefer the formations dip at comparatively steep angles to the west and northwest, whereas to the east and southeast there is an area which has the appearance of a westward-tilted elongated dome. From a point about a mile south of the middle of T. 17 N., R. 12 E., the formations dip to the southwest, thus indicating a depression or basin in the vicinity of Mounds. Eastward from the line between ranges 12 and 13 the formations seem to dip either slightly to the east or lie nearly flat, but this part of the field has not been studied in sufficient detail to warrant definite statements concerning its structure.

To the north and northeast of the syncline through Sapulpa there is a fairly well defined anticline whose axis trends approximately east-west a mile or so south of the line between Tps. 18 and 19 N. Along the crest or on the flanks of this anticline are a number of producing areas, notably Red Fork, Taneha, Turkey Mountain, and the Perryman pool east of Arkansas River.

The region east and southeast of Tulsa is anticlinal in a general way, the structure resembling an irregular, westward-tilted dome.

CONCLUSIONS.

In the northern Oklahoma oil and gas belt it is almost an infallible rule that where oil is found in a certain sand, salt water will be found down the dip at some place in that particular sand, and gas is likely to be found at some point up the rise from the oil. There are modifying conditions, of course, such as lack of continuity of the sand in one direction or another, irregular "pay streaks," and various other factors undeterminable from mere study of the surface strata.

In wildcatting, a knowledge of geologic structure would be of great value. If sands occur beneath a certain chosen area, and if those sands contain oil and salt water, then it is almost certain that the oil will be found in the upward folds or anticlines and the water in the basins or synclines. The presence or absence of the sands can be ascertained only by drilling.

It is probably fortunate for the northern Oklahoma oil and gas field that the productive sands are either not continuous or not continuously of sufficient porosity from deeply buried pools to the outcrops of the sands on the east to permit free passage of oil and gas, because infiltering surface water would gradually displace these minerals and they would be driven up the slope of containing sands, finally to be dissipated in the air or to come to the surface as asphalt deposits. But reservoirs are produced as effectively by a combination of monoclinal dip and lack of porosity or absence of a sand as by anticlinal structure. The gas and oil, followed by water, will travel up the rise until a zone in the containing sand is reached, where the sand either pinches out or becomes impervious or "tight." Thus, an accumulation of oil and gas in a given sand is likely to have an irregular or ragged boundary on the east and, provided the sand be continuous in that direction, a boundary of salt water on the west. To the north or south the productivity of a sand may be terminated either by lack of porosity, absence of the sand, or, if the structure is favorable, by salt water.

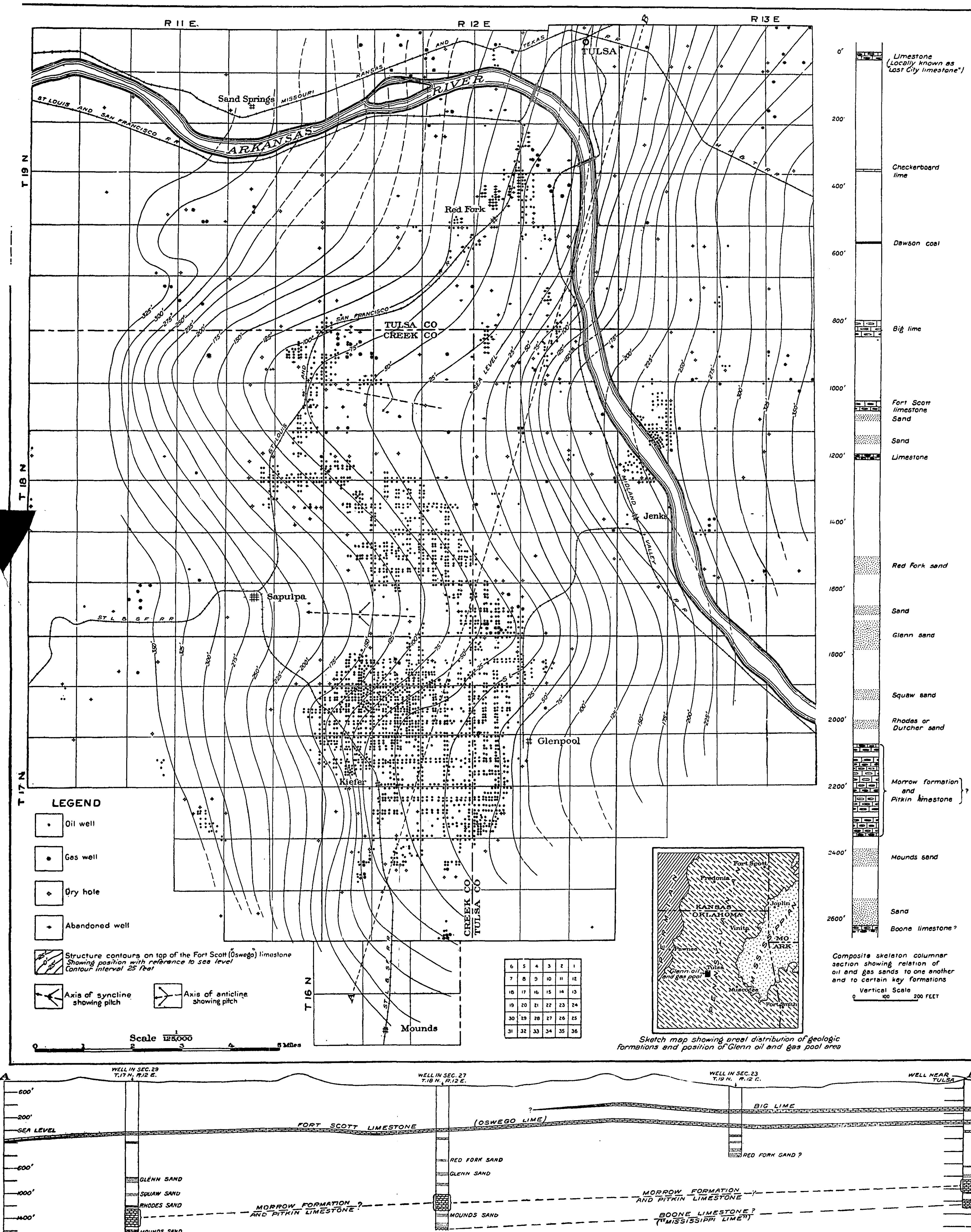
It appears, therefore, that vagaries in the development of porous parts or "pay streaks" in a sand may produce reservoirs where little favorable geologic structure is evident. Very favorable conditions exist in the Glenn pool—a combination of a thick porous sand with anticlinal structure.

QUALITY OF THE OIL.

In the following table partial analyses of several samples of crude oil from the Red Fork, Glenn, and Mounds pools are shown. These samples were analyzed by D. T. Day, of the United States Geological Survey. For a description of the method used and the analyses of many other samples from the Mid-Continent field see United States Geological Survey Bulletin 381.

Analyses of crude oil from Oklahoma.

Sample collected from—	Location of well and pool.	Number of well.	Depth of well.	Physical properties.		Paraffin.	Asphalt.
				Gravity at 60° F.	Color.		
	TULSA COUNTY.						
	Red Fork pool:		*Feet.*	*Baumé.*		*Per ct.*	*Per cent.*
Well	J. I. Yorgee lease, Robt. Galbreath, Tulsa.	3	638	37.3	Green	2.60	0.0
Do	do	5	601	38.2	Dark green.	4.39	.05
Leader pipe	Van Yorgee lease, Robt. Galbreath, Tulsa.	1-7	1,240	36.4	do	6.37	.05
Well	Missouri Lincoln Trust Co. lease, L. E. Mallory & Son, Tulsa.	1	1,200	37.5	Black	3.92	.35
Pipe line	Pump station at Red Fork, Prairie Oil & Gas Co., Independence, Kans.			32.9	do	4.88	.15
	CREEK COUNTY.						
	Glenn pool:						
Well	Grace Berryhill lease, Oklahoma State Oil Co., Kiefer.	9-13	1,500	35.5	do	5.41	.11
Do	Pittman farm, sec. 7, T. 17 N., R. 12, Argue & Compton, Tulsa.	11	1,500	35.5	do	6.98	.45
Pipe line	Pump station, Prairie Oil & Gas Co., Kiefer.			35.4	do	5.99	.24
Well	Thos. Berryhill lease, Indiana Oil & Gas Co., Kiefer.	7	1,518	35.9	do	7.53	.90
Do	Wm. Berryhill lease, Indiana Oil & Gas Co., Kiefer.	15	1,529	38.0	do	11.46	.35
Do	W. B. Self lease, Prairie Oil & Gas Co., Tulsa.	23	1,523	37.2		3.12	.21
Do	do	7	1,553	36.2	Black	9.70	.51
	Mounds pool:						
Do	Corndoffer lease, sec. 18, T. 16 N., R. 12, Swasey Oil Co., Fort Worth, Tex.	1	2,340	32.2	Bright green.	8.44	.62



MAP OF GLENN OIL AND GAS POOL AND VICINITY, OKLAHOMA.

By Carl D. Smith.