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Chas. N. Gould, Director

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OIL AND GAS IN OKLAHOMA

Volume III

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FOREWORD

The present volume, Bulletin 40, Volume III, of the Oklahoma Geological Survey, includes the papers which have been published during the years 1926-1930, as separate chapters.

Bulletin 40 of this Survey is a revision of Bulletin 19, part II, entitled, "Petroleum and Natural Gas in Oklahoma," which was issued in 1917. On account of the rapid development of the oil and gas industry in this State, it has been found necessary to revise this bulletin and bring it up to date. On account of the fact that appropriations for carrying on his work were lacking, the Director called to his aid a number of working geologists throughout the State and these individuals have contributed freely of their time and efforts to the preparation of the manuscripts, which includes about fifty separate chapters in all.

The greater number of the chapters are concerned with the geology and oil conditions of a single county or group of counties in Oklahoma. These are published as Volume II and Volume III of Bulletin 40, Volume II dealing with the counties in western Oklahoma and Volume III dealing with the counties in the eastern part of the State.

The several papers included in Volume III, published herein, are those of a general nature dealing with certain phases of geology and of the oil industry throughout the entire State.

Both the authors of the various papers and the staff of the Survey realize very keenly that these chapters do not represent the last word on the various subjects discussed. New data are constantly coming to light, necessitating the revision of former ideas. However, we believe that the facts as herein set forth represent our best information of the date of publication.

NOTTING, Oklahoma
July 1, 1930

CHAS. N. GOULD
Director.

Volume III

OIL AND GAS IN OKLAHOMA

CREEK COUNTY

By

John W. Merritt and O. G. McDonald

INTRODUCTION

PURPOSE

Since the publication in 1917, of Bulletin No. 19, Pt. II, entitled "Petroleum and Natural Gas in Oklahoma", by the Oklahoma Geological Survey, a great amount of development has taken place in Creek County. Up to 1917, the major production in this county came from that portion of the Glenn pool lying within Creek County and from the Cushing pool. Since 1917 only two pools of major size have been developed, the Slick and Continental pools. The former was found on a broad terrace with minor local irregularities. The latter is made up of a group of small structures. All remaining new development has taken place upon small structures of all varieties, some production being found even in synclines. These small structures are difficult to map upon surface outcrops and are becoming increasingly hard to find. It is growing more and more evident that the discovery of new production in this county will depend upon the application of an interpretation of the nature and origin of these small structures. This chapter, therefore, besides describing the production of the county, will lay considerable emphasis upon a study of the nature of the structures here and attempt the interpretation of their origin.

Figure 1.—Index map of Oklahoma showing location of Creek County.
(This report originally issued as Bulletin 40-C, August, 1926).
CREEK COUNTY

LOCATION AND AREA.

Creek County is located in the northeast quarter of the State and extends from T. 14 N., to T. 19 N., inclusive, and from R. 7 E., to R. 12 E., inclusive. The area is approximately 963 square miles.

TOPOGRAPHY AND DRAINAGE.

Creek County, like the eastern portion of Osage County, lies within the "sandstone hills region", a belt of rather rugged country, fairly well covered by timber.

The county is drained by Cimarron River and its tributaries, and by Deep Fork and Little Deep Fork, tributaries of the North Fork of the Canadian, and by Polecat Creek which, like Cimarron, is tributary to the Arkansas.

The valleys of most of the streams tend to be V-shaped, with narrow flood plains, with the exception of Canadian River valley, which has a broad flood plain.

Hills in this county tend to lie in roughly parallel zones, trending northeast-southwest, frequently with steep escarpments on their east-facing slopes. The hills are usually capped by resistant sandstones (or limestones), especially when east-facing escarpments are found. Between these hill-ranges are lower lands of smoother topography developed in the softer strata. The most prominent escarpments are found in the northwestern part of the county where the Pawhuska limestone forms the resistant bed. Surface elevations vary from 600 to 950 feet.

HISTORY OF DEVELOPMENT

Active development in Creek County began in 1906, when the famous Glenn pool was discovered. The first well was completed in this pool in December, 1905, and by the end of 1906, about 110 wells had been drilled. The maximum production from the Glenn field was obtained in October of 1907, when 3,441,662 barrels were produced for the month. The Cushing field was opened in 1912, with the maximum production coming in June, 1915. The Slick pool was developed in 1919 and 1920, and activity continued into 1921. The Continental or Bristow pool was opened up in 1921 and 1922. During the period between the development of the Cushing pool and the Slick and Continental pools' activity, which was an era of prevailing high prices for oil, many smaller fields were discovered. Active development has continued in Creek County up to the date of the present writing. In recent years, also, some old shallow pools have been given new production from deeper sands.

ACKNOWLEDGMENTS.

The authors have made use of Bulletin 19 as far as possible in been made to numerous articles touching this area and concerned with structural interpretations also of other areas, the stratigraphy and structure of which are similar to those of Creek County. One unpublished paper by Evan Just is also cited. A bibliography of the above articles will be found at the end of this report. The Creek County production map included herein was furnished by the Triangle Blue Print & Supply Company of Tulsa. The authors are also indebted for personal comments, criticisms, and suggestions to Luther White, Richard Hughes, L. L. Foley, Evan Just, and others.

AREAL GEOLOGY

The rocks appearing at the surface in Creek County have been most recently described by Gould in Bulletin No. 35 of the Oklahoma Geological Survey. They comprise a portion of the upper Pennsylvanian, and range from the Coffeyville formation upward to and including the Pawhuska formation. The Checkerboard limestone, which lies near the base of the Coffeyville formation, outcrops near Mounds and crosses the southeastern corner of Creek County. The upper limestone member of the Pawhuska formation caps the high hills near Drumright in the northwestern part of the County. The strike of these and intermediate formations is approximately N. 20° E., and the formations lie in belts of irregular width which cross the county in parallel form, as shown on the new Oklahoma geological map.1

STRATIGRAPHY

SURFACE FORMATIONS.

A brief description of the formations exposed at the surface in Creek County, largely quoted from Bulletin No. 35, of the Oklahoma Geological Survey, and arranged in ascending order, is as follows:

The Coffeyville formation has an average thickness of about 300 feet. The lower part is made up of hard or greenish-gray shales. In this portion, near the bottom, is found the Checkerboard limestone. The latter has a thickness of 2 or 3 feet and is bluish-white when freshly exposed and yellowish-white when weathered. It is fine grained and fossiliferous. The Coffeyville formation grades upward into sandstones of gray to brown color.

The Hogshooter limestone, locally known as the Lost City limestone, is a single bed of limestone with a maximum thickness of about 20 feet where it enters the county just south of Sand Springs. It thins southward. It is well jointed and presents a "shelly" appearance upon weathered surfaces. Its color is medium to light gray. This is the basal formation of the Drum group.

The Nellie Bly formation is made up of alternating beds of shale and hard gray sandstone. The thickness in the north-

ern part of the county is about 200 feet. It is the middle formation of the Drum group, and overlies the Hogshooter limestone and is immediately overlain by the Dewey limestone.

The Dewey limestone in Creek County is a shaleey blue-gray limestone which frequently weathers to dark grayish-yellow or brown. It varies in thickness up to 8 or 10 feet. It is usually quite fossiliferous. It forms the upper member of the Drum group and is overlain by the Ochelata formation.

The Ochelata formation is essentially made up of shales, containing some sandstone and limestone members. Of the latter, the most prominent in this county is the Avant limestone, which, here, attains a thickness usually of 10 feet or less. It is a gray ferruginous limestone which weathers to a dark brown to a reddish-brown color.

The Elgin sandstone is a brownish-gray, heavy bedded sandstone of relatively even texture. At some places there are shale partings. It resists erosion fairly well and its upper surface forms an excellent stratigraphic boundary. Its thickness ranges in this county from 50 to 80 feet. It immediately overlies the Nelagony formation and is overlain by the Pawhuska formation.

The Pawhuska formation consists chiefly of red and gray shales, interbedded with gray sandstones and capped by one or two limestone beds known as the Pawhuska limestone. The sandstones range in thickness up to 20 feet and the limestones are from 2 to 5 feet thick. The whole formation in Creek County varies from 140 to 160 feet in thickness.

Two groups mentioned by Gould in Bulletin No. 35 should be noted here. The Copan, so named by Oehrn in 1910, includes the lower portion of the Ochelata formation, the Dewey limestone, and the Nellie bly formation. The Bris-tow, named by Fath in 1925, includes the Nelagony formation and the upper part of the Ochelata formation down to the base of the Tiger Creek sandstone, which latter, with the Avant limestone, form a part of the Ochelata formation.

**SUBSURFACE FORMATIONS.**

(See Map Nos. I and II)

From the east side of the county the sediments dip westward at about 60 feet per mile and the elevation of the surface tends to rise. All formations, therefore, except the Pawhuska, are partly exposed and partly covered. All exposed rocks have been grouped with the surface formations and unexposed rocks thrown into the subsurface group. The latter are described briefly in descending order, as follows:

The Broken Arrow formation lies below the Dawson coal and above the Fort Scott limestone. The equivalents of this formation to the north in descending order are, Labette shale, Pawnee limestone, Bandera shale, Altamont limestone, and Nowata shale. In its type locality the Broken Arrow has a thickness of 350 to 500 feet but thickens westward and southward. In Creek County the thickness is 800 feet or more, except in the extreme northeast corner of the county, where it has a thickness of 400 to 500 feet. This formation is made up largely of shales, with a few interbedded sandstones and limestones in the upper portion. The Cleveland sand is a part of this formation.

The Fort Scott limestone, according to Fath's bulletin on the Bristow quadrangle, comprises a zone of limestones, with interbedded shales making up a thickness of 100 to 200 feet. This zone is capped by the "Big Lime" of the drillers and includes at its base the Oswego limestone. The Wheeler sand is correlated with the latter.

The Cherokee Shale lies immediately under the Fort Scott limestone. This portion of the section is made up chiefly of shale with a few thin interbedded limestones and thicker bodies of sandstones. The Cherokee averages about 900 feet in thickness in this county, though it thins to 600 feet or less over the Cushing group of structures and is elsewhere found as thick as 1,100 feet. The shales vary in color from light to dark gray. Within the Cherokee are found the following oil producing shales, arranged in descending order: True, Red Fork, Bartlesville (or Glenn), Tucker (or Taneha), and Dutcher.

The Boone formation ("Mississippi lime") underlies the Cherokee shale in Creek County. A stratigraphic hiatus exists both above and below this formation. It is made up of a series of limestone beds sometimes separated by shale partings. The Boone ranges in thickness from a little over 200 feet up to 470 feet. According to Aulin, Clark and Trager the "Mississippi limestone" is divisible lithologically into three members. The lower member is not found much south of the north line of this county. It is made up of a gray limestone and chert. The middle member is a black limestone and is found throughout the county. The lower member is a gray limestone and is absent in the Okmulgee district.

The Chattanooga shale underlies the Boone throughout the county and ranges in thickness from 5 to 70 feet in the logs used for the cross sections shown in this chapter. (See maps Nos. I and II.) There is a hiatus both above and below this formation. This shale is black and slaty and of fairly uniform texture.

The Misener sand, which is correlated with the Sylamore sandstone of eastern Oklahoma and Arkansas, is composed of thin, irregular patches of wind-blown sand believed by White and others to have been derived from the erosion of older sediments at the close of Devonian time. It would be, therefore, related rather to the Chatta-nooga shale overlying it than to the older underlying formations.

The Hunten formation, part of which correlates with the St. Clair marl of eastern Oklahoma, has not thus far been identified in

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Creek County, though it has been found in some wells in the east central part of Lincoln County. It is possible that this formation may later be found in the southwestern part of Creek County.

Where encountered in wells, this formation consists of a continuous white to gray dolomitic crystalline limestone, showing very little shale. The shales are very limy, or are really softer members of the limestone.

The Syrwar shale, shown in Luther White’s map of Northeastern Oklahoma, occupies most of Creek County south and west of Bristow. This shale where found overlain by Hunton is greenish blue to olive green in the upper five to fifteen feet. It is composed of a dark shale toward the base. It is very remarkable in its lithologic uniformity over broad areas and has long been recognized as a distinct formation. It is slightly calcareous and contains a few thin beds of limestone. Its total thickness ranges from 75 to 135 feet. The age of the shale, according to White, is Richmond, and may be correlated with the Cason shale of Arkansas.

The Viola limestone (“white lime”), which in the Arbuckle mountain area has a thickness of from 500 to 600 feet, ranges from 40 to 50 feet thick in Creek County, due to the absence of the lower beds. Here it is made up principally of two beds. The upper bed is a white to grayish, coarsely crystalline limestone and the lower bed is a dense brownish-gray limestone closely resembling lithographic stone. Due to its thinness, where exposed to erosion at the close of the Devonian it has been left frequently as outliers. This accounts for its absence in some well logs in this county. It has been correlated with the Fernvale limestone of the Harrison quadrangle.3

The Simpson formation is composed of post-“Wilcox” Simpson, the “Wilcox”, the Tyner and the “Burgen”, all overlapping the lower Simpson beds.4

The Simpson lies between two unconformities, one under the Viola and the other above the Arbuckle, and extends out beneath the post-Hunton unconformity.

The post-“Wilcox” Simpson is made up of a series of brown or gray sandy dolomitic limestones interstratified with some green shale and thin sandstone members. This attains a thickness at Stroud, Holdenville, Okemah and Cushing of as much as 140 feet.

The “Wilcox” is a white sandstone attaining a thickness of 50 to 200 feet. It has a pure, uniform character which differentiates it from the Tyner.

The Tyner formation is composed of green sandy shale interstratified with thin beds of sand and sandy dolomitic limestone. In the northern part of the county the basal portion is more dolomitic and becomes more sandy southward.

The “Burgen” (Hominy) sandstone, laid down in most of Creek County over the eroded surface of the Arbuckle limestone, is a well cemented gray sandstone. Because of its siliceous cementation it is relatively non-productive. It may be absent in places because of islands of Arbuckle or “Siliceous Lime” in the “Burgen” sea. It reaches 50 feet or more in thickness.

The lower Simpson beds, composed largely of sandy shale and sand, which attain a thickness of 300 feet or more south of Wewoka, probably do not occur in much, if any, of Creek County.

The “Siliceous Lime”, which is correlated with the Arbuckle limestone of lower Ordovician age, is found in several wells in Creek County. From this formation comes the “Turkey Mountain” sand production. It is generally thought to contain no shale breaks of a thickness noticeable in well logs, though one well shown on the accompanying cross-sections has two shale beds of from 10 to 20 feet in thickness in that portion of the section which the writers believe to be the “Siliceous Lime.” Most generally this formation is chiefly made up of limestone, sandy limestone and sandstone beds.

Granite is found in certain in only one well in Creek County. This is located in sec. 30, T. 19 N., R. 7 E. where it was encountered at from 3,670 to 3,704 feet. In this well the granite overlie by 600 feet of “Siliceous Lime.” Overlying the “Siliceous Lime” is the Tucker sand, while the “Wilcox” is missing. The granite is probably pre-Cambrian.

It is not known just what the topography of the granite surface in Creek County is, nor whether buried ranges of hills or mountains of granite may occur here. The single occurrence in Creek County is under the south end of the Cushing group of structures, suggesting a relationship between possible granite ranges and the larger structural features. This relationship will be discussed in a later paragraph.

STRUCTURE

GENERAL STATEMENT.

Since a large part of Creek County is well covered by timber and the greater number of hard outcropping sediments are sandstones with irregular thickness and extent, reconnaissance of the surface structures is very difficult. In addition to this, with a few exceptions, the surface structures are small and with relatively low structural relief. For these reasons it is the belief of the authors of this report that there is much undeveloped territory in Creek County underlain by small structures yet to be discovered which hold promise of future production. It is also their belief that a study of the typical structural conditions and their interpretations in Creek County will present a key to the whole Creek County problem which will be of value to operators interested in exploiting this territory.

3. Published in the Oil and Gas Journal, April 1, 1925. Also published as Bull. 49-B of the Oklahoma Geological Survey.
5. See cross-section accompanying Luther White’s map, Bull. Okla. Geol. Survey No. 46 B.
Since the structures of Creek County appear to have been formed by a relatively uniform group of forces, and seem to have a more or less definitely arranged pattern, and since certain types of structure appear to follow more or less fixed rules regarding position of axial plane, surface and subsurface dips, and the like, a correct interpretation of the origin of the structures in this county seems absolutely necessary, not only to the search for undiscovered anticlines, but also to the proper recommendations for the testing of any single structure. The authors, therefore, present this chapter on structure with a view to reach, if possible, the true interpretation of the forces acting in this general region, and the effect of these forces upon the rocks of Creek County.

STRUCTURE OF THE AREA

Regional structure. The rocks of this county strike from North 10 degrees, to North 20 degrees, East and dip Westward at an average rate of about 75 feet per mile. This general monoclined dip is rarely to be found regular for any great distance, but is almost everywhere interrupted by faults and folds of various types. The faults are almost always normal and are usually arranged in groups. Within the groups these faults are en echelon. The folds take the form of synclines, domes or closed anticlines, plunging anticlines, and terraces or arrested monoclines. The anticlines are also frequently arranged en echelon, but less noticeably than are the normal faults.

Normal en echelon faults. Most of the faults of Creek County are normal and are arranged en echelon in fairly straight-line zones. These zones trend about North 10 degrees, to North 20 degrees, East, which is about the same as the normal strike of the rocks of the county. The faults themselves take a northwesterly direction making an angle of about 45 degrees with the line of the zone in which they lie. (See Fig. 2.) There is a striking parallelism between the individual faults in any single zone. There appears to be little difference between the number of faults with the downthrow on the northeast and the number with the downthrow in the opposite direction. These faults seldom exceed two miles in length (the maximum being about 3½ miles) and the throw is rarely in excess of 75 to 1000 feet (with a maximum of 130 feet). The average length appears to be between a mile and a half and a half while the average throw seems to be less than 50 feet.

Faith states that these en echelon faults have their greatest displacement near the basement rocks, that the displacement decreases upward, and that many of the faults do not reach the surface. It is the opinion of the authors that the throw of the en echelon faults decreases downward. Their reasons for this belief will be set forth in a later paragraph.

There are a number of surface phenomena accompanying these faults, such as slicksiding of sandstone and limestone beds, where cut by the faults, shearing and veining of sandstones and limestones in the zone of faulting, buckling of ledges into ridges following the fault trace, and the formation of abnormal dips probably by slumping toward the fault plane which may take place on either the upthrown or downthrown side of the fault, or on both sides.

Normal northeast-southwest faults. So far as the authors are aware, no northeast-southwest normal faults reach the surface in Creek County. It is suspected by several geologists, however, that some such
faults occur in the Pennsylvanian rocks below the surface. Such an one is described by Path as cutting across the Slick field in Tps. 15 and 16 N., R. 10 E., marked by a series of dry holes. Several such faults have been mapped, however, in Hughes, Seminole and Okfuskee counties. The strike of these faults closely coincides with the trend of the en echelon zones in these counties. These faults range in length from 2 to 10 miles and in displacement from 100 to 300 feet.

**Thrust Faults.** The authors know of only one thrust fault in Creek County. This crosses the northwest quarter of Sec. 10, T. 18 N., R. 10 E. It strikes northeast and southwest and lies approximately at right angles with the trace of the en echelon faults, and parallel with the axes of the small northeast-southwest folds. Its best exposure is in a creek bank near the north side of the section, where a heavy limestone bed is cut by the fault at an angle of 40 to 45 degrees with the horizontal. The fault plane is well slickensided. The maximum throw is about 60 feet.

**Large northeast-southwest folds.** There are a number of anticlines in the county much larger than the average, such as the domes in the Cushing field. (See Fig. 3.) The long axes of these folds lie more nearly north and south than those of the folds next to be described, and are closely parallel with the trend of the en echelon fault zones in this part of the county. As well as being larger areally, these anticlines usually also have much more pronounced structural relief. Maximum reverse dips on the Cushing structures range between 100 and 160 feet from top of dome, to the bottom of the deepest part of the syncline. These domes range from 1 to 3 miles in width and from 2 to 5 miles in length.

The structural relief on the surface of the Cushing group of structures is much lower than that on the producing sands. Beal mentions this difference in interval between surface and lower formations showing the same in the form of tables. The increase in dip of the sub-surface formations over those at the surface ranges from 50 to 200 feet approximately. Beal also mentions the fact that the high point on the producing sands sometimes appears to be eastward from that on the surface beds.

**Small northeast-southwest en echelon folds.** It is to be observed that within the zones of en echelon faulting there is usually more or less intense folding, while between these belts there is little or no folding of any prominence. The folds in the fault zones may be grouped into three general classes. These classes will be described in this and the following two paragraphs. These folds rarely exceed a mile or two in length and may take the form either of domes or of open anticlines.

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The first class is that of anticlinal folds, the long axes of which lie northeast and southwest, approximately at right angles with the traces of the en echelon faults, and at an angle of about 45 degrees with the direction of the fault belt in which they occur. Like the larger folds of the Cashing field, the structural dips of these folds increase with depth. The surface formations show the reverse or southeast dip on these anticlines ranging from 5 to 10 feet up to 30 or 40 feet. The corresponding dip on the deeper subsurface formations is frequently double that on the surface formation above them. The authors have often observed that the axes of these anticlines are inclined westward, placing the top of the anticline on the oil sands west of the top of the same anticline on the surface formations. Sometimes this pitch of axial plane will shift the sub-surface apex as much as a quarter of a mile or more west of the surface apex. (See Fig. 7). Sometimes these anticlines are terminated on their northeast ends by faults.

Small northwest-southeast folds. This is the second class mentioned above, and into this group fall the folds whose long axes lie roughly parallel with the individual faults in the fault zones. (See Fig. 3). These folds are thought to decrease in intensity with depth. They are most usually found in the zones of faulting and, more frequently than not, are associated with the faults themselves. They appear to be less uniform in character than the class last described above.

Folds without regular pattern. Into this third class are thrown folds whose pattern is so irregular as to make classification difficult. They appear to be formed by the modification of one or the other of the folds described above.

Terraces. The most common form of terrace is that which has its greatest elongation roughly parallel with the strike of the rocks of the region, and also parallel with the lines of en echelon faults. Terraces of this sort may be several miles long and a mile or more wide, and may be modified by anticlinal, synclinal or fault irregularities. Some of these terraces are very productive. Such a terrace is to be found occupied largely by the Glenn pool. (See Fig. 3). This terrace is crossed by flutings or slight anticlinal and synclinal parallel folds whose axes lie about at right angles to the long dimension of the terrace. The Slick pool is on another terrace which has an irregular surface. In this pool the more prolific wells are found upon the small “highs” which form these irregularities.

Terrace production is more frequently found upon the westward edge of the flattened area and part way down the steeper slope west of the “break” in the structure.

Another form of terrace has been observed whose longer dimension takes a diagonal course down the normal dip. It is much smaller than the examples cited above and has probably a distinctly different origin.

Minor irregularities. At no place in the county do the structure contours follow straight lines, nor are they anywhere spaced uniform-

ly for any great distance. They rather follow irregularities in direction which may be due to the forces which combined to form the more prominent structures already described, or they may be due to such conditions of sedimentation as thickening and thinning of beds locally, or both. Since these small features are rarely significant as touching the problem of production, they will be ignored in the further discussion of the structures and their origin.

Origin of Structural Features.

General statement. Several theories have been advanced to explain the origin of the Mid-Continent types of structure. The authors will now attempt to discuss the greater number of these theories one by one, and to test, as far as possible, the applicability of these theories to the local problems in Creek County. After testing these theories the authors will bring up conditions which these theories do not satisfy, either wholly or in part, and will attempt to find a theory which seems to explain more completely the origin of Creek County structures. The reader must not allow himself to think that any simple theory will explain structural conditions in this county any more than in any other region.

Folding by vertical thrust. Gardner9 in 1917 suggested that local folds may have been formed by vertical transmission of pressure from deep seated sources in the zone of rock flowage. It is possible that the presence of granite ridges at relatively shallow depths in the Mid-Continent region might suggest some such explanation for the structures overlying them. On the other hand, for every structure underlain by a prominent granite ridge there are hundreds that show no such relationship. Furthermore, the average Mid-Continent structure is very small and this fact alone precludes any such explanation, because it seems impossible for forces to come from the zone of flowage and apply themselves to such small areas. This theory, also, does not seem applicable to a territory in which structures are aligned and have definite axial arrangement.

Warping of sediments accompanied by faulting during deposition. McCoy10 explains the faulting and folding of this area by the statement that during the deposition of the Pennsylvanian, two basins were formed, one in southeastern Kansas and one just north and northwest of the Arbuckles in central Oklahoma, leaving the territory of Tulsa, Osage, Creek, and Pawnee counties as a fulcrum between these two basins. The formation of these two basins, he believed, would cause tension in the fulcrum area which would be relieved by tension faults with northwest-southeast trend. In order to spread these faults over the territory in a northeast-southwest direction, he assumed a shift back and forth of the fulcrum point.

In considering this explanation, it does not seem possible to develop enough tension to explain even a very small proportion of the faults actually found in the area, even if no readjustment by differential movement were considered. If small, sharply folded anticlines may be formed with little or no faulting, (and many cases may be cited), certainly a broad arch which is hundreds of miles across cannot be expected to develop tension faults upon its crest. Such slight folding would most readily and immediately be taken up in slight differential movement and readjustments.

**Packing and condensation of sediments.** Blackwelder\(^7\), commenting upon the structures of east-central Kansas, believes compacting of sediments over buried topography will account for most of the anticlines in that region. He states that the folds do not take the form expected as a result of tangential compression, that the arrangement of the folds is not en echelon, as would be expected by tectonical movement, and that there appears to be no relationship between adjacent faults and folds. He notes the divergence of beds away from the axes of the domes and states the belief that this divergence is best explained by the compacting of the sediments during deposition.

Nonnelt\(^8\) explains the origin of some of the Mid-Continent structures also by the theory of compaction. He lays special emphasis, however, upon the effect of sand lenses in causing irregular consolidation of the sediments.

Powers\(^9\) believes also in the efficacy of sedimentary compression during deposition, especially over old land surface irregularities, but, in order to explain the increase of structural dips with depth in many cases, he also invokes pressure, either regular or spasmodic, uplift of the buried hills as partially responsible for the origin of at least some of the structures. Minor structures between certain "granite buttresses" he explains are due to compressive or local tangential forces.

Rubey\(^10\) also agrees that gravitational compaction has at least something to do with the formation of some structures in the Mid-Continent region. Many others follow the same line of reasoning as that adopted by the foregoing writers.

Lewis\(^11\) has made a volumetric study of compaction of the silts in the Hudson River and states that clay silts there, when buried to a depth of 50 feet, suffer a reduction in pore space of about 55 per cent. Deposition there is very rapid.

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**Figure 4.** Quantitative sketch showing how compaction of sediments over old topography would affect the overlying sediments, if it is assumed that the sediments will compact as much as 50 per cent and that compaction does not take place until deposition is complete. A is one level of completed deposition compacted to A'. B is another level of completed deposition compacted to B' and on the old surface the same as if A and A' were not present. It will be noted that compaction always takes place vertically, and that the diameter of the base of the reflected structure will be the same as the diameter of the base of the buried hill, regardless of the thickness of the sedimentary section. Also the amount of structural relief obtainable depends on the height of the buried hill and not upon the thickness of the sediments deposited above line A. Thus line A (200 feet of shale) compacted to A' gives as much relief as B (950 feet of shale) compacted to B'. The stratigraphic interval will be the same to the side of the buried hill as directly over it. It seems obvious that compaction never waits until deposition has ceased before becoming effective, and that such an ideal condition as indicated above is never obtained in nature. Complete compaction means that the surfaces of all the individual particles are in contact and nothing but pore space remains.
Leith and Mead, & show that clays have an average pore space of 27 per cent while shales have an average in pore space of 33 per cent. This reduction in pore space from clay to shale is almost identical with that found by Lewis in his Hudson River study.

Just, & after citing Leith, Mead, Lewis and others, concludes that even in extreme cases the compaction deformation in sediments would not exceed 35 per cent of the original volume (measured in amount of slump of overlying beds) and rapid compaction at beginning of deposition would lessen even this 35 per cent.

The authors concede that compaction does take place during deposition of sediments, and must be taken into consideration as a factor in discussing the origin of structure in sediments. They cannot however, consider compaction as any more than a minor element. The following observations militate against sedimentary condensation as the principal explanation for the origin of Mid-Continent structures:

(a) If all Mid-Continent structures must be explained as originating from compression of sediments during deposition over old land surface irregularities, the large number of these structures, and their relatively small size and frequent steep dips, makes necessary the presence of an old land surface of extremely rugged character. This rugged topography must have existed on top of the Mississippi lime or later, because the rocks of Mississippian age and older are less compressible and, furthermore, many unconformities below Mississippian rocks would tend to fill in the depressions and eradicate all but the most extreme irregularities over older land surfaces.

(b) If compaction is the chief element in the formation of structures in this region, one would expect a surface structure map of any and all parts of the region to show some resemblance to an ordinary surface topography map. General drainage patterns and the like, however, cannot be found, even in the modified form that one would expect.

(c) While there is an increase in structural dip on many of the Mid-Continent anticlines and domes as one progresses downward, which may be accounted for by compaction during deposition (See Fig. 5), this may more adequately be explained by progressive folding during deposition.

(d) Compaction cannot take place at once, but rather appears to be going on during the entire period of deposition, with probably the greatest amount of shrinkage in any one body of sediments taking place almost simultaneously with the deposition of that body. This is particularly well illustrated by the Hudson River clay silts. The tendency, therefore, will be for this immediate compaction to result

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17. Just, Ewan, Unpublished manuscript, 1925.

Figure 5. Quantitative sketch showing how compaction of sediments over old topography would effect the overlying sediments if it is assumed that the sediments will compact as much as 30 per cent, and that compaction takes place as deposition proceeds. A is compacted to A’. On top of the compacted surface A’ sediments up to B are deposited; these are compacted to B’. This process continues until P is compacted to P’ and the compacted surface is almost flat. Also, the stratigraphic interval to the side of the buried hill is greater than that immediately above it, which condition can only be obtained by compaction during deposition or by progressive folding during deposition. Assuming complete compaction to take place at intervals of about 200 feet, by the time 1,200 feet of sediments are deposited and compacted, very little reflection of the old topography is noticeable. Recent observation has shown that complete compaction very nearly takes place after 100 feet of burial. The above case greatly exaggerates the amount the sediments above the Mississippi lime would compact, and doubles the depth at which complete compaction would probably take place. Since the buried topography does not generally reach within 2,400 feet of the surface in Creek County or northeastern Oklahoma, it does not appear that compaction can account for the type of structural features found there.
in the accumulation of more sediments in the compaction basins. (See Fig. 5), which would overcome a large proportion of the results expected from compaction should it all take place late in the period of deposition. Furthermore, after deposition has reached the tops of the buried hills, compaction structures being formed in the sediments being deposited, would tend to show themselves in the form of seafloor hills. These higher places would be much more subject to the erosive effect of waves and currents and such water action would tend to remove them and reduce the sea floor to a dead level. This, therefore, would greatly reduce the effect of compaction in the formation of structures, especially as deposition continues to considerable depth.

(c) In order to explain some relatively deep closed synclinal basins by the compaction theory, one would have to have in the old buried topography an exceptionally deep, steep sided, closed basin, such as would only probably be found in karst topography. In some cases the topographic basin would have to be over 200 feet deep if we assume compaction takes place after deposition, and much more if it takes place during deposition, because early compaction during deposition would tend to obliterate the effect of compaction over such basins, for by the time the basin itself was filled with sediments the compaction would be almost complete and there would be relatively little settling of sediments lying above it. Basins of that character and depth are hardly to be expected in this region.

(f) Compaction would hardly explain the formation of a fault with a dome on one side and a closed depression on the other, especially where the structure contours are “D” shaped with the fault forming the straight side. A good example of this may be seen in Fath’s map (U. S. G. S. Bull. 759, Pl. VIII) of the Bristow quadrangle in Creek County, sections 13 and 84, T. 17 N., R. 9 E. Many similar examples may be found in Creek County and elsewhere in the Mid-Continent area. (See Fig. 8).

(g) Many closed structures of the Mid-Continent area show steeper reverse dips than basinward dips. While this is not necessarily the rule, the frequency of their occurrence raises the question as to whether such variance of dip can be explained by compaction. To explain it by this theory requires the occurrence of buried topography with an equal number of hills with exceptionally steep east slopes.

(h) Subsurface studies have brought out the fact that axes of a great number of structures in this region plunge in a basinward direction, i.e., the high point on the the high point on the surface formations. Often this shift deeplying strata is located in a basinward direction from amounts to over a quarter of a mile, where subsurface formations are mapped at a depth of three thousand feet or more. This axial shift can in no manner be explained by compaction. (See Fig. 7).

(i) Many structures have been reported in which the folding decreases with depth. These cannot be explained by the compaction theory. The explanation of their origin will be found elsewhere in this chapter.

(j) Compaction cannot explain faults of the en echelon type, or even adjacent parallel faults of any frequency. Faults caused by compaction would tend to take directions at a tangent to the curve of the structural contour lines.

(k) At least one thrust fault has been found in Creek County. This cannot be explained upon the basis of the compaction theory.

Direct tangential compression. The earlier study by geologists of anticlines and synclines was carried on in regions where tangential compression on a large scale had taken place. Indeed the earlier production of oil came from such regions. Geologists familiar with that form of structure (Appalachian type, for instance) working later in regions of flat dip, such as the Mid-Continent area, naturally turned first to the tangential theory to explain the origin of our Mid-Continent structures. The forces of compression under this theory may be transmitted either horizontally through the sediments, or through the basement complex and by it into the overlying sediments in the form of more or less vertical movements.

It is not possible, however, to accept the tangential compression theory as applied through the sediments because of the incompetency of a sedimentary body of less than a mile in thickness to transmit such forces through a hundred or more miles of distance horizontally. If the Paleozoic sediments were subjected to severe thrusting from the Ozarks, as is assumed by some, there would be severe shearing and folding at the point of thrust which would die out rapidly and disappear long before the central region of Oklahoma and Kansas was reached. Besides, the Ozark uplift is not sufficiently great to cause any appreciable shortening in the sedimentary section. In fact, the very small shortening possibly caused by the synclinal form taken by the sediments between the Ozarks and the Rocky Mountains would most likely be taken up in rearrangement of sedimentary particles so that no crumpling of sediments would be necessary. It is to be noted that there are no steep and rapidly drying folds developed from the Ozarks westward.

On the other hand, the basement complex (crystalline rocks underlying the Paleozoic sediments) is amply competent to transmit horizontal thrusts, and Powers explains the successive uplift of buried


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hills in this region by this means. It does not seem possible, however, to explain the uplift of small more or less isolated points such as the buried hills (e.g., the Nemaha Mountains) in this way, especially at such great distances from the points of thrust, even granting the competency of the crystallines to transmit these forces. In the first place, the same type of folding (steep near point of origin, and rapidly dying out westward) would be expected in the crystallines as in the case of the sediments already mentioned. Such deformations would be reflected in the overlying sediments and should be found if they occur. To obtain a crumpling of the crystalline rocks by tangential compression would require forces much greater than are known to have been at work in the Ozarks. Gentle thrusts, however, would result in development only of broad arches and not in the formation of small local uplifts.

Such close folding as a result of tangential compression does occur, however in the Ouachita-Arkabucklerogenic element, (Ouachita Mountains of Arkansas and Oklahoma with connecting Arkabuck and Wichita Mountains in Oklahoma). In such cases, however, thrusting comes from the wrong direction to explain structural features in Oklahoma and Kansas as a result of direct tangential movement. Neither is the axial direction of the Ozark uplift parallel with the direction of the buried hills of northern Oklahoma and Kansas.

Rotational stress transmitted to sediments by shearing in the basement complex. Comparatively little literature is to be found developing this theory, as applied to the interpretation of the origin of the Mid-Continent structures. One of the earliest was Fath who set out to explain the origin of the faults and anticlines of the northern Mid-Continent area by this theory. Fath, in the preparation of a report on the Bristow Quadrangle of the possible origin of the echelon faults in this region is not, therefore, advanced in this bulletin. Later, however, in U. S. Geol. Survey Professional Paper 128, he took up the discussion of the origin of the Mid-Continent structural features. He noted first that the alignment of the echelon fault zones, the major anticlines, and the Nemaha ridge is essentially parallel. He noted also that the pre-Cambrian rocks are very competent, that the Cambrian, Ordovician, and Mississippian rocks are competent but less so than the pre-Cambrian, that the Pennsylvania rocks are relatively incompetent. He states that the Ozark uplift has two phases, (1) late Mississippian or early Pennsylvania and (2) post-Paleozoic. He states further that the Ozark uplift is the cause of the prairie plains monocline and that slight movements or readjustments

ments took place during Pennsylvania deposition intermittently. These he considers very significant. He observes the location and arrangement of the faults of this area and states that they originate from forces operating parallel with the direction of the en echelon line. He believes that the controlling forces must have been transmitted not by the sediments, which are not competent, but by the crystalline basement rocks, which are amply competent. Horizontal movements, he thinks, in the basement rocks set up rotational stress in the overlying weaker sediments and these stresses resulted in the formation of en echelon faults. He thinks many fault planes occur at depth and disappear before reaching the surface and that faults which may be found at the surface increase with depth. He believes that some anticlines were formed by the change from a fault into a fold toward the surface. Other folds, he thinks, are due to vertical displacements of master faults in the basement rocks. Depressions he explains by reverse displacements. Thus, combined horizontal and vertical movement may produce both folding and faulting. Also, he states that reverse movements at different intervals in the same place may compensate each other and produce greater folding in the upper than in the lower beds, as at the Cushing, Mount Pleasant and Shamrock domes in the case of the Wheeler and Layton closures. Fath admits the weakness of his theories to explain (1) reverse diys against fault planes, (2) why some vertical displacements along major faults did not reach the surface at some places where sediments are not over 1000 feet thick, and (3) divergence of some anticlinal axes from the direction which they would be supposed to take according to his theory. He explains the formation of the granite ridges as due to vertical movement along lines of weakness or master faults. This conforms with Moore's hypothesis. In commenting upon Fath's work the authors wonder why he did not observe in the development of his tortional theory that at right angles to tension, causing the en echelon faults, there would also be compression. This is especially well shown by Mead's (see Fig. 6).

Heald rather follows Fath in favoring faulting along major zones of weakness with attendant secondary effects as being the cause of the origin of deformation in the northern Mid-Continent area.

Just also explains the deformation of this region as originating from rotational stresses set up in post-crystalline sediments by horizontal movements along master faults in the basement complex. Like his predecessors, he fails to offer an explanation for the origin of the major movements. He goes one step further than Fath, however, in explaining many of the small folds associated with the en echelon faults as due to compression developed by the rotational stress.

Foley, working independently, coincides essentially with Just in discussing the immediate causes of the origin of the faults in Creek and Osage Counties, Oklahoma, but he goes further and attempts to discover the origin of the major forces causing the development of the rotational stresses. He performed experiments in which he covered two wooden blocks with wax and moved one block horizontally relative to the other, developing a master shear plane, above which the wax was deformed. This caused in the wax faulting and folding of the en echelon type. He thinks the major forces were brought about by a thrust from the Ozarks toward the Kansas granite ridge, using the latter as a buttress, and explained the granite ridge as probably originating from forces coming from farther west, possibly from the Rocky Mountains. If one considers, however, that the thrust forces in the region between the granite ridge and the Ozarks came from the uplift of either one or the other or both of these elements, it does not seem possible to develop sufficient shortening in the upper sediments to account for any appreciable deformation even if the latter should be competent to transmit these forces. On the other hand, if the thrust is transmitted through the crystalline rocks from one point to another, it does not seem possible for any one small element (ridge) in the crystallines to act as a buttress to movements in the crystalline mass itself. Also according to his theory, his master shear zones would tend to follow a northwest-southeast direction as well as the direction shown by Fath. The former shear zones would develop en echelon faults at right angles both in direction and trend with those found on the structure map. Such are not known to occur in any appreciable amount.

For reasons set forth in preceding paragraphs the authors believe that deforming forces other than gravity must be discovered to explain the types of deformation found particularly in northeastern Oklahoma and Texas. Logically, one should look for the evidence of these forces in the areas of greatest deformation in this region and trace the effect of that deformation into the adjacent areas in which these forces moved. The area of greatest deformation near here is the Ouachita portion of the Ouachita-Arthucke orogenic element in the southeastern part of Oklahoma and the southwestern part of Arkansas.

in the opposite direction caused by undercutting. This type of structure does not necessarily presuppose an igneous basement. Dikes, resisting erosion, especially where cutting much less resistant sediments, frequently form straight ridges. The dike rock, however, was originally injected into fault or joint openings and its presence presupposes earlier lines of weakness and really fall into the first class. Cuestas, also, frequently are eroded into very irregular lines by the more active work of some stream systems than others crossing them, and consequently would not tend to form straight ridges for great distances without some considerable local changes of direction. Therefore, where one finds straight-line topographic features, he naturally expects to discover that this topography is controlled by structure showing movements along previous lines of crustal weakness.

Some of the prominent lines of weakness in the United States are as follows: California Coast Ranges, Sierra Nevada fault block, majority of basin ranges, faults and folds of the high plateaus, Rocky Mountains, Ozarks, Illinois-Wisconsin flexure, Cincinnati arch, and the Appalachian Mountain systems. Closely paralleling these are the buried granite ridges of Kansas, sometimes called the Nemaha Mountains, which extends from northern Oklahoma, across Kansas, to the southern part of Nebraska. In reality this ridge falls about half way in direction between that of the Appalachian region and that of the Rocky Mountains. This granite ridge is, of course, minor in character to those first mentioned. Also, all across the country are thousands of minor lines of weakness which give the continent a "grained" character as mentioned by van der Graaff.13

Upon the surface of the pre-Cambrian rocks in the Mid-Continent region are deposited sediments of Paleozoic and later age of varying thickness. It is reasonable to suppose that the pre-Cambrian rocks had been much disturbed prior to Paleozoic deposition, and that most, if not all, of the post-Cambrian disturbances of the Mid-Continent area took place following lines of weakness developed in pre-Cambrian time. During, and even subsequent to Paleozoic time, orogenic activity took place (especially around the eastern and southern sides of the northern Mid-Continent region) forming the Ozarks and the Ouachita-Arkansas orogenic element and forming the prairie plains monoclinal. The seat of this activity, as evidenced by the intense folding in the Ouachita Mountains, appears to be in that region, lying to the south and southeast of the Kansas-Northern Oklahoma portion of the Mid-Continent area.

The direction of the forces originating in the Ouachita region, as related to the Northern Oklahoma-Kansas region, appears to be northward, (See Fig. 6), with the amount of force dying out westward from the Ouachita Mountains toward the Arbuckles and Wichitas. The resultant of this thrust would be rotational in character and would be west of north. This thrusting movement, acting upon the basement rocks, would result in re-opening lines of weakness in these rocks in northern Oklahoma and Kansas which already had a northeast direction about at 45 degrees with the resultant thrust mentioned above. The thrusting would set up a horizontal differential shearing in the crystalline rocks which would follow these lines of weakness. The amount of shearing would tend to diminish westward and northward from the Ouachita region.

The effect of this shearing would be to set up in the overlying incompetent beds rotational stresses which would result in the formation of dome-type compression anticlines and tension faults. These folds and faults would follow the lines of shear and be related directly to them. The folds would tend to have long axes in a northeast-southwest direction and the direction of the faults would tend to be in a northwest-southeast direction, about at right angles with the antecedent axes, and both at about 45 degrees with the lines of shear. (For illustration of the principles applying to this type of structure, see Fig. 6 and Fig. 7).

While in the crystalline rocks the dominant movement will be essentially horizontal, there will doubtless be some raising or lowering of the surface of the crystallines on one side or the other of the shear zones, especially at points closer to the region of thrust. These vertical movements would give rise to folds and faults in the overlying sediments with lines corresponding to the direction of the shear zones. These features are apt to be larger and more prominent than the en echelon faults and smaller anticlines caused by rotational stresses over the shear zones. Faults caused by vertical movements in the basement rocks along shear zones would tend to diminish in displacement toward the surface, sometimes even resolving themselves into folds with axes parallel with the line of the underlying shear.

Besides the series of en echelon faults and folds, there are in this region folds whose axes closely parallel the direction of en echelon faults. These can easily be formed by the change of such faults upward into slumps or diapirs. A modification of the en echelon type of fold (northeast-southwest axis) by folding over buried en echelon faults (northwest-southeast) may result in any number of types of irregular folds. The en echelon folds, it must be borne in mind, are compression folds, while the plunging anticlines caused by slumping against or over en echelon faults are tensional in character.

Sometimes (See Fahy’s structure map of the Bristow Quadrangle) D-shaped closed synclines are found with the straight side formed by a normal fault. These synclines are always on the down-thrown side of the fault. The amount of throw in a normal fault is always greatest in the middle and diminishes to extinction toward its ends. Such closed synclines are, therefore, formed by the simple slumping of the down-thrown element. Sometimes these occur directly opposite D-shaped closed anticlines on the opposite side of the fault. This type of structure is impossible to explain by any other means, such as sedimentary compaction. (See Fig. 3).

It is clear to be seen that under ideal conditions the amount of throw in a tension fault in sediments caused by horizontal movement in basement rocks along shear zones will be directly related to (1) the amount of horizontal movement tending to stretch the sediments in the direction of elongation of the strain ellipsoid, and (2) the thickness of the sedimentary prism. Assuming, therefore, a fixed amount of horizontal movement at a given point, the amount of vertical readjustment due to stretch would increase upward from the basement rocks. This readjustment may take the form of a simple normal fault rising from the basement rocks upward with increasing throw toward the surface, or it might be changed by passage through more plastic rocks such as shales into slump or tension folds. On the other hand, since both the tensional and compressional readjustments following the movement in the basement rocks along the shear zones are local in character and must balance each other more or less, and the incompetency of the sediments does not permit the transmission of shear from the crystallines to the surface, the mild resistance of friction in the more plastic sediments and the lateral slip of the sedimentary beds will tend to readjust these beds so as to mask effects of the stresses set up by basement shear. If a thick enough sedimentary prism overlay the crystalline shear zone, therefore, it is conceivable to expect tension faulting to increase in throw upward until a point is reached where horizontal (possibly rotating) movements in the beds would begin to diminish the vertical readjustments. From this point vertical readjustments would decrease upward till at some point horizontal movements between beds would entirely mask lower structures and no disturbance would result. This accounts for the fact that many en echelon faults decrease with depth, often disappearing before reaching the “Wilcox” horizon. This fact has been called to the attention of the authors by Richard Hughes and others, as applicable to Seminole and adjacent counties. These geologists have mentioned, also, the continuance of northeast-southwest faults in the same region, mentioning the fact that they appear to increase in throw with depth. These latter faults are explained in an earlier paragraph.

In the case of the en echelon type of folds, formed by the compressional element of rotational stresses, the most active forces are set up right at the contact of the sediments with the basement rocks where the horizontal movement is greatest. In the Creek County region, as elsewhere in this part of the Mid-Continent area, the thrusting component set up by the shearing of the basement rocks is from the southeast side. This would result in steeper anticlinal dips on that side of the axis and gentler on the other. This would cause the formation of asymmetrical (or lop-sided) folds, as shown in Fig. 7, which causes the axial plane of the anticline to plunge northwestward. This axial plunge is so great that in some cases folds of this type have their high point on the “Wilcox” sand as much as a quarter of a mile northwest of the axis of the surface anticline. This lack

Figure 7. Diagrams of the possible origin of the northeast-southwest folds with their frequent shift of the axial plane to the west. If sketch A be an undeformed cross-section taken between OC of sketch B. In figure 6, then B, C and D above show the progressive effect of this compression. The greater movement in the basement crystalline rocks is always in the segment southeast of the zones of shearing (Figure 6, sketch D). This in turn causes the greatest compressive forces in the sediments to come from the southeast. This compression is greatest on the lower beds, tending to drag them under the upper beds. Arrows indicate the relative intensity of the horizontal movement in the beds.
of symmetry is notably absent in the larger anticlines following the direction of the shear zones and caused by direct vertical movements, and is not noticeable in the slump folds due to faulting.

Where either vertical movements in the basement rocks or rotational stresses caused by horizontal shearing of the basement crystallines affect the overlying sediments in uplifting them periodically during sedimentation, it is conceivable that the sediments would be deposited more thinly over the uplifted portions, and the result would be an increase in the sedimentary intervals away from the structural axes. (See Fig. 8). This would tend to make the deeper beds in the anticlines show steeper structures than the beds found toward the surface. This would further emphasize the same effect (shown in Fig. 6) due to greater compression of the folds near the basement rocks by rotational compression stresses, in the case of the en echelon type of folds. On the other hand, especially in the case of vertical movements in the basement rocks transmitted to the overlying sediments, it is conceivable to expect occasional reverse or reactionary movements causing the reverse condition to take place, as in the case of the Cushing structure already cited.

This covers the discussion of all structural features of Creek County, with the exception of the one thrust fault already mentioned. The direction of this thrust fault is closely parallel with that of the axis of the en echelon type of fold and roughly at right angles with the direction of the en echelon faults. This only adds to the proof of compression forces set up by the rotational stresses already described. The relative absence of these thrust faults proves the incompetency of the sediments of this region, where thrusts result in folding more than in overthrust faulting.

As mentioned by Thom in his remarks upon Foley's paper, there are a number of thrust faults in the region just north of the Ouachita Mountains. These strike in a direction slightly north of east, and about at right angles with the direction of the Ouachita thrust, and are due directly to that movement. They are accompanied by numerous normal faults which probably largely followed the active thrusting action and are due to relaxation and readjustment.

As previously stated, it is to be noted that the faults which follow a northeast-southwest direction are most common in the southern part of the northeastern Oklahoma area. These northwest-southeast faults, however, persist in great numbers until the Kansas line is reached, when they die out rather rapidly. Less data, however, is available in a large way for southern Kansas. The small folds, which take the form of "noses" in Seminole, Lincoln, Okmulgee, Creek and Tulsa counties, increase in structural prominence and a greater percentage of them are closed into dome form as Osage County is reached. The structural relief of the small anticlines which is very prominent in Osage County gradually dies out into Kansas. This change


Figure 8. Sketches showing the effect of progressive folding during sedimentation on the stratigraphic interval, also what might be obtained if the direction of the vertical movement was reversed. This may be a possible explanation of the abnormal conditions found on the Cushing structure.
in structural character as one progresses northward is probably due largely to three things: (1) decrease in thrusting effect as one proceeds away from the region of the origin of that force, causing diminution in the amount of the resultant shear in the crystallines and its effect upon the overlying sediments, tending to cause decrease in both folding and faulting northward; (2) thinning of the sedimentary overburden northward, causing the surface rocks in Osage County, for instance, to be nearer the crystalline shear zones than in Creek or Okfuskee counties so that the structure at the surface in Osage County would more nearly be correlated with sub-surface structures in the counties southward and thus have more relief than the surface structures in the latter counties; and (3) change northward in the character of the sediments, thus bringing about a different result from the same submerging forces when acting upon those sediments. In the Kansas area there is more true shale and fewer sandstones, and more limestones than in northern Oklahoma. The shales of the northern Oklahoma area, especially in the group of counties in which the en echelon faults predominate, are most frequently apt to be of a sandy character. It is to be noted also that the en echelon type of faults disappears both eastward and westward where, largely, more limestones and true shales appear as also, northward into Kansas. Sandstones and sandy shales readjust themselves by breaking rather than by folding. Clay shales fold rather than break. Limestones, allowing for the time element, (though brittle to sudden shocks) easily fold by recrystallization of the calcite particles and gliding of the crystals. Such folding is, however, very difficult to obtain by placing sandstones under stress. Thus, it is to be seen that northward into Kansas, where clay shales and limestones prevail, the pressure component of the rotational stresses is taken care of, as elsewhere, by folding, while the tension component is also taken care of by folding because the rocks are less apt to fault than the sandstones and sandy shales of northern Oklahoma. Further evidence of the effect of the forces on the more brittle rocks of the sandstone area of northern Oklahoma is the thrust fault in northern Creek County which would have taken the form of a compression fold had it been in the clay shale-limestone area.

CONCLUSION.

In the preceding paragraphs, numerous theories advanced to explain the origin of the various types of deformation in the northern Mid-Continent area have been described and discussed. While here, as elsewhere, no single theory will suffice to explain the sum total of the whole structural problem, the theories of differential settling or compaction, folding by vertical thrust, warping of sediments accompanied by faulting during deposition, and direct tangential compression all fall far short of solving the complete problem. On the other hand, as developed in the foregoing arguments, rotational stress transmitted to sediments by shearing in the underlying crystalline rocks, may be invoked to explain the origin of all forms of deformation in Creek County and the adjacent territory. The authors by no means declare that other forces are not present to a sufficient extent somewhat to modify some of the deformation features of this region, but that such forces are not necessary to explain the types of deformation found here. The rotational stress theory is not a purely hypothetical assumption applied to this region, but the work of such stresses has been noted by the writers in many other parts of the country. Too frequently the student thinks only of metamorphic areas when considering problems of shear and rotational stress. Some of the following examples outside of the Mid-Continent area show effects of rotational stress in areas of slight deformation, or in areas in which the sediments are not metamorphosed: en echelon anticlines in the Los Angeles basin of southern California; en echelon structures in the plains area of central eastern Colorado; and en echelon structures in the plains area of southeastern New Mexico where en echelon faults and folds are clearly seen and their relationships marked; en echelon structures in the plains area of southeastern New Mexico where en echelon folds and faults were mapped over a considerable distance.

RELATION OF FUTURE DEVELOPMENT TO STRUCTURE INTERPRETATION

GENERAL STATEMENT

Oil in Creek County, as elsewhere, usually occurs in porous sandstone or limestone beds accompanied by salt water. In such cases oil accumulation is found, logically, in traps formed by anticlines, lenses, monoclines where frictional resistance caused by sudden change in dip retards movement, and in dipping beds cut off on upward edges by faults which place impervious sediments in contact with upper edges of porous oil-bearing beds. Where salt water is absent in quantity, as in one sand particularly in southern Creek County, oil accumulates by gravity into the synclines.

STRUCTURAL INTERPRETATION APPLIED TO EXPLOITATION.

As set forth in the opening paragraph, there are doubtless in Creek County a large number of favorable structures which, because of the masking effect of vegetation, absence of outcrops or presence of imperfect or confusing outcrops, are yet undiscovered. Since a large proportion of the structures found and tested have proved to be prolific sources of oil and gas, no remaining favorable structure should be left undrilled. If the structural interpretation brought out in the foregoing portions of this work are to have a practical value, they should aid in the search for undiscovered structures in this county and the adjacent areas.

According to the theory of rotational stress set forth above, the greatest deformation in this area will be in the sediments immediately overlying the shear zones in the basement rocks. The locus of the shear zones may be found by locating zones of en echelon faulting and folding. Since such shear zones may be expected to follow straight lines, one may extend his work logically from either end of a fault or fold zone in the line of that zone with a fair expectation of finding other faults and folds by more careful work. The best structures, likewise, are found in the zones of faulting. Therefore, in an area of known faults where anticlines have not been mapped, careful search should be made for structures which must surely be present.

STRUCTURAL INTERPRETATION APPLIED TO DRILLING.

Relative merits of different structures. Sand conditions being equal, the dome, or closed anticline is the best type of structure for oil and gas accumulation (except in the single case of synclines where water is absent). The anticlines in Creek County whose axes lie northeast-southwest (the en echelon type of fold) are more apt to take a closed form, especially in the lower horizons, than anticlines with other axial arrangements. Large folds and terraces in Creek County, related probably to vertical movements in the basement rocks along or adjacent to shear zones, have probably all been discovered and may be ignored in this discussion as far as future exploitation is concerned. The en echelon anticlines usually increase in amount of folding with depth. This makes them the more valuable for possibilities in the lower producing horizons.

Anticlins with northwest-southeast axes are less apt to be closed in form because they are related more often to faulting or to slumping over or adjacent to faults. Since in Creek County, the direction of normal dip is rather close to the strike direction of the en echelon faults, anticlines related to these faults in the manner above tend to take the form of plunging anticlines which rarely are closed even by means of fault cut-off. While these produce, they are less apt to be prolific than the type mentioned in the preceding paragraph.

Location of tests on structure. In drilling the en echelon type (compression) fold the operator should take into account the tendency for these anticlines to have plunging axial planes. Since this plunge in Creek County takes a northwestward direction, the location of a test well on such a structure should be made sufficiently northwest of the surface axis to reach the lowest horizon to be tested upon the axis in that horizon, and not too far down the dip to cause failure in the upper horizons.

CREEK COUNTY

OIL AND GAS DEVELOPMENT

GENERAL STATEMENT.

In developing the producing oil and gas fields of Creek County the following horizons have been found of chief importance, named from top downward: Muskelman, Layton, Jones, Cleveland, Wheeler (Oswego lime), Prue, Skinner, Red Fork, Bartlesville, Tanha (Tucker, Booch), Dutcher, Misener, "Wilcox," and "Turkey Mountain," ("Siliceous Lime"). For distribution, thickness and intervals of the most important sands, the reader is referred to the cross-sections, Map Nos. 1, 11 and 13, and figures 9 and 10. There are other producing sands in this county, but, generally, they are not named and are not of great importance. Frequently such sands, because they are unnamed and local in distribution, are merely called "stray" sands.

Oiltown

T 19

N 19

R.7E. R.8E. R.9E.

Taken from Oil & Gas Journal map showing depth to oil sands in central Oklahoma

\[\text{Figure 8.—Map of Creek County Oil Pools.} \]

\text{Shaded areas—production above the Mississippian lime.} \]

\text{Solid areas—production below the Mississippian lime.}
DESCRIPTION OF PRODUCING SANDS.

The Musselman sand, which has been found productive of gas in the Cushing pool, occurs there at about 700 feet and attains a thickness of about 25 feet.

The Layton sand is productive of oil and gas principally in the northern part of the Cushing field, but also in the area between Drumright and Bristow and in another area a few miles south of Shamrock. It ranges in thickness from 20 to 100 feet, with an average of about 50 feet. Some places it is absent. It underlies a hard limestone 10 to 20 feet thick, often called the Layton lime. This lime sometimes contains gas. The sand is coarse-grained, comparatively soft, porous, and fairly uniform in texture and porosity. It occurs at depths ranging from 1,200 to 1,500 feet, depending upon the locality. Saturation within the sand is incomplete and irregular, due to cross bedding and other irregularities in sedimentation. Layton oils are usually of high gravity. In the Cushing field the Layton ranks highest in gravity, with Bartlesville next and Wheeler last. An excellent description of this sand, as well as the other principal sands of the Cushing field is to be found in Beal's paper on that field.

The Jones sand, which produces gas at about 1,730 feet in the Cushing area, is relatively unimportant in Creek County. It attains a thickness, where productive, of about 25 feet.

The Cleveland sand also is of relatively no importance in Creek County. Its average thickness is less than that of the Jones sand. It occurs on the Cushing structure at about 1,920 feet and contains only small shows of oil and gas.

The Wheeler sand (correlated with the Oswego Lime) is productive chiefly on the Cushing structure. Of the Fort Scott group, composed of an upper limestone, an intermediate shale which sometimes grades into coal, and a lower limestone, the upper limestone member is frequently called the "Big Lime" and the lower member is called the "Oswego Lime." Frequently, (especially if one member is found missing), the two have been confused. On the whole, however, the Fort Scott is one of the most persistent and uniform horizons lying above the Mississippi lime and makes an excellent mapping horizon. The lower member, or Oswego lime, frequently changes in character from lime to sandy lime or even sandstone. Such is the case where it is called the Wheeler sand. This sand, as also in the case of the Bartlesville and the Layton, is not saturated completely. In its most important producing locality the Wheeler production covered about 11 square miles for oil and 21 square miles for gas.

The sand attains a thickness of 60 or 70 feet, but with an average thickness of considerably less. In the Cushing area, the Wheeler "sand" is a coarse grained brownish limestone which includes porous or sandy layers that contain the oil. Sometimes the upper limestone member

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A and B Microphotographs of Wilcox sands.
C and D Microphotographs of Hominy sands.
E and F Microphotographs of Bartlesville sand.
G and H Microphotographs of Elgin sand.

(Courtesy of the Journal of Economic Geology)
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The Dutcher sand carries gas in paying quantities. In the same area this sand is found at a depth of about 2,350 feet.

The Price sand reaches its major importance in T. 14 N., R. 8 E., where it produces from synclines. Here the sand is found at about 2,350 feet and has an average thickness of about 50 feet. Elsewhere this sand produces from anticlines.

The Skinner sand is productive of oil and gas in relatively small quantity in the Cushing and Glenn pools. At the former locality it is found at about 2,620 feet with a thickness of about 20 feet. In the Glenn pool it occurs at about 1,050 feet.

The Red Fork sand is chiefly important in the eastern and northeastern parts of Creek County where it is found at depths ranging from 1,300 to 1,150 feet. Its thickness ranges from 20 to 60 feet. In this county it is productive mainly in the Red Fork, Sapulpa, and Glenn pool areas.

The Bartlesville (Glenn) sand is by far the most uniformly productive sand throughout Creek County, with its chief production coming from the northern half of the county.

This sand is usually brown and grades from fine sandy shale to coarse grained sand. The general appearance of the grains of the Bartlesville sand may be seen from the microphotograph (Plate I-E and Plate I-F). The grains appear to be poorly sorted with a predominance of angular grains and a small percentage of well rounded grains.

The sand attains a thickness sometimes of as much as 200 feet, being thickest in the south central part of the county and thinning out northward and eastward. It is found at about 1,450 feet in the northwestern part of the county, 2,300 feet in the southeast, 2,500 feet in the southwest, 3,170 feet in the southeast, and 4,200 feet in the southwest and 4,200 feet in the southeast. It occurs generally over the whole county, though locally it is missing, sometimes possibly cut out by faulting.

The Bartlesville is found abundantly productive on terraces, anticlines, and sometimes on monoclines where leaching or change in porosity causes barriers to form to hold the oil or gas accumulation. The sand is never completely saturated, usually only the upper portion being productive. Sometimes, however, alternate water and oil bearing streaks occur. Despite irregularities, however, the Bartlesville is well liked by operators because of the staying qualities of the production and the slower initial decline and the great ultimate yield.

The quality of the oil in the Bartlesville is much better than that in the Dutcher, the "Turkey Mountain" and some of the other sands, and is very well liked for refining purposes.

The Panola (Tucker, Bosch) sand occurs at from 1,650 to 1,750 feet in depth in the northeast part of the county, 2,300 in the southeast and 2,900 feet in the northwest. It accounts for some fair production of oil and gas in the northern, central and eastern parts of the county. Its thickness ranges from 25 to 50 feet. Its importance is less than that of most of the other sands mentioned in this description.

The Dutcher sand attains considerable importance in Creek County. Its best productive areas lie in the eastern, central and southeastern parts of the county. This sand thins out from the Bristow area northward and northwestward until it appears to be entirely absent. Almost everywhere encountered this sand yields a showing of oil or gas. It produces from anticlines, terraces and faulted monoclines.

The Dutcher appears to be found in Creek County in two horizons, separated by a shale break. Sometimes the upper, sometimes the lower, and sometimes both are missing in well records. Production may occur in either or both in the same well, and sometimes one will contain oil and the other, more frequently than not the upper and lower respectively. The Dutcher zone varies in thickness up to over 100 feet. Upon favorable structure this sand has yielded some phenomenal initial production, many wells yielding over 5,000 barrels and one well on the "Poor Farm" structure southwest of Bristow over 15,000 barrels initial. This lenticular character of the Dutcher sand accounts for many dry offsets to good producers. The Dutcher is found at from 1,600 feet in the northeast part of the county to 3,450 in the southwest.

The Miserer sand has been well described as to distribution and general character elsewhere in this paper. Because of its discontinuous lenticular character, it is thought to be of relatively little potential economic value in Creek County. It correlates with the Mound pond sand of Beggs. Its chief occurrence in this county is in T. 15 N., R. 10 E., and lapping over into the township east.

The "Wilcox" sand is an important factor in the oil and gas production of Creek County. This sand ranges in thickness up to 200 feet and over, probably averaging slightly less than 100 feet, and is found at depths ranging from 1,500 feet in the northeast part of the county to 1,000 feet in the southwest corner. It is a pure white sand made up largely of highly angular grains, with some few rounded large etched grains, and more small round grains. This sand is difficult to distinguish from the "Bergen" but is considered a much more uniform fine grained sand. The "Wilcox" produces chiefly from well defined anticlines, usually domes, and because of this and also because of the fact that the "Wilcox" is usually much more closely folded than the higher formations, these productive areas are relatively limited in size. This sand has been very prolific in some places, sometimes exceeding 30,000 barrels per acre. The oil is of high gravity and is much sought for because of its good refining qualities. This sand is productive in a belt across the northern part of the county and again in the central and southern parts. (See Fig 9.)

The "Silurian Lime" ("Turkey Mountain" sand), which is the upper weathered or porous part of the Arbuckle limestone, has been found productive in the northeastern part of Creek County. The production is confined to the upper truncated surface of this limestone body and not to any one horizon in that limestone. The upper 20 feet consists of pure to sandy dolomitic limestone and below that is a dense
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dolomitic limestone containing quartz fragments and crystals. Wherever the Arbuckle limestone has been entirely drilled through in this region the drill has passed into granite. The upper surface of this limestone, therefore, may be considered as the last chance for production in the downward search for oil and gas.

Figure 16. Well log of MeCoMB No. 1 in the SE. of the SW. of the NW. of sec. 10, T. 17 N., R. 10 E., giving a detailed description of the strata below the Mississippi lime. Samples were collected and identified by Luther White.

POSSIBLE FUTURE PRODUCTION

It may be inferred from the last paragraph above that the lowest probable productive stratigraphic horizon has been reached and all intervening possible pay sands penetrated here or there in this county. Future production, therefore, as far as Creek County is concerned, will have to be found in structures as yet undiscovered or developed or in structures not yet developed to the deepest known pay horizon. Methods for the search for new structures in this county have been suggested in earlier paragraphs. On the other hand, for making deeper tests on already developed structures only sufficient courage, coupled with good geologic judgment as to what kind to structure to test,

and as to possible occurrence in that particular area of the desired deeper sand under favorable conditions, is requisite.

SUMMARY

In order to aid in the writing of a new bulletin covering oil and gas development and future possibilities in Oklahoma, to replace Bulletin No. 19, pt. II, published in 1917 and now out of date and out of print, the authors have prepared this chapter covering Creek County. This county occupies an area of about 963 square miles in the northeast quarter of the state, lying in the sandstone hills portion of that part of Oklahoma and drained by Cimarron River and tributaries of the Arkansas system and Deep Fork and Little Deep Fork of the Canadian system. The area is rough and hilly, with surface elevations ranging from 600 to 950 feet.

Development began actively in 1906 in the Glenn Pool area and continues active to the present day. During this time probably all the larger available producing areas have been found and their production outlined.

The rocks outcropping at the surface comprise the upper formations of the Pennsylvanian, and the rocks penetrated by the drill range downward through the Pennsylvanian, Mississippian, Devonian, Silurian, Ordovician and Cambrian and into granite. The chief unconformities come below the Pennsylvanian, below the Chatahoocha and Misener, below the Viola, below the Burgen, and below the Arbuckle.

The general structure of the region is that of a westward dipping monocline, interrupted by anticlines, terraces, synclines and faults. The faults are mostly normal (only one thrust fault being recorded) and strike northwestward and tend to fall in en echelon belts trending northeast-southwest. Some northeast-southwest en echelon compression folds and a few larger northeast-southwest anticlines lying more northward than the compression folds just mentioned are found. Some tension folds in the form of northwestward plunging anticlines also occur, together with a number of folds of irregular shape probably caused by a combination of forces.

The authors discuss many theories previously formulated to explain the origin of the numerous small structures of this portion of the Mid-Continent field, such as vertical uplift, compacting, direct tangential compression, and various phases of the rotational stress theory. They find the formation of such small structures by direct uplift difficult to explain. They find the shape and position of the structures, together with the absence of close folding and other evidence of intense thrusting between the Mid-Continent fields and the Ozarks (the supposed source of tangential thrust) arguing against that theory as an explanation of the origin of the small structures. They present diagrams and other arguments proving the inadequacy of compaction as the cause of the formation of these structures. Following
this, they conclude that, while some structural conditions in the northern Mid-Continent area may be explained in part by one or more of the other theories, that of rotational stress set up in the sediments by horizontal movements in the basement complex, caused by thrusts originating in the Ouachita Mountain region of southeastern Oklahoma and northwestern Arkansas, best serves as an explanation of the origin of the structural forms found in the northern Mid-Continent area. The authors admit, of course, the possibility that some of the other forces mentioned may have slightly modified the effects of the group of forces finally accepted as chiefly responsible.

From the above studies the authors believe that an application of the accepted rotational stress theory may lead to the discovery of many small obscure or hidden structures in this as well as adjacent counties, and may be followed by the development of additional production. An application of the same theory also is made to the relative evaluation of different types of structure and to the choice of drilling sites on the various kinds of structures discovered.

Following the structural discussion the writers describe the sands and production of the following horizons in Creek County: Musseelman, Layton, Jones, Cleveland, Wheeler (Oswego lime), Prue, Skinner, Red Fork, Bartleseville (Gcenn), Tanelia, (Tucker, Bococh), Dutcher, Misener, "Wilcox," and "Turkey Mountain" ("Si icenos Lime"), and indicate possibilities of future production in these sands within the county.

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OKMULGEE COUNTY

By
Robt. W. Clark

INTRODUCTION

GENERAL STATEMENT

For eight years the author has been studying the conditions controlling the accumulation of oil and gas in the oil fields of Okmulgee District of Oklahoma. The larger and more productive pools in the fields have been found to lie on the tops of domes mapped on the producing sands, while the surface beds give but slight indication of the presence of such subsurface conditions. In other words, domes in the deeper lying formations are not reflected at the surface. In fact, this situation caused many geologists, in the early period of the development of the area, to pass it by as improbable territory, while as a matter of fact, it has already produced approximately one hundred million barrels of oil.

The purpose of this report is to set forth the oil and gas development of Okmulgee County, Oklahoma, and to show the conditions under which oil and gas have accumulated.

ACKNOWLEDGMENTS

In the preparation of this report various sources of information have been consulted and used without direct reference. Among them are Oklahoma Geological Survey Bulletin 19, Part II, Petroleum and Natural Gas in Oklahoma; Bulletin 35, Index to the Stratigraphy of Oklahoma, by Chas. N. Gould; also the U. S. Geological Survey folios by Joseph A. Taff on the Coalage and Muskogee quadrangles. My thanks are hereby expressed to Messrs. W. E. Wood, W. C. Newman, J. P. Rissner and E. H. Galigan, who have been operating in this area since the beginning, for information contained in the paragraphs on the history of development of the county. Grateful appreciation is also expressed to Chas. I. O'Neill, Secretary of the Okmulgee District Oil and Gas Association, for compilation of the data on drilling operations and production in the county.

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LOCATION

Okmulgee County is located in the east-central part of the State. It extends from T. 11 N. to the middle of T. 16 N., and from R. 11 E. to the middle of R. 15 E., in its widest parts. There are 16 entire townships and 7 half townships or a total of 702 square miles in the county.

Figure 11.—Index map of Oklahoma showing location of Okmulgee County.

TOPOGRAPHY

Okmulgee County lies within the sandstone hills region. The topography consists of roughly parallel sandstone ridges between which are rather broad shale valleys. The ridges have very steep to vertical eastward facing slopes, but have gradual slopes to the west on the west side corresponding to the dip of the rocks. In other words, the west slopes are dip slopes while the east slopes are escarpments. The sandstone hill zones have been deeply dissected by streams, giving a rather rough topography. The surface ranges in elevation from less than 600 feet to more than 1,000 feet. The lowest point is where the Deep Fork of the Canadian River leaves the county in sec. 33, T. 12 N., R. 14 E. The highest point is in sec. 19, T. 15 N., R. 13 E.

The northeast portion of the county is drained by tributaries of the Arkansas River. The largest stream in the county is the Deep Fork of the Canadian River which flows through the west and central portions of the county and drains at least two-thirds of its area. The extreme southern portion of the county drains directly into the North Fork of the Canadian River, which crosses the southeast corner of the county in sec. 36, T. 11 N., R. 13 E.

STRATIGRAPHY

SURFACE GEOLOGY.

GENERAL STATEMENT

The surface rocks in Okmulgee County are Pennsylvanian in age with the exception of recent sands and gravels along the stream valleys. The following formations outcrop in the county, beginning with the lowest: Boggy shale, Thurman sandstone, Stuart shale, Senora formation, Calvin sandstone, Wetumka shale, Wewoka formation, Holdenville shale, Seminole conglomerate, Coffeyville formation, including the Checkerboard limestone, and the Nelly Bly formation. These formations cross the country in a northeast and southwest direction so that the lowest one has its widest extent in the southeast part of the county and the topmost one just crosses the northwest corner of the county. Description of these formations has been briefly and conveniently outlined by Chas. N. Gould in Bulletin 35 of the Oklahoma Geological Survey. A more detailed description follows.

The Nelly Bly formation, which outcrops across the southwest corner of T. 16 N., R. 11 E., consists largely of shale with some interbedded sandstones. Farther north in Creek County the sandstones become massive and cap the high ridges and afford a rather rugged topography. The total thickness of the formation is not exposed in Okmulgee County.

The Coffeyville formation consists largely of clay shales with a few shaly sandstone beds in its lower part. The upper part has more of the sandstone beds, some of which become quite massive. Near the base of the Coffeyville is the Checkerboard limestone, so-called because of a double system of joints whereby it breaks into cubical blocks which on the top look like the squares of a checkerboard. Exposed surfaces of the lime are yellowish in color while a fresh fractured surface is bluish. It is about three feet thick and outcrops in draws and on the down dip slopes, rarely on the east facing steep slopes. The thickness of the Coffeyville is about 400 feet.

The Seminole conglomerate is a sandstone with beds and lenses of chert conglomerate. These beds seldom exceed two feet in thickness in the county and the angular chert particles are from one-eighth to one-quarter of an inch across. South of Okmulgee County the chert pebbles are much larger in places and the conglomerate beds may be considerably thicker. The total thickness varies from 15 to 35 feet.

The Holdenville shale has an average thickness of 180 feet. It is predominately clay shale with a few thin beds of sandstone more or less shaly, which do not form continuous ledges. In the street on the hill in the west side of Beggs there is a limestone in the
Holdenville shale. This limestone is about three feet thick but cannot be traced for any distance along the strike of the formation.

The Wewoka formation is about 450 feet thick and is predominantly a sandstone with beds of clay shale between the sandstone beds. The lowest member is a sandstone bed about six feet thick that is very persistent in its outcrop. The middle part of the formation is a massive sandstone member that can be traced continuously across the county and for many miles beyond in both directions. The upper part of the Wewoka formation is more cross-bedded and contains more shale and shaly sandstone than the middle and lower parts. It grades into the overlying Holdenville shale in such a manner as to make the contact quite indefinite.

The Wetumka is essentially a clay shale formation with occasional thin sandy shale beds in it. A thin limestone that is quite persistent also occurs in this formation. The thickness of the Wetumka shale is 120 feet.

The Calvin sandstone is composed largely of massive sandstone in the southern part of the county, but toward the north it becomes more and more shaly. The massive sandstone on the hills at Henryetta is basal Calvin sandstone. The city of Okmulgee sits on the upper Calvin sandstone, but about a mile north of the city the sandstone disappears and the Calvin changes to a clay shale. Sandstones occur again in the Calvin in the Bald Hill area.

The Senora formation is 250 feet thick. In the southern part of the county it consists of massive sandstone beds alternating with beds of clay shale. Like the Calvin the massive sandstones pinch out toward the north so that the formation is nearly all shale north of T. 12 N. In T. 15 N., R. 14 E., there are again some massive sandstones in this formation, but they are not continuous with the sandstones in the southern part of the county. The Henryetta coal beds occur in the Senora formation.

The Stuart formation is a clay shale about 200 feet thick with a few thin shaly sandstone beds. In T. 14 N., R. 14 E., it cannot be differentiated from the shales of the Senora above and the Boggy below.

The Thurman sandstone consists for the most part of massive sandstone in the southern part of the area and gives rise to the rugged topography and timbered hills in the southeast corner of T. 13 N., R. 14 E. To the south in McIntosh County massive sandstones predominate, but the formation is predominately shaly in eastern Okmulgee County.

The Boggy shale is a formation that borders the east side of the county. Its total thickness is not exposed in the county, but it extends eastward into Muskogee County.

SUBSURFACE GEOLOGY
GENERAL STATEMENT

Because of the westward dip of the Pennsylvanian and Mississippian formations the same sands are found at much greater depths in the western part of the county than in the eastern part. This statement does not apply, however, to sands below the Mississippian as will be explained later.

SALT SAND, GLENN SAND

The stratigraphically highest sheet sand in the county is called the Salt sand in the eastern part of the county and the Glenn sand in the western part. It is the equivalent of the Glenn sand of the old Glenn Pool, which in turn has been correlated with the Bartlesville sand. This is not the same as the Glenn sand of the Bald Hill area in T. 15 N., R. 14 E. Its depth varies from about 600 feet on the east side of the county to 1,900 feet on the west side and its thickness varies from 200 feet in the eastern part of the county to less than 50 feet in the western part of the county. It is a gas and oil pay sand and always carries water in its lower part, which has to be cased off in drilling a well to formations below it.

SHALLOW STRAY SANDS

In sections 26 and 35, T. 13 N., R. 12 E., a very prolific pool has been developed in a sand approximately 800 feet above the Salt sand. This sand has been found to carry gas and oil to the west of this pool and especially in T. 13 N., R. 11 E.

In the vicinity of the village of Morris oil and gas have been obtained from a sand about 325 feet above the Salt sand. This sand or its approximate equivalent has been found productive in several places in the eastern part of the county.

BOOCH SAND, TANNEHA, RED FORK

About 250 feet below the Salt sand is the first Booch sand, and about 100 feet below that is the second Booch sand. These sands are thin, generally not over 25 or 30 feet thick. In the Bald Hill area the lower Booch is called Red Fork but the true Red Fork is above the Salt sand. In the western part of the county the two Booch sands are represented by the Tanneha sand, which may be as much as 300 feet thick. The Booch sand has been the source of much of the oil so far produced in the eastern half of the county. It generally requires a heavy shot to make a well, but 1,500 to 2,000 barrel wells are not uncommon when only a small show was apparent before the shot.

DUTCHER, MORRIS, GLENN, FIELDS, AND YOUNGSTOWN SANDS

Below the Booth sand in the basal part of the Pennsylvanian system is a group of sands, sandy limes, and limes, known as the Dutcher group. They make up the Fayetteville formation. As many as three different sands can be recognized in this group and they have received different names in different parts of the county. In the eastern half they are in descending order: Morris, Glenn, and Fields sands. This Glenn sand is deeper than the Glenn sand referred to above as the equivalent of the Salt sand and is frequently called the “Glenn-of-Morris” sand to distinguish it from the other. It received its name when the first well was drilled in the Bald Hill area by a driller fresh from the Glenn Pool, because the two sands occur at the same depth. It is an important pay sand in the Bald Hill area. The Glenn and Fields sands often coalesce but are generally separated by a thin shale break. In the vicinity of Preston the Dutcher sands are often called First and Second Preston or Hamilton Switch sands while in the western part of the county they are known as First and Second Youngstown or First and Second Dutcher sands. In the southern part of the county the names Deeran and Kingwood are often used although these names were first applied across the line in Okfuskee County. Accumulation in the Dutcher sands appears to be due as much to lensing and variations in the character of the sand as to structure, although the large pools of big producing wells are always found on well defined dome structures. It is not uncommon for a dry hole in the Dutcher sand to be surrounded by large producing oil wells.

LYONS—QUINN SAND

Below the Dutcher group is a series of limes which belong to the lower part of the Pennsylvanian and the upper part of the Mississippian systems and correspond respectively to the Morrow and Pittkin limestones. In the southern and eastern portions of the county porous sandy zones occur in the Pittkin lime and are often productive of oil and gas. This is called the Lyons-Quinn sand. It is a pay horizon in the west side of T. 11 N., R. 12 E., in Turkey Pen Hollow just north of Henryetta and through the Hoffman, Morris and 14-14 area. In the northern and northwestern part of the county it has not yet been found productive.

The stratigraphic section below the Lyons-Quinn sand is well known to operators and field men in the county and will be discussed a little more in detail.

BOONE LIMESTONE

The Boone limestone is the uppermost member of the series. It is about 200 feet thick, and is black or brown in color. Often the top of it is soft and may be called slate by the drillers. It is frequently called the Mississippi lime.

OKMULGEE COUNTY

CHATTANOOGA SHALE

Lying below the Boone limestone is the Chattanooga shale. It is black in color and about 40 feet thick. It is the lowest member of the Mississippian system and rests unconformably upon pre-Mississippian formations.

The pre-Chattanooga formations have been very ably described by White. They dip to the southwest across Okmulgee County at the rate of about 40 feet to the mile. A period of erosion representing part of the Silurian and all of Devonian time followed the uplift which dipped these formations to the southwest so that the Chattanooga was deposited on the beveled edges of these formations. It overlies and is in contact with the highest member in the southern part of the county and with successively lower members toward the north.

HUNTON FORMATION

This formation appears as a thin limestone below the Chattanooga in the extreme southern and eastern parts of the county. Some of the Wilcox sand wells at Hoffman and also those at Eram show this limestone. The Ratcliffe well in sec. 33, T. 13 N., R. 11 E., also shows it. It has come to be known as a pay horizon in other parts of the State, but not in Okmulgee County.

SYLVAN SHALE

Many wells in the southern half of the county show the black Chattanooga shale underlain by light shale that is often greenish in color. This is the Sylvan shale and varies considerably in thickness. In those places where the Hunton lime is present the Sylvan is directly below the Hunton but in the rest of the area it is directly below the Chattanooga.

VIOLA LIMESTONE

The Viola limestone is a coarsely crystalline white limestone that varies in thickness up to 60 feet. It is often called the “Buttermilk lime” in the field. Throughout most of the county, except in the extreme northern part, it lies just above the Wilcox sand and is an important marker for the drillers. Where the Sylvan is present the Viola lies just under it, otherwise it is in contact with the Chattanooga.

WILCOX SAND

The Wilcox sand is a very important oil producing horizon in Okmulgee County and is the goal of most of the present day developments in the county because it may be a very prolific pay sand
and the oil has the highest value of all. In the N1/2 of T. 15 N., R. 14 E., and the S1/2 of Tps. 16-13 and Tps. 16-14, the Viola lime is absent and the Wilcox sand lies directly under the Chattanooga shale. Throughout the rest of the county the Viola overlies the Wilcox sand.

**MISENER SAND**

Lying in the top of the Viola limestone a pay sand is encountered locally. It is called the Misener sand, and has been found productive in the west side of T. 15 N., R. 11 E. It consists of small lenses and is not a sheet sand. Accumulation in it is due to the leasing and not to dome structure. It has been correlated with the Sylvanmore sandstone and is much younger than any of the other formations in the pre-Wilcox series.

The Wilcox sand is the lowest pay sand at the present time in Okmulgee County. Its depth varies in different parts of the county, but not in the same way as the upper sand depths. It is shallowest in T. 15 N., R. 14 E., where it is found to produce oil at a depth of approximately 2,200 feet. In the Eram Pool in sec. 5, T. 13 N., R. 15 E., the Wilcox sand is 2,700 feet deep; in Pine-Smith Pool, secs. 1 and 12, T. 13 N., R. 13 E., the depth is 2,500 feet; at Hoffman 2,890 feet; sec. 9, T. 13 N., R. 12 E., 2,700 feet; sec. 30, T. 15 N., R. 11 E., 3,000 feet; Phillipsville Pool, sec. 22, T. 14 N., R. 11 E., 2,800 feet; Simms Pool, sec. 31, T. 12 N., R. 12 E., 3,300 feet.

**HOMINY AND TURKEY MOUNTAIN SANDS**

In a number of widely separated tests, shows of oil have been encountered in formations below the Wilcox sand. In sec. 19, T. 14 N., R. 13 E., the Wilcox sand was found at 2,600 feet. A good show of oil was found at 2,880 feet in a sand which is probably the Hominy sand (correlated with White as the Burgen). At 2,920 feet another good show of oil was found in a sandy phase of the Siliceous lime. This is probably the Turkey Mountain sand. In sec. 22, T. 14 N., R. 14 E., the Wilcox sand was found at 2,278 feet and after drilling through the Tyner formation a good show of oil was found in the Siliceous lime at 2,455 feet. This is thought to be the Turkey Mountain sand although it might be the Hominy as no cuttings were available to make a definite correlation.

In sec. 33, T. 13 N., R. 11 E., the Wilcox sand was found at 3,330 feet and was 200 feet thick. The Tyner formation is believed to be absent or very thin, and the Hominy encountered at 3,548 feet had a good show of oil. The Arbuckle limestone, with sandy phases corresponding to the Turkey Mountain, begins at 3,590 or 3,600 feet.

The character of the oil obtained from the various sands is different. The Wilcox sand produces the highest grade of crude oil in the county, and the upper Dutcher produces the lowest grade of crude. The data in the following table were furnished by Dr. A. P.

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**Character of Oil Obtained from Various Sands.**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>SAND</th>
<th>COLOR</th>
<th>GRAVITY DEGREES BAUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-13-13</td>
<td>Wilcox</td>
<td>light amber</td>
<td>41.4</td>
</tr>
<tr>
<td>1-13-12</td>
<td>Wilcox</td>
<td>light amber</td>
<td>42.6</td>
</tr>
<tr>
<td>22-11-11</td>
<td>Wilcox</td>
<td>light green</td>
<td>42.0</td>
</tr>
<tr>
<td>25-11-11</td>
<td>Lower Dutcher (Glenn)</td>
<td>dark green</td>
<td>35.7</td>
</tr>
<tr>
<td>16-11-14</td>
<td>Glenn</td>
<td>green</td>
<td>35.9</td>
</tr>
<tr>
<td>8-12-12</td>
<td>Lower Dutcher</td>
<td>light amber</td>
<td>37.7</td>
</tr>
<tr>
<td>4-11-11</td>
<td>Lower Dutcher</td>
<td>dark green</td>
<td>31.0</td>
</tr>
<tr>
<td>5-11-12</td>
<td>Lower Dutcher</td>
<td>dark green</td>
<td>31.6</td>
</tr>
<tr>
<td>22-11-11</td>
<td>Lower Dutcher</td>
<td>dark green</td>
<td>36.1</td>
</tr>
<tr>
<td>21-12-11</td>
<td>Lower Dutcher</td>
<td>green</td>
<td>36.3</td>
</tr>
<tr>
<td>8-11-11</td>
<td>Upper Dutcher</td>
<td>black</td>
<td>29.9</td>
</tr>
<tr>
<td>7-12-11</td>
<td>Upper Dutcher</td>
<td>black</td>
<td>21.6</td>
</tr>
<tr>
<td>15-11-11</td>
<td>Upper Dutcher</td>
<td>dark brown</td>
<td>32.3</td>
</tr>
<tr>
<td>11-12-11</td>
<td>Brook</td>
<td>dark green</td>
<td>32.6</td>
</tr>
<tr>
<td>21-11-11</td>
<td>Lyons-Quinn</td>
<td>green</td>
<td>40.1</td>
</tr>
</tbody>
</table>

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**STRUCTURE**

**SURFACE STRUCTURE**

**GENERAL STATEMENT**

The strata in Okmulgee County belong to the Prairie Plains monocline. They strike about N. 25° E., and dip N. 65° W. The rate of dip in the west half of the county is 80 to 90 feet to the mile, while in the eastern half it is 50 to 60 feet to the mile. Local variations in the direction and rate of dip give rise to noses and terraces. These generally indicate the presence of closed structures or domes capable of trapping oil in the deeper formations.

**STRUCTURAL FEATURES**

Two anticlines are known to exist in Okmulgee County. The largest one of these is known as the Schulte anticline. It extends southwestward from the village of Schulte in sec. 17, T. 12 N., R. 13 E., toward the city of Henryetta. The highest part of this anticline shows a reversal or east dip of approximately 120 feet measured on the coal.

The second anticline extends from the village of Hoffman north- eastward across T. 13 N., R. 14 E., T. 14 N., R. 14 E., and into T. 14 N., R. 15 E. The total height of this anticline cannot be measured on the surface rocks because they are mostly shales and do not form continuous mapable ledges. The east side of this anticline in Tps. 12 and 13 N., R. 14 E., is marked by a fault with the downthrow on the east side. The throw amounts to as much as 300 feet in places.
SUBSURFACE STRUCTURE

GENERAL STATEMENT

The structure of the buried sands is not parallel to that of the surface beds. The general attitude of the Salt sand and the Boeoch sand is that of a northwestward dipping monocline with many minor variations in the direction or rate of dip. Unlike the surface beds, small closed structures or domes are frequent although these are generally not very high and rarely more than a half mile across.

BURIED STRUCTURAL FEATURES

The Dutccher series thickens to the south and to the east across this area so that the interval between the Salt sand above the Dutccher and the Boone lime below the Dutccher is much greater in the southern part of the county than in the northern part. It is also greater on the east side of the county than on the west side. Figure 1 shows in a general way how this interval increases to the south and east. There are also local variations in this interval around the domes that produce oil from the Wilcox sand. It is thinner on the tops of the domes than on the flanks and may vary as much as 100 feet in one-quarter of a mile.

Closed structures in the Dutccher sand are generally higher or show more closure than do the overlying Boeoch and Salt sands. Production from the Dutccher sand is associated with domes and similar structural conditions but porosity and lensing of the sand also appear to be important factors in accumulation in the Dutccher sand. It is not unusual for dry holes to be surrounded by good producers even on favorable structural locations.

The structure of the Lyons-Quinn sand often varies considerably from that of the overlying formations and is in a general way parallel to that of the deeper lying Wilcox sand. A dome in the Lyons-Quinn sand generally lies above it a lower dome in the Dutccher and upper sands but not all domes in the upper sands have Lyons-Quinn domes under them. On the other hand the structure of the Wilcox sand will be found to be nearly the same as that of the Lyons-Quinn sand except that the amount of dip and the shape of the Wilcox dome may be slightly different from that of the Lyons-Quinn sand dome.

Domes in the Wilcox sand are the highest and steepest of all. The Wilcox sand produces oil in paying quantities only from structures of the dome type. The area of production is rather small, usually not to exceed 100 acres although the total producing area of a few pools exceeds that amount. Dips in the Wilcox sand are generally quite steep especially on one side of a producing structure. Thus in the Eram Pool in sec. 5, T. 13 N., R. 15 E., the north dip amounts to 150 feet in a quarter of a mile. In the Brookins Pool in sec. 9, T. 13 N., R. 12 E., the southeast dip amounts to more than 200 feet in a quarter of a mile.

Domes in the Wilcox sand are always reflected in the overlying formations. However the height of the dome gradually diminishes.
toward the surface until, in the surface beds, only a nose or terrace is present to indicate the possible producing structure below. The converse of this is not true. Not all noses or terraces or even all domes in the Salt or Dutcher sands indicate the presence of a Wilcox sand dome beneath them. This has become a very important factor in the present day development of Okmulgee County. A considerable area of the county has been developed in the Salt, Boeche and Dutcher sands. The tendency today is to redrill all the old developed acreage in search of production from the Wilcox sand.

Locations are selected where the shallower sands show a good dome structure but it is further necessary to make a very careful study of the logs of the few scattered wells that have been drilled to the Wilcox sand in the vicinity of such a dome to see whether a Wilcox dome is possible under the shallower sand dome. Often the Wilcox shows a normal dip or is even synclinal under a good dome in the upper formations.

**ORIGIN OF THE DOMES**

**GENERAL STATEMENT**

Much has been written on the origin of the structures or domes of the Mid-Continent area. It is believed that any one theory will not explain all types of domes and anticlines in this broad area.

**OZARK UPLIFT**

Folding of the earth's sedimentary shell is the most frequently used explanation for the origin of domes and anticlines. A great positive land mass known as the Ozark Uplift lies to the northeast of this area. The principal uplift here occurred during and after Pennsylvanian time and resulted in the tilting of the beds in Okmulgee County together with the rest of northeastern Oklahoma forming the westward dipping monocline throughout this region. Had there been a thrust with this movement the closed structures of this area would be of the Appalachian type, i.e. elongated anticlines associated with thrust faults. With the two exceptions noted above all the structures of Okmulgee County are more or less circular and of very small areal extent, usually less than a square mile. Such closed structures are only found in the tilted beds while overlying them the surface beds show only small noses and terraces. Some faulting exists in the surface beds of Okmulgee County, but all the faults are of the normal type. Thus, it does not appear that there has been any thrust in this area from the Ozark Uplift and folding cannot be assumed as a cause for the domes.

**VERTICAL UPLIFT**

In 1918 Gardner ascribed the domes of the Mid-Continent to a vertical uplift caused by an igneous mass. It is very doubtful

In those anticlines like the Cushing structure and the Nemaha Mountain anticline of Kansas where granite is known to underlie the sedimentary rocks and was probably an important factor in the development of the anticline, the structures are long and narrow and not of the circular dome type that we have in Okmulgee County.

**Differential Settling**

Blackwelder\(^4\) believes the domes in the central Kansas oil fields are due to differential settling of the sediments deposited on an eroded topography, this settling having been caused by differential degrees of compression of the various kinds of sediments by the weight of overlying materials. He adopted the entire theory within reason a condensation of 2 per cent in sandstones, 5 per cent in limestones and 15 to 35 per cent in shales. He shows that a pre-Pennsylvanian hill with a maximum relief of 700 feet would be sufficient to cause the gentle dips that are found on any of the domes of that area.

Monnet's\(^5\) in 1922 made a very general application of that theory to the whole Mid-Continent area.

In the same year Powers'\(^6\) carried this theory even further and showed the nature and cause of the pre-sedimentary topography in the major anticlines and domes of the Mid-Continent oil fields. An igneous mass is noted in all the major folds of that field, showing that the settling of sediments around pre-Cambrian hills or ranges is the cause of such structures.

In 1918 Mather\(^7\) explained the cause of small domes by deposition of sediments around hills on an originally inclined floor. The sediments were deposited in an inclined position, giving rise to the dips that are now noted on them.

The formations below the Chattanooga shale are largely limestone, sandstones and sandy limestones. At least 1,400 feet of these formations have already been noted in the test in sec. 29, T. 13 N., R. 14 E. Since the dips on the domes in the Wilcox sand are very steep and since the materials in this part of the stratigraphic section are the least compressible it does not appear that settling of sediments had very much to do with the domes that now exist in the Wilcox sand. However, such domes are fully explained by the theory that the materials were deposited originally in an inclined position on the flanks of a hill of pre-Ordovician or pre-Cambrian time. One objection to this theory is that such hills would have to be more or less circular knobs of rather small areal extent which could not be expected. If the beds were in a horizontal position the hills would be of the knob type rather than the ridge type and although the producing area of a Wilcox dome is rather small, nevertheless the formations generally show a gradual rise from all directions for several miles toward the top of the dome. The development of the domes in the formations above the Wilcox sand is apparently due to a combination of differential settling of sediments together with the deposition of materials on a slope too steep for them to remain in repose.

The shale interval between the Viola limestone and the Boone limestone is much thicker in those wells drilled down the flanks of the Wilcox sand domes than it is in wells drilled on the tops of the domes. Likewise the interval between the base of the Salt sand and

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the Boone is greater around the edges of the domes than on the tops. Following are some examples of this change if interval to be noted in passing from a well on the flank of a dome over the top to one on the opposite flank. The interval given in this table is that from the base of the Salt sand to the top of the Wilcox sand.

**Change of interval between Salt sand and top of Wilcox sand.**

<table>
<thead>
<tr>
<th>POOL-LOCATION</th>
<th>FLANK WELL</th>
<th>TOP WELL</th>
<th>FLANK WELL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oklahoma Central</td>
<td>SW, Cor. NE 4</td>
<td>Cen. S. l, NW 4</td>
<td>Cen. N. l, NE 4</td>
</tr>
<tr>
<td>Sec. 23, T. 15 N., R. 11 E.</td>
<td>Sec. 22 976</td>
<td>Sec. 22 986</td>
<td>Sec. 22 908</td>
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<tr>
<td>Wilcox</td>
<td>SW, Cor. NE 4, SW 4</td>
<td>Cen. W. l, SW 4</td>
<td>N.E. Cor. SE 4, SW 4</td>
</tr>
<tr>
<td>Sec. 24, T. 15 N., R. 11 E.</td>
<td>Sec. 24 1029</td>
<td>Sec. 25 920</td>
<td>Sec. 25 928</td>
</tr>
<tr>
<td>Hitting-dea</td>
<td>N.E. Cor. NW 4, SE 4</td>
<td>N.W. Cor. Sec. 21</td>
<td>N.W. Cor. SW 4, SW 4</td>
</tr>
<tr>
<td>Sec. 15, T. 15 N., R. 12 E.</td>
<td>Sec. 15 976</td>
<td>Sec. 15 976</td>
<td></td>
</tr>
<tr>
<td>South Beggs</td>
<td>N.W. Cor. NE 4, SE 4</td>
<td>Cen. SW 4, SE 4, N.E. 4</td>
<td>N.W. Cor. NE 4, SW 4</td>
</tr>
<tr>
<td>Sec. 12, T. 14 N., R. 11 E.</td>
<td>Sec. 13 1066</td>
<td>Sec. 13 959</td>
<td>Sec. 12-14-12 979</td>
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<tr>
<td>Phillipsville</td>
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<td>N.W. Cor. SE 4, SW 4</td>
<td>SW, Cor. NW 4, SW 4</td>
</tr>
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<td>Sec. 22 1012</td>
<td>Sec. 22 1051</td>
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<td>Elkins</td>
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<tr>
<td>Sec. 5, T. 13 N., R. 12 E.</td>
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<td>Sec. 9 1257</td>
<td>Sec. 15 1382</td>
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<td>Mine-Smith</td>
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<td>Cen. SW 4, SE 4</td>
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<td>Sec. 12-13-14 1410</td>
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<td>Evans</td>
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<td>SW, Cor. Sec. 5</td>
<td>SW, Cor. SE 4</td>
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<tr>
<td>Sec. 5, T. 13 N., R. 15 E.</td>
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<td>Sec. 5 1814</td>
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</tr>
</tbody>
</table>

A cross-section through the Eram Pool in a north-south direction and another in an east-west direction also show this change of interval. All the pools that have been developed to the Wilcox sand in Okmulgee County show a similar condition. The slopes of the correlation lines are much steeper in the deeper formations like the Wilcox sand than they are in the shallower formations such as the Salt sand. A set of structure maps of the Eram Pool prepared on the base of the Salt sand, on the Dutcher sand and on the Wilcox sand, Figure 15, show that the deeper the formation the steeper are the flanks of the domes and also the higher are the domes, or the deeper domes show more closure. Every Wilcox pool in Okmulgee County shows this same condition and this set of structure maps may be taken as types.

The cross-sections through the Eram Pool, Figure 13, show the slopes of the correlation lines relatively great in the lower part of the stratigraphic section from the Wilcox sand to the Dutcher sand. From the Dutcher sand upward they flatten out quite rapidly. The fact that the interval between the base of the Salt sand and the top of the Wilcox sand is greater in the flank wells than it is in the wells on the tops of the domes is accounted for principally by an increase in thickness of the shale just above the Viola limestone and the shale just above the Dutcher sand. If the sediments deposited during the time interval represented by the series from the lower part of the Pennsylvanian downward, including the Wilcox sand, had been deposited on an irregular topography, of which the
slopes were greater than the angle of repose, gravity would tend to pull the elastic materials, of which the shales and sandstones are composed, down the side of the hills and pile it up around the flanks. This would cause such elastic sediments to be thinner on the tops of the hills than on the sides. A glance at the cross-sections through the Eram dome shows this to be the case. As the elastic material is piled up around the flanks of the hills there would be less initial dip in the successive layers of limestone and all the sediments would have a tendency to flatten out in passing upward from the Wilcox sand.

Opposing this phenomenon is the fact brought out by Blackwelder that the shales are much more compressible than the sandstones and limestones. Thus in those flank wells, where there is a greater thickness of shale between the Boone limestone and the Viola limestone, there is a greater shortening due to compression than in the top wells. This has a tendency to maintain the steep dips noted in the harder and less compressible materials. However, the compacting of sediments is not sufficient to offset the effect of piling up of materials around the flanks of the hills, and the steepness of the dips gradually diminishes in passing upward from the Wilcox sand.

Between the Dutcher sand and the surface the geologic column shows a preponderance of shale. By the time the Dutcher sand had been deposited the piling up of elastic materials around the sides of the hills had reduced the steepness of the slopes until the angle of repose was reached. After that gravitation ceased to pull material down from the top of the hill and pile it up around the flanks. The main factor causing the flatter dips of the formations above the Dutcher sand appears to be the differential compressibility of the sediments on different parts of the domes. Because there is more shale on the flanks than on the tops there is a greater compression on the flanks, which causes the dips in the upper part of the series of sediments. Passing upward toward the surface, the overload gradually becomes less and less, resulting in less compacting of the sediments until, at the surface, only minor irregularities in the normal dip occur.

**HISTORY OF DEVELOPMENT**

Prior to 1904 there were no producing wells in Indian Territory south of Red Fork. The Indian Bureau of the Interior Department had made no regulations for leasing the land and none was leased outside of townsites. Therefore, the first well drilled in Okmulgee County was a townsite well drilled near the site of the water tower in Okmulgee. It was drilled by the Citizens Oil and Gas Company to the Salt sand at a depth of 1,272 feet and shot on May 23, 1904. It produced six or seven barrels a day for about a week and was then abandoned. About the same time the Boggs...
by O. K. Peck et al, to a depth of about 1,500 feet. Late in 1904 a gas well was drilled in the south edge of Henryetta. It furnished gas to the city for a number of years. This well is still producing enough gas to operate a gin although it is twenty-two years old.

On April 21, 1904, Congress passed an act in which “All restrictions upon alienation of the lands of all allottees of either of the Five Civilized Tribes, who are not of Indian blood, except minors, are, except as to homesteads, hereby removed.” This opened the way for extensive leasing of Indian lands in Okmulgee County and development began to increase rapidly.

In 1906 two gas wells were drilled in the townsite of Morris to the 1,200 foot sand, afterwards called the Booch sand. In the fall of that year Dr. L. S. Skelton laid a gas line to Okmulgee to supply that city with gas from the Morris wells. In the same year two gas wells were drilled in sec. 27, T. 13 N., R. 14 E., but this gas was not used extensively except for drilling in the vicinity. Another important well drilled in 1906 was located in the NW ¼ sec. 20, T. 13 N., R. 14 E., on the Booch farm and gave the name to the Booch sand, which afterwards became famous for large wells. This well, however, was only a 10 barrel well after a shot and was never commercially produced.

Early in 1907, C. A. H. deSaulles, representing the Tulsa Fuel and Manufacturing Company, a Guggenheim subsidiary, drilled a well in the southeast corner of sec. 20, T. 13 N., R. 14 E. It was completed to the Morris sand at a depth of 1,486 feet in March and produced about 5,000 barrels of oil after which it was shot and went to water. The diagonal offset to this well in the northwest corner of sec. 28, T. 13 N., R. 14 E., was completed in May, 1907, and is still producing, being nearly twenty years old. This started intense activity in the Morris area.

The Shelter Shoestring was opened up by Smith and Swan in 1907 with the “Picnic Well.” This well was drilled in sec. 22, T. 12 N., R. 13 E., near where Coalton now is. It made 60 barrels from the 1,800 foot sand. A picnic was planned and people invited to come and see the well. They came from far and near bringing their lunches so this was called the Picnic Well. Later some very large wells were obtained in this pool.

The north end of the county was not neglected in this early day. In 1907, Smith and Swan got a gas well in the 2,100 foot sand in the SW. corner of section 20, T. 16 N., R. 12 E., and this one well supplied gas to Mounds for ten years.

In the early spring of 1908, Joe Burns and Lou Caton completed a well near the center of the NE ¼ sec. 6, T. 14 N., R. 14 E. The sand was 1,651 feet deep and the well came in for 400 barrels.

This is the first well in the Bald Hill area and started the development there. In the same year Bob Galbraith came down directly from the Glenn Pool and drilled a good well in sec. 22, T. 15 N., R. 14 E. He found the sand around 1,700 feet deep and, being about the same depth as the pay in the Glenn Pool, he called it the Glenn sand. That name stuck but the correlation was not correct as this is a member of the Dutcher group while the real Glenn sand is the Salt sand.

In the spring of 1908 the Tiger Oil and Gas Company completed a well a little over 2,300 feet deep in the southeast corner of the W ¼ NW ¼ sec. 10, T. 12 N., R. 12 E. It flowed 270 barrels a day for a few days until all the tankage was full when it was shut in. Two years later when it was opened up there was no oil there and the offsets were dry. The boiler and tools for this test were the first to cross the old wooden bridge across the Deep Fork in sec. 22, T. 13 N., R. 12 E., and the teamster demanded insurance on his team before he would take them over. The next year the Aztec Oil Company opened a small pool around the center of sec. 9, T. 12 N., R. 12 E., and some of these wells are still producing. The Mitchell Oil Company drilled its first well near the center of the NE ¼ sec. 20, T. 12 N., R. 12 E., in the early spring of 1913. The production here was in the 1,900 foot sand. This was the beginning of the development of the Tiger Flats area.

In August, 1909, Alex Preston completed the first well in the Hamilton Switch Pool. It was an edge well but started the development in sections 11 and 12, T. 14 N., R. 12 E., where wells of very large initial production were obtained in the Dutcher sand.

The Salt Creek Pool was opened by a well on the north line of the Tobler allotment in sec. 25, T. 13 N., R. 11 E., in October, 1910. The land was owned by Chas. Douglas who sold townsite lots under contract to have a well drilled on the townsite. Newman, Galligan and Spinks owned the leases and turned them over to the Prairie Oil and Gas Company for a consideration of $20,000.00, payable entirely in oil. The Prairie drilled the well to a depth of 2,307 feet and got about a 200 barrel well. The bonus on the lease was paid out and this was the first production in the western part of Okmulgee County.

The gas field lying east of Henryetta, partly in Okmulgee and partly in McIntosh Counties, was developed in 1909 and 1910. In the latter year there was so much gas in sight there that smelters were brought to Henryetta to furnish a market for the gas.

The area west of Henryetta was opened in August, 1912. After two or three failures had been made by others, M. C. French drilled the first successful oil well in the southwest corner of the SW ¼ SE ¼ sec. 8, T. 11 N., R. 12 E. The sand was 1,100 feet
deep. Several wells were later completed to this sand and deeper sands were found.

From these beginnings development spread rapidly throughout the county. In 1913, T. A. Johnston and Northrup demonstrated the value of shooting the Bocch sand in a well in the southwest corner of the NW 1/4 sec. 1, T. 13 N., R. 14 E., and thus started an intense development campaign in the 13-14 and 14-14 area for Bocch sand wells. Some of these wells would have only a show but after a heavy shot would produce up to 500 or 600 barrels. One Bocch sand well in sec. 18, T. 14 N., R. 14 E., is reported to have made 5,000 barrels a day.

One of the most interesting wells in the county from this standpoint of its effect upon the county as a whole is the Huckaby No. 1, drilled by the Okmulgee Producing and Refining Company in sec. 25, T. 14 N., R. 11 E. It was completed in January, 1918, in the Youngstown sand and started the development in the Youngstown Pool, which was the beginning of a new era of prosperity for Okmulgee and Okmulgee County. The well was located without the aid of a surveyor and its location was later found to be wrong by 300 feet or more. Later development showed that if it had been drilled in the correct location it would probably have been dry and this pool might never have been opened or its opening at least delayed for some time. The year 1918 marked the beginning of deeper drilling to the Wilcox sand in Okmulgee County and development has been going on ever since all over the county in an effort to locate production from deeper sands, especially the Wilcox sand. The following table shows the year in which the principal Wilcox sand pools of the county were opened up.

<table>
<thead>
<tr>
<th>Wilcox Sand Pools</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NAME OF POOL</strong></td>
</tr>
<tr>
<td>Brinton</td>
</tr>
<tr>
<td>Deep Fork</td>
</tr>
<tr>
<td>North Heggs</td>
</tr>
<tr>
<td>Tarman</td>
</tr>
<tr>
<td>Wilcox</td>
</tr>
<tr>
<td>Phillipsville</td>
</tr>
<tr>
<td>Mose Carr</td>
</tr>
<tr>
<td>Morris (Gas)</td>
</tr>
<tr>
<td>Independent</td>
</tr>
<tr>
<td>Oklahoma Central</td>
</tr>
<tr>
<td>Bram</td>
</tr>
<tr>
<td>Berian</td>
</tr>
<tr>
<td>Pine-Smith</td>
</tr>
<tr>
<td>Peavonian</td>
</tr>
<tr>
<td>Glenn</td>
</tr>
<tr>
<td>Foxann</td>
</tr>
<tr>
<td>Jolly-Oge</td>
</tr>
</tbody>
</table>

The above are actual pipe line runs from Okmulgee County. Previous to January 1, 1918, Okmulgee and many adjoining counties were not classified separately, but were grouped together and there are no available records regarding the actual production of Okmulgee County in the years preceding 1918.

All of the above figures are from the files and official records of the Okmulgee District Oil and Gas Association.

**NATURAL GASOLINE**

The manufacture of gasoline from natural gas is a very important industry in Okmulgee County. There are forty plants in operation in different parts of the county and they have a combined daily capacity of 73,075 gallons of gasoline. Both the compression and the absorption types of plant are in use and in some plants both processes are used. Following is a table showing the plants in the county January 1, 1926.

**FUTURE POSSIBILITIES**

Although a first glance at the production map (No. V) would seem to show that Okmulgee County had been pretty thoroughly developed, never-the-less there are several thousand acres of potential oil land in the county that have never been tested by the drill. Thousands of acres are now or have been producing
### Gasoline Plants Operating in Okmulgee County

<table>
<thead>
<tr>
<th>Operator</th>
<th>Location</th>
<th>Type</th>
<th>Daily Average Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twitchell &amp; Myers</td>
<td>12-14-14</td>
<td>1 Unit Comp.</td>
<td>200 Gals.</td>
</tr>
<tr>
<td>Denver P. &amp; R. Co.</td>
<td>22-13-13</td>
<td>2 Unit Comp.</td>
<td>990 &quot;</td>
</tr>
<tr>
<td>Burkett Pet. Corp.</td>
<td>22-13-12</td>
<td>2 &quot;</td>
<td>1,000 &quot;</td>
</tr>
<tr>
<td>Pure Oil Co.</td>
<td>9-13-12</td>
<td>2 &quot;</td>
<td>1,200 &quot;</td>
</tr>
<tr>
<td>Okmulgee P. &amp; M.</td>
<td>10-13-12</td>
<td>2 &quot;</td>
<td>750 &quot;</td>
</tr>
<tr>
<td>Atlantic Pet. Corp.</td>
<td>10-13-13</td>
<td>2 &quot;</td>
<td>Shut Down</td>
</tr>
<tr>
<td>Barbra Oil Co.</td>
<td>8-13-13</td>
<td>4 &quot;</td>
<td>3,000 Gals.</td>
</tr>
<tr>
<td>Devonian Oil Co.</td>
<td>29-13-13</td>
<td>4 &quot;</td>
<td>2,600 &quot;</td>
</tr>
<tr>
<td>Coates</td>
<td>12-13-13</td>
<td>4 &quot;</td>
<td>890 &quot;</td>
</tr>
<tr>
<td>Chestnut &amp; Smith</td>
<td>26-13-13</td>
<td>4 &quot;</td>
<td>500 &quot;</td>
</tr>
<tr>
<td>TNC Gasoline Co.</td>
<td>11-13-13</td>
<td>2 &quot;</td>
<td>1,800 &quot;</td>
</tr>
<tr>
<td>Total Oil &amp; Ref. Co.</td>
<td>32-12-13</td>
<td>2 &quot;</td>
<td>75 &quot;</td>
</tr>
<tr>
<td>Twitchell &amp; Myers</td>
<td>32-12-13</td>
<td>1 &quot;</td>
<td>250 &quot;</td>
</tr>
<tr>
<td>Tiger Oil</td>
<td>32-12-13</td>
<td>1 &quot;</td>
<td>2,500 &quot;</td>
</tr>
<tr>
<td>Aslee Oil Co.</td>
<td>11-12-13</td>
<td>1 &quot;</td>
<td>Shut Down</td>
</tr>
<tr>
<td>Hompetta Ref. Co.</td>
<td>11-12-13</td>
<td>1 &quot;</td>
<td>250 Gals.</td>
</tr>
<tr>
<td>Magnolia Petroleum Co.</td>
<td>30-11-13</td>
<td>1 &quot;</td>
<td>Shut Down</td>
</tr>
<tr>
<td>Eagle Fisher Lead &amp; Zinc Co.</td>
<td>6-11-13</td>
<td>1 &quot;</td>
<td>1,500 &quot;</td>
</tr>
<tr>
<td>Blue Ribbon Gasolene Co.</td>
<td>30-10-11</td>
<td>1 &quot;</td>
<td>1,200 &quot;</td>
</tr>
<tr>
<td>H. F. Wilcox</td>
<td>30-10-11</td>
<td>1 &quot;</td>
<td>1,200 &quot;</td>
</tr>
<tr>
<td>H. F. Wilcox</td>
<td>30-10-14</td>
<td>10 &quot;</td>
<td>12,000 &quot;</td>
</tr>
<tr>
<td>Benko Oil Co.</td>
<td>11-12-13</td>
<td>1 &quot;</td>
<td>1,000 &quot;</td>
</tr>
<tr>
<td>Highway Oil &amp; Ref Co.</td>
<td>29-11-14</td>
<td>2 &quot;</td>
<td>700 &quot;</td>
</tr>
<tr>
<td>Invaders Oil Co.</td>
<td>23-11-14</td>
<td>2 &quot;</td>
<td>1,600 &quot;</td>
</tr>
<tr>
<td>Sinclair Oil Co.</td>
<td>23-11-14</td>
<td>2 &quot;</td>
<td>6,000 &quot;</td>
</tr>
<tr>
<td>Texas Crude Co.</td>
<td>23-11-14</td>
<td>2 &quot;</td>
<td>2,000 &quot;</td>
</tr>
<tr>
<td>TNC Gasoline Co.</td>
<td>28-11-14</td>
<td>2 &quot;</td>
<td>7,000 &quot;</td>
</tr>
<tr>
<td>Phillips Higdon</td>
<td>11-12-14</td>
<td>2 &quot;</td>
<td>1,200 &quot;</td>
</tr>
<tr>
<td>Powers &amp; Quinlan</td>
<td>12-12-12</td>
<td>2 &quot;</td>
<td>600 &quot;</td>
</tr>
<tr>
<td>Mid-Century Oil U.S.</td>
<td>12-12-12</td>
<td>2 &quot;</td>
<td>Shut Down</td>
</tr>
<tr>
<td>Oil State Gasolene Co.</td>
<td>12-12-12</td>
<td>2 &quot;</td>
<td>Shut Down</td>
</tr>
<tr>
<td>Polar P. &amp; R. Co.</td>
<td>12-12-12</td>
<td>2 &quot;</td>
<td>Shut Down</td>
</tr>
<tr>
<td>Texas Company</td>
<td>11-14-12</td>
<td>2 &quot;</td>
<td>1,000 &quot;</td>
</tr>
<tr>
<td>White Phillips Co.</td>
<td>11-14-12</td>
<td>2 &quot;</td>
<td>3,500 &quot;</td>
</tr>
<tr>
<td>Highway Oil &amp; Ref Co.</td>
<td>9-14-13</td>
<td>2 &quot;</td>
<td>50 &quot;</td>
</tr>
<tr>
<td>Invaders Oil Co.</td>
<td>33-14-13</td>
<td>2 &quot;</td>
<td>250 &quot;</td>
</tr>
<tr>
<td>Elm Oil Co.</td>
<td>33-14-13</td>
<td>2 &quot;</td>
<td>250 &quot;</td>
</tr>
<tr>
<td>Sequoyah Oil Co.</td>
<td>10-14-14</td>
<td>2 &quot;</td>
<td>Shut Down</td>
</tr>
</tbody>
</table>

from the shallowest sand like the Salt sand and the Boeck sand and have never been tested below them while only a small portion of the county has been properly tested to the deepest known pay, the Wilcox sand. In other words, in addition to the virgin territory there is still a great area to be tested by deeper drilling and the extent of that area is directly proportional to the stratigraphic depth of the pay sand. A great deal of development is now going on throughout the county and the goal of each test is the Wilcox sand. However, it frequently happens that the test never reaches that depth because a good well is found in some other of the shallower sands. Possible pay horizons deeper than the Wilcox sand should also receive due consideration since it has been shown by tests in different parts of the county that the Hominy or Burgen sand and also the Siliceous lime or Turkey Mountain sand contain oil. It is quite probable that somewhere the conditions for accumulation are favorable and paying production will be obtained from these sands.

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**WAGONER COUNTY**

By J. Philip Boyle

**INTRODUCTION**

In the history of geological work, for the purpose of locating oil and gas pools, no intensive consecutive study seems to have been made of the agencies governing the accumulation of oil in Wagoner County until two years ago, when the author commenced doing work over the entire county to determine these facts. The result of the last two years work convinced the author that oil production occurring in Wagoner County is closely related to the folding, faulting and settling which occurred during and after the disturbance which caused the Seneca and other small parallel faults, and that there occurs in Wagoner County general lines of production governed by long sharp anticlinal folds. The sands producing oil and gas in the county are called by any name which happens to occur to the operator and as the majority of operators in Wagoner County have received very little help from a geological standpoint, the author is writing this report with the purpose of familiarizing the operator with the producing horizons and why they produce.

![Figure 17.—Index map of Oklahoma showing location of Wagoner County.](This report originally issued as Bulletin 40-L, May, 1927.)
OIL AND GAS IN OKLAHOMA

ACKNOWLEDGMENTS

In gathering information for this report, written references on this county were found to be meager. The most useful printed information was obtained from the U.S. Geological Survey maps and those of the Oklahoma Geological Survey. The author is indebted to Luther H. White for valuable information concerning distribution of the formations below the Mississippi limestone, and to Roger W. Sawyer for samples and general information concerning the county.

Mr. Oliver A. Sewell and other local operators were very kind in giving practical information and saving samples from wells.

HISTORY OF DEVELOPMENT

Oil development in Wagoner County progressed from the west side of the county toward the east. (Map No. VI). The year 1914 seems to have ushered in the discovery of oil in commercial quantities in the county. Following the initial discovery, the years 1915 and 1916 brought development in T. 17 N., R. 15-16 E., to the extent that the large pools such as the Stone Bluff area and the pools in T. 17 N., R. 15 E., were brought in with initial wells of from 10 to 1,500 barrels. From 1916 to the present date, operations have spread over practically the entire county with the result that three distinct producing horizons have been proved in the greater part of the county.

LOCATION

Wagoner County lies in the northeastern part of Oklahoma, and extends from Tps. 15-19 N., R. 15-20 E., inclusive. It includes eleven entire townships and parts of ten others. It is very irregular in shape because some of the boundary lines are streams. The approximate area of the county is 580 square miles.

TOPOGRAPHY

The entire county slopes from the north and west to the south and east. The maximum relief of the entire county is approximately 460 feet and lies within the sandstone hills region, with the exception of the extreme northeastern part, which is in the Ozark plateau. The greater part of the surface of the county is a level plain. In the extreme western part the sandstone formations have been cut by stream erosion, forming eastward facing hills which are quickly recognized by their covering of scrub oak vegetation.

The country adjacent to the Grand River has been cut by a number of small streams, forming hills of considerable size. The point attaining the highest elevation is in T. 16 N., R. 14 E., with an elevation of 900 feet, and the lowest point is approximately 500 feet, and marks the point where the Arkansas River flows out of the county. The Arkansas River and its tributaries drain the entire county. Next in size to the Arkansas River is the Verdigris River, which drains two-thirds of the county and the Grand River which drains the extreme eastern part of the county. The streams have reached the stage where they form meandering channels, and a great many oxbow conditions occur in their broad valleys.

STRATIGRAPHY

SURFACE GEOLOGY

The rocks exposed on the surface of Wagoner County belong chiefly to the Pennsylvanian series and the subdivisions of the Pennsylvanian rocks exposed are the Morrow, Winslow, and Fort Scott formations, and a narrow exposure of the Labette shales.

RECENT OR PLEISTOCENE SEDIMENTS

<table>
<thead>
<tr>
<th>Stratigraphic Column</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td></td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>5 to 80</td>
</tr>
<tr>
<td>Pleistocene</td>
<td></td>
</tr>
<tr>
<td>Sandy clays</td>
<td>30 to 80</td>
</tr>
<tr>
<td>Clays</td>
<td></td>
</tr>
<tr>
<td>Labette shale</td>
<td>40 Exposed</td>
</tr>
<tr>
<td>Fort Scott</td>
<td>60</td>
</tr>
<tr>
<td>Winslow</td>
<td>750</td>
</tr>
<tr>
<td>Morrow</td>
<td></td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Mississippian</td>
<td></td>
</tr>
<tr>
<td>Pitkin lime</td>
<td></td>
</tr>
<tr>
<td>Lyons-Quinipe lime</td>
<td></td>
</tr>
<tr>
<td>Lower Mississippi lime</td>
<td></td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Devonian</td>
<td></td>
</tr>
<tr>
<td>Chattanooga shale</td>
<td></td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Ordovician</td>
<td></td>
</tr>
<tr>
<td>Viola limestone</td>
<td></td>
</tr>
<tr>
<td>Wilcox sand</td>
<td></td>
</tr>
<tr>
<td>Tyner series</td>
<td></td>
</tr>
<tr>
<td>Upper Tyner sand</td>
<td></td>
</tr>
<tr>
<td>Green shales</td>
<td></td>
</tr>
<tr>
<td>Burgen</td>
<td></td>
</tr>
<tr>
<td>Lower Tyner sand</td>
<td></td>
</tr>
<tr>
<td>Cambro-Ordovician</td>
<td></td>
</tr>
<tr>
<td>Turkey Mountain sand</td>
<td></td>
</tr>
<tr>
<td>Arbuckle limestone</td>
<td></td>
</tr>
</tbody>
</table>

Deposited unconformably upon the eroded surface of the Winslow formation in Wagoner County are two horizons of sediments of Recent or Pleistocene age. These sediments are of sub-areal character and represent a flood plain condition of two cycles of erosion by the Arkansas River. The younger formation consists of unconsolidated clays, sands and gravels deposited in the present flood plain of the Arkansas River. These beds, where present, contain numerous pieces
of chert derived from the Winslow formation. Farmers along the
Arkansas River bottoms derive their water supply from this for-
mation by sinking sand points.

Approximately 70 feet above the present flood plain of the Ar-
kansas River occurred an earlier cycle of erosion, during the latter
part of which the Arkansas River deposited over the area west of
Coweta and in the vicinity of Red Bird unconsolidated clays with
a maximum thickness of 40 feet. These clays differ from the youn-
ger formation by being of more uniform texture, and containing few-
ger gravels. These late sediments were deposited, after the struc-
tural disturbances occurred which caused the Seneca fault, and conceal
on the surface some structures now producing oil and gas.

LABETTE SHALE

The Labette shale overlies the Fort Scott formation in Wagoner
County, and is exposed over a small area with an approximate thick-
ness of 60 feet just east of Broken Arrow. The Labette formation
consists of thin shales with an occasional heavy sandstone.

FORT SCOTT FORMATION

The Fort Scott formation overlies the Winslow but a very small
portion of it remains. It is exposed only over a small area in the
northwestern corner of the county and is made up of several lime-
stone members, separated by shales. Its probable total thickness as
exposed in Wagoner County does not exceed 60 feet.

WINSLOW FORMATION

The Winslow formation is exposed over almost the entire county.
It consists of blue and black shales, clay, sandy shale, brown sand-
stone, occasional beds of chert and thin lenses of coal. The sandstone
varies in character from hard thin-bedded to massive. The sand-
stone is more or less equally divided between the upper part of the
formation and the lower. The upper sandstones go to make up some
of the bald hills noticeable in the county.

In some restricted areas the hard, thin-bedded sandstones be-
come interspersed with calcareous nodules, in places grading into
pure limestone lenses. The clays and shales make up most of the val-
leys throughout the county. The thickness of the whole formation
exposed is approximately 750 feet. This formation is equivalent of
the Cherokee formation to the northwest.

MORROW FORMATION

The Morrow formation, lowest of the group, consists of
limestone and shales with local beds of thin sandstone. The lime-
stone predominates in the lower part of the formation, while the
upper part consists mostly of a thin series of sandstones. This for-
mation is exposed along the Grand River in the eastern part of the
county.

SUBSURFACE GEOLOGY

The subsurface geology of Wagoner County from the standpoint
of oil and gas production may be divided into two distinct divisions
—those horizons containing sands occurring above the Mississippi
limestone and those occurring between the Chattanooga shale and
the top of the Arbuckle limestone. The first sands occurring in
the upper division are those of Dutcher age which are reached
at a depth of from 200 to 1,400 feet, depending upon the geogra-
phic location, and how the area being drilled is located structurally.
These sands are not continuous throughout the county, or even
through a township. They lens in and out either being replaced
by the shales, or taking the place of shale intervals.

These sands are often very hard on the axes of folds; some-
times to such an extent that a large shot is necessary to obtain pro-
duction. The cement in these sands varies from a small content of
iron to a high content of calcium carbonate. Initial production
in these sands varies from very small wells up to wells producing
as high as 1,500 barrels per day.

MISSISSIPPI LIMESTONE

The Mississippi limestone is from 200 to 450 feet thick and
throughout Wagoner County contains a shale break in the center.
The top part of the limestone represents the Pitkin limestone, the
top of which has a very irregular surface. In the depressions of these
irregularities there sometimes occurs a sand probably the equiva-
 lent of the Burgess sand found north of Tulsa. This sand has been
found to produce oil or gas in commercial quantities only in very
rare instances. The shale break in the Mississippi lime occasionally
carries a sand which sometimes produces small quantities of gas.
The Mississippi lime is variable both in interval and texture and
ranges in color from gray-white to black. It lies directly upon the
Chattanooga shale where the Chattanooga is present.

CHATANOOGA SHALE

The Chattanooga shale which directly underlies the Mississippi
lime is Devonian in age and is found throughout almost the entire
county with an approximate thickness of 60 feet, where drilling
records are available to a sufficient depth. This shale varies from
soft to very hard, and is usually a dark brown to black color.

VIOLA LIMESTONE

The Viola limestone occurs over a small area in the southern part
of Wagoner County (See Fig. 18). This limestone, white to gray in
color, varies from 5 to 20 feet in thickness and is hard to chalky
in texture. It is often called the "white" or "buttermilk" lime by drillers. It occurs just below the Chattanooga shale and lies upon the Wilcox sand where the Wilcox is present. The shore line of deposition of the Viola is very irregular and scattered lenses of this formation occur as far north as Coweta. The main body of Viola limestone thins out with the Wilcox sand.

WILCOX SAND

The Wilcox sand is present in a very small area in Wagoner County, south of the M. K. & T. Railroad. Where present it directly underlies the Chattanooga shale and is a coarse, white to brown sandstone and is an important producing horizon. The normal dip is to the southwest at the rate of approximately 20 feet per mile. The Wilcox shore line crosses Wagoner County in an irregular direction following approximately the right of way of the M. K. & T. Railroad from Broken Arrow to Muskogee.

TYNER SERIES

The Tyner series of Ordovician age underlies the Wilcox sand when that sand is present and directly underlies the Chattanooga shale when the Wilcox sand is not present. This series is found in drilling records throughout practically all of Wagoner County and is principally recognizable by its light green color. It has a variable interval ranging from 40 to 200 feet in thickness and varies in texture from pure clay shale to sand shale. Two distinct sand horizons occur in this formation throughout Wagoner County and the author has subdivided these formations into the upper Tyner and the lower Tyner sands. Both of these sands are commercially productive of oil and gas and are usually referred to by local operators as the "Wilcox sand." The upper Tyner sand is usually encountered directly under the Chattanooga shale. It varies from nothing to 45 feet in thickness. The lower Tyner sand is encountered at the base of the green shale series and varies in thickness from 10 to 55 feet, usually white to light green in color and very soft. Sands of the Tyner series are easily identified by their characteristic green specks of shale.

BURGEN SANDSTONE

The Burgen sandstone of Ordovician age, deposited in early Ordovician times and found over the entire county, is a clean white sandstone varying from 10 to 40 feet in thickness. It became important as a producing horizon in 1925 when R. W. Sawyer and the Newman Corporation opened a gas field in this sand in T. 17 N., R. 16 E. Structures in this sand conform to those in the Tyner series.

TURKEY MOUNTAIN SAND

At the top of the Arbuckle (siliceous) limestone occurs a sandy horizon sometimes productive of gas in Wagoner County and nearly always referred to by the local operators as the Turkey Mountain sand. This horizon is encountered by drilling everywhere in the county where the top of the Arbuckle limestone happens to be sandy in texture.

ARBUCKLE LIMESTONE

The Arbuckle limestone directly underlies the Burgen sandstone and is found throughout the county in drilling records of sufficient depth to encounter this horizon. The top of this limestone is usually grayish in color and is often logged in drilling records as gray sand. The Arbuckle limestone, from a standpoint of oil and gas development, is an important horizon in this county insofar as it marks the limit of depth at which known oil producing horizons may be encountered. The author does not recommend that any wells be drilled deeper than the top of this limestone.

STRUCTURE

The structure of Wagoner County, from a standpoint of oil and gas, may be divided into two horizons; that of the Mississippian and Pennsylvanian in the upper division, and that of the formations...
lying below the Mississippi lime in the lower division. The surface structure of Wagoner County in general is that of a westward dipping monocline, while that of the lower division is a southwestern dipping monocline. These general dips were disturbed in late Pennsylvanian and early Cretaceous times, causing minor folds and faults which are directly related to the accumulation of oil and gas in this county. (See Map No. VII).

**MAJOR FOLDS**

The major fold or structural disturbance which at the time of the uplift, or later, directly or indirectly, caused most of the oil producing structures in Wagoner County, is the Seneca fault. This fault originated in late Pennsylvanian time, and resulted in the fracturing of all the sedimentary rocks along its axis, to the extent that a throw as much as 300 feet is developed in places. It further resulted in parallel faulting due to settling and lateral adjustment after the occurrence of the major fault. The Seneca fault crosses the county in a northeast-southwest direction along an approximate line drawn from the southwestern corner of T. 17 N., R. 16 E., to a point where Bull Creek empties into the Verdigris River. This major fault disturbed the normal dip to such an extent that some anticlines were formed which attained a maximum crest 800 feet above the synclines. Following this disturbance of the sediments, the natural process of settling and cross-folding progressed to the extent that most of the structures now producing oil and gas were formed.

**PENNYSYLVMAN SURFACE TYPES**

*Coweta Gas Field*

The Coweta gas field, located in W.½ sec. 17, and E.½ sec. 18, T. 17 N., R. 16 E., is a typical gas producing structure of this county. It produces from a sand of the Dutcher series with an initial production of from one to six million cubic feet of gas per well. This small anticlinal dome has a complete closure of 40 feet and a direct east dip of at least 70 feet. It resulted from the drag of a small fault running north and south through the eastern half of sec. 17, and is one of the two typical Pennsylvanian type structures in the county.

Figure 10 represents a structural map of sec. 32, T. 18 N., R. 16 E., based on the outcropping beds of this area. The fault along the axis of this structure parallels the Seneca fault and is the top of a hogback anticline running through this section, having the same axis as the fault. The west limb of this anticline dips 750 feet in one mile to the west and 350 feet in one-fourth mile to the east. The cross-section of the producing horizon shown in the figure is drawn to scale and is based upon subsurface data obtained from wells located in the northeastern corner of this section. This cross-section shows the width of the producing area and the effect fault-
The structures occurring in the subsurface of the Pennsylvanian formations are usually reflected at the surface, but due to surface conditions are not always workable by the geologist. The sharp hogback folds and faults to which all Pennsylvanian structures are closely related apparently gain in surface intensity with depth. In the southwest corner of the county, these sharp folds very likely cause normal domes and anticlines in the surface beds in the area of Stone Bluff due to the fact that the section increases considerably in thickness.

Subsurface geology in Wagoner County is much more dependable than surface geology. The axes of fold shift with depth and in structures where the oil accumulated near or against the footwall of the fault. The exact position of this plane is not always determinable, and sometimes shows an apparent producing area on top, so that a well located upon surface geology might miss production in the formations below. These conditions are important both in the upper and lower producing horizons.

ORDOVICIAN STRUCTURAL TYPES

The Ordovician formations directly underlying the Chattanooga shale constitute the lower division of sand horizons from which oil and gas are being produced. These formations are made up of sand, very thin limestone and light green shales. At the top of this series occurs the Wilcox sand, which is in place south of the M. K. & T. Railroad only (See Fig. 18), with the exception of some of the deep synclines and re-entrants of Ordovician time, giving the shore line of the Wilcox sand a rather meandering edge.

The upper Tyner sand occurs where the Wilcox is not present, production from which apparently has the same relationship to structure as the Wilcox sand. Occurring in the lower part of the Ordovician series is the lower Tyner sand, with the same producing relationship to structure as the upper Tyner. The large type of producing structures in the Ordovician series nearly always reflect on the surface as some type of structural high, but cannot be mapped accurately on the surface. Many of the small dome type of structures do not show at all on the surface and are very small in area.

Figure 31 shows a small producing dome in the Tyner sand. This structure does not show at all on the surface, but has a complete closure of at least 30 feet, and a direct east dip of 50 feet. The green shale seems to have been cut away on the top of this fold and replaced by a coarse sand very similar to eroded Wilcox. As no samples are obtainable, this re-deposited sand may be either Wilcox or Tyner. The entire area of this pool does not cover over 30 acres. There are numerous small pools of this type producing in the county, and as one location in the wrong direction means a dry hole, this type of folding has influenced the operator to believe
that a spotted lenticular condition governs the accumulation of oil more than a structural condition. However, this idea is erroneous and these small producing areas are due to small-scale domes.

The large faults, some of which show on the surface, and some of which occur only in the Ordovician beds form the closure on the east side of the structure and are consequently the direct agency in the accumulation of oil.

Figure 22 is a subsurface map based on a producing horizon of the lower Tyner sand. This structure shows on the surface, but the surface reflects very poorly the conditions below the Mississippi lime. The cross-section A-A shows the lower section of the logs of wells drawn to scale. The fault which causes the trap for the accumulation of oil in this structure does not show in the Mississippi lime and is a characteristic condition on structures now producing from the Ordovician series. Near this area is a new gas field producing from the Burgen sandstone which occurs under the first lime below the Tyner series. The Burgen is a white, clean sand, very porous in character, and produces from structural types analogous to those in the Tyner series. This sandstone is found nearly everywhere in Wagoner County and is often referred to by the local operator as the "Turkey Mountain" or Wilcox sand.
The author does not believe that any large pools will be discovered in the future, due to the small structural types characteristic of this area.

CONCLUSIONS

All of Wagoner County may be considered very probable oil and gas territory west of a line drawn north and south through the town of Wagoner. The author considers geological data very valuable to the operator and with the exception of the silted areas along the river bottoms, practically all of Wagoner County can be either mapped on the surface or subsurface, and by these methods the larger types of structures discovered.

Atoka, Pushmataha, McCurtain, Bryan, and Choctaw Counties

By
C. W. Meness

LOCATION AND ACCESSIBILITY

Atoka, Pushmataha, McCurtain, Bryan, and Choctaw counties lie in the southeast corner of Oklahoma, and comprise an area of approximately 6,000 square miles, about one-twelfth of the total area of the State. The northern half of Atoka County, most of Pushmataha County, and the northern half of McCurtain County cover a large area in the Ouachita Mountains; the southern half of Atoka County, the southern half of McCurtain County, and all of Choctaw and Bryan counties lie in the Red River Plain, which is a part of the Gulf Coastal Plain, contiguous on the south.

Fig. 23—Index map of Oklahoma showing location of Atoka, Pushmataha, McCurtain, Bryan, and Choctaw Counties.

The principal towns in the area are: Atoka, Antlers, Idabel, Durant, and Hugo, each of which is accessible by rail. Durant, Hugo, and Idabel are situated on the Ardmore branch of the Frisco Railroad, which runs east-west, and makes connections north and south over the Santa Fe Railroad at Ardmore, Oklahoma, and north and south over the Kansas City Southern Railroad at Ashdown, Arkansas. Connections are made north and south also over the Missouri, Kansas and Texas Railroad, and over the Kansas, Oklahoma and Gulf Railroad at Durant; and north and south over the main line of the Frisco Railroad at Hugo. The main line of the Frisco passing through Hugo passes also through

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Antlers, the county seat of Pushmataha County; and the Missouri, Kansas and Texas Railroad, goes through Atoka, the county seat of Atoka County. There is no railroad north or south from Idabel, the county seat of McCurtain County, but the Kansas City Southern Railroad approaches very close to the Oklahoma-Arkansas State line over its right-of-way, and points in northern McCurtain County are accessible from it. The Texas, Oklahoma and Eastern Railroad, originally a logging road, joins Valliant, a town on the Frisco in McCurtain County, with DeQueen, a point on the Kansas City Southern Railroad in Arkansas. This line passes through Eagleton, Broken Bow, and Wright City, all of which are in central McCurtain County.

There are also numerous automobile roads in southeastern Oklahoma. Thus, one may approach from the north via McAlester or Poteau to the small town of Victor, by automobile, thence south over the mountains to Talihina, Albion, Tuskaoma, Finley, Antlers, and Hugo; or one may enter the region from the west, coming in from Ada via Atoka and Durant, or from Ardmore to Durant, thence to Hugo. The region is easily accessible from the south over the Red River bridge at Arthur's Bluff, Texas, south of Hugo; and from the east over good roads from De Queen, Arkansas, to Broken Bow, Oklahoma. One may also come in from Ashdown, Arkansas, to Idabel, thence north to Broken Bow, or proceed west from Idabel to Hugo.

**TOPOGRAPHY AND DRAINAGE**

The area of the Ouachita Mountains in Oklahoma, in which falls the northern half of Atoka County, practically all of Pushmataha County, (all except the southern margin), and the northern half of McCurtain County, is for the most part one of high sandstone ridges and intervening wide flat valleys having an east-west direction, but locally there are considerable areas of flint hills. The sandstone ridges are steep sided, strewn with blocks of loose rock, and many of them are of mountainous dimensions, 80 to 50 miles in length and several miles broad. They range in height up to 2,900 feet above sea. The valleys between the principal ridges are established on broad belts of shale or slates, chiefly which, because of less resistant character, have been worn down by the streams. Some of the larger valleys are several miles broad and terminate abruptly against the flanks of the mountains. In these valleys, locally, are certain low ridges or rounded hills and knolls, and some rolling prairie lands, which are the result of the weathering of sandstones. The areas of flint, such as the Potato Hills in northern Pushmataha County, Pine Mountain, He Mountain, and numerous other (unnamed) mountains all in central McCurtain County, and the flint hills in central Atoka County, are composed of black, bluish, and gray to white flint. These hills are not as high as the sandstone ridges, but they are rough and rocky and have, generally, much steeper slopes; also the chert or flint, which is continually breaking away from the parent ledges in place, to form a loose, sharp, angular rubble, covers the surfaces and makes walking difficult.

**ACKNOWLEDGMENTS**

The writer is under obligations to the Empire Gas and Fuel Company, for the logs of wells drilled in Bowie County, Texas, and in Miller and Little River counties, Arkansas; and to Frank H. Gerlof of Tulsa for logs and elevations of wells in the same area. The locations and total depths of the wells drilled in Fannin, Lamar, and Red River counties, Texas, were obtained from the offices of the Gulf Production Company, Texas. Information on the wells drilled in Oklahoma was obtained largely from the Gypsy Oil Company. Miss May Pepperdine of the Gypsy office has very kindly drafted the maps, and others of my colleagues have assisted with the typing and proofing of the manuscript. A liberal use has been made of the literature touching upon the general area, but credit is given to authors in the footnotes, which constitute a fairly complete bibliography.

**GEOLOGY**

**GENERAL STATEMENT**

The five counties here under review, namely: Atoka, Pushmataha, McCurtain, Bryan, and Choctaw, lie partly in a region of highly folded ancient (Paleozoic) sediments, and in part in an area of nearly flat-
ly, loosely consolidated sands and clays of more recent (Cretaceous) age. The outcrop of the old rocks lies north of a line joining the towns of Atoka, Antlers, and Broken Bow. (Map No. VIII), and is known, physiographically, as the Ouachita Mountains. South of this line to Red River and beyond, the terrane belongs to the Coastal Plain. The area to be considered is just about equally divided, therefore, geologically. I shall discuss first the stratigraphy and structure of the Ouachita Mountains as it pertains to the particular area and problem, and take up second the stratigraphy and structure of the Coastal Plain, insofar as it concerns Bryan, Choctaw, and McCurtain counties in particular.

**Ouachita Mountain Stratigraphy**

The rocks exposed in the Ouachita Mountains are almost wholly of the non-calcareous types, consisting of shales (slates), sandstones, and shaly or cherts. These have been described in detail, their thickness determined, and other facts about them made known largely through the labors of J. A. Taff, G. H. Girty, Hugh D. Miser, and C. W. Hones. For present purposes it will not be necessary to repeat all of these details, and I shall give only such facts briefly as are of immediate interest. Following is the succession of formations in stratigraphic order from youngest (top) to oldest (bottom) as determined by the various geologists who have worked in the region.

**STRATIGRAPHIC SECTION OF THE OUACHITA MOUNTAINS**

**Atoka formation** (Pennsylvanian). The Atoka formation consists of blue and black shales, and dark brown sandstones of varying hardness, all generally thin bedded, and having a total thickness of 3,100 feet in Atoka County. In Pushmataha and McCurtain counties the Atoka has been largely removed by erosion, since the mountains were formed.

**Wapanucka limestone** (Pennsylvanian). The Wapanucka limestone is in part clastic and in part a cherty fossiliferous limestone, with dark sandy shales at the base, the total thickness being about 100 feet in Atoka County. Farther east this formation is locally present as a calcareous sandstone, but in general it has been cut away by erosion.

**Caney shale** (Pennsylvanian and Mississippian). The Caney is a mass of blue and black shales including limestone segregations and er-


**Atoka, Pushmataha, McCurtain, Bryan, Choctaw**

Ratonic boulders of limestone and sandstone. It has a total thickness in Atoka County of 800 feet or more, but appears not to have been deposited in its typical phase farther east.

**Jackfork sandstone** (Mississippian). The Jackfork sandstone is a formation 6,600 feet in thickness consisting chiefly of massive beds of fine to medium grained sandstone interbedded with minor amounts of blue shale. It is exposed widely in Atoka, Pushmataha, and northwest McCurtain counties, and is responsible for all the highest mountains in this area.

**Stanley shale** (Mississippian). The Stanley is a formation of dark colored, thin bedded, ripple-marked sandstones and dark gray or black shales and slates interbedded in one vast series 6,000 to 10,000 feet thick. The sandstones are unusually hard, and in places they become quartzites. A bed of volcanic ash (tuff) 90 feet in thickness occurs near the bottom of the formation in McCurtain County, and a lentil of black chert up to 50 feet in thickness appears in the middle of the Stanley in this same region. The Stanley is widely exposed throughout the length and breadth of the Ouachita Mountains.

**Arkansas novaculite** (Devonian). The Arkansas novaculite may be subdivided into three parts: (1) a heavy bedded white novaculite (flint), carrying locally pockets of manganese ores, and composing the lower one-third of the formation; (2) thin bedded black novaculite (chert or flint) and black shales or slates forming the middle portion; and (3) a manganese-bearing white novaculite, 100 feet thick or less, occurring at the top. The total thickness of this rock ranges from 250 feet in western McCurtain County to 540 feet in eastern McCurtain County. In northern Pushmataha County and central Atoka County the upper part of the Tahlina chert is the Arkansas novaculite and this part of the chert appears to have a thickness of about 250 feet here. The novaculite is exposed extensively in central McCurtain County and locally elsewhere.

**Missouri Mountain slate** (Silurian). This formation consists wholly of green and red shales or slates, weathering buff, their thickness being 60 to 100 feet. The outcrop appears only in central McCurtain County.

**Blaylock sandstone** (Silurian). The Blaylock is a formation of hard, quartzitic, thin bedded, green sandstones and hard, green slaty shales, 600 to 800 feet thick. Upon exposure the entire mass weathers red. The outcrop appears only in central McCurtain County.

**Polk Creek shale** (Ordovician). The Polk Creek shale is jet-black in color, richly graphitic or carbonaceous, soft, contains abundant grapholites, and is uniform in character throughout its geographic extent. It is about 100 feet thick. The main outcrop appears in central McCurtain County, but a portion of the Tahlina chert in Atoka and Pushmataha counties resembles the typical Polk Creek, and is doubtless of the same age.
Bigfork chert (Ordovician). The Bigfork chert consists of wavy thin beds of black chert and black cherty limestone interbedded with minor amounts of black slaty shales, having a total thickness of approximately 800 feet. The outcrop appears in central McCurtain County where it covers many square miles, but the lower part of the Talihina chert in Atoka and Pushmataha counties has been identified as the Bigfork, which therefore must be present throughout the entire Ouachita region. The Bigfork chert is synchronous with the Viola limestone of the Arbuckle region.

Womble shale and sandstone (Ordovician). The Womble formation consists of soft, micaceous, argillaceous, fine grained, green sandstones and clay shales which have a total thickness of 1,000 feet or less. These have been modified by folding and uplift, and by hydrothermal action. They have also suffered from quartz intrusions, with the result that the slates split readily across the bedding, and the sandstones have taken on a schistose character which is decidedly characteristic. Although green when fresh these rocks invariably weather red and finally brown. The outcrop is confined to central McCurtain County, but the Stringtown black shales which appear beneath the Bigfork in the Potato Hills in northern Pushmataha County and in the flint hills of central Atoka County are probably of the same age as the Womble.

Blakey sandstone (Ordovician). A dark gray quartzite composed of spherically rounded quartz sand grains and having numerous smoky quartz veins cutting across it has been called the Blakey. It is approximately 15 feet thick, and outcrops in central McCurtain County.

Mazarn shale (Ordovician). The Mazarn shale is a mass of dark colored carbonateous shales, which split across the bedding. The thickness is estimated at 1,000 feet, but there is doubt about the identity and correlation of these Oklahoma deposits with the type Mazarn shale areas, which are in Arkansas. The Oklahoma “Mazarn” crops out typically along Glover Creek (sec. 15, T. 5 S., R. 23 E.) in central McCurtain County.

Crystal Mountain sandstone (Ordovician). The Crystal Mountain sandstone is composed essentially of coarse, spherically rounded quartz sand, now firmly cemented with silica. The rock is massive, without bedding, hard, and gray in color, but weathers brown, due to the presence in it of a ferruginous carbonate. At the base is a conglomerate, 14 feet thick, which contains angular as well as rounded blocks of limestone and black chert up to eight inches in length. The total thickness of the Crystal Mountain sandstone is 500 feet, and it outcrops in central McCurtain County.

Collier shale (Ordovician). The Collier shale consists of dark colored metamorphosed shales and shales containing local minor developments of conglomerates and limestone. This is the oldest formation exposed in the region, and we see only the topmost 200 feet of it. Its total thickness is not known, and what lies beneath it is not known. The outcrops of the Collier appear in central McCurtain County.

Ouachita Mountain Structure

The structure of the Ouachita Mountain area is of that type commonly known as Appalachian. It resembles, that is to say, the well-known structure of the Appalachian Mountains, which is essentially a series of tightly compressed, and in part, overturned folds (anticlines and synclines), accompanied by faulting. Viewed at large the Ouachita Mountains are clearly but a fragment of a former, extensive range, which indeed may have, at one time, connected with the Appalachian Mountains. There is a great deal of evidence in support of this supposition. It is also clear that the present mountains once did, and that the structures still do, continue far to the south and west into the State of Texas. We are describing, therefore, a type of structure which is not locally confined to the present mountains, but is more general, regionally larger, and deep seated.

The present Ouachita Mountains, extending from Atoka, Atoka County, Oklahoma, east into Arkansas, and occupying a belt 50 to 60 miles broad, is essentially a mass of complexly folded sandstones, shales and cherts (flints), which have been, since they were folded, subjected to erosion. During this interval of erosion the tops of the folds were gradually cut away, and one sees now only the roots of the former mountains, and only the jagged edges of the rock strata that compose the arches and troughs. The rocks were not folded into broad basins and domes, but for the most part were pushed together to form the isoclinal and recumbent types of folds, and these were packed tightly together, or inclined one upon the other, in a manner that left the strata all plunging in one direction for any single large area. The rocks were also broken in an infinite number of places, jointed, and the shales, which were softer, must have yielded much as putty in the hands of the glazier. In numerous places large masses of rock slipped past other large masses along definite lines of displacement, which are many miles in length and thousands of feet deep in the ground; also there were slips (faults) of small dimension. The friction of these moving masses of rock, which, by the way, moved in a northerly and northwesterly direction, developed a great deal of heat, and heat, combined with the pressure which was brought to bear on this mountain mass, caused the rocks to be changed physically and chemically, from their original soft nature to harder materials. There is evidence that at greater depths this movement was accompanied by the intrusion of melted rock, for the sediments now exposed at the surface have suffered intrusions of thick masses of quartz and locally other igneous matters. All the older rocks have been steamed in hot waters containing lime and iron carbonates and silica, which come from below.

One of the larger upfolded masses in the Ouachita Mountains is the Choctaw anticline, which occupies all of central McCurtain County, and extends southwest, without the shadow of a doubt, beneath the Coastal Plains sediments at least as far as Red River, and presumably much farther. This anticline is a region of general uplift, and it is
extremely complicated structurally, for it carries on either flank as many as fifty minor thrust folds (anticlines and synclines) and numerous faults, yet the strata dip uniformly to the north (northeast on the east flank, and northwest on the west flank) throughout the mass. Half of the rocks in this structure are, therefore, upside down. (See areal maps and structure sections, Okla. Geol. Surv. Bull. 32, Pt. I, Plates I, LXIX, and LXXXII, 1923.)

Another large anticline appears in northern Pushmataha County and southern Latimer County. The rocks exposed along the central part of this axis form the Potato Hills, 15 miles long by six miles broad. The entire anticline may be thought of as extending roughly 35 miles, in an east-west direction. Like the Choctaw anticline the Potato Hills anticline is also extremely complicated, having many small folds on its back, but in this case the strata are tilted in various positions, mostly toward the south. The rocks dip to the south generally over all of northern Pushmataha County north of Kiamichi Mountain, and over all of southern LeFlore County, south of the Choctaw fault.

There are a number of large down folded areas or synclines in the Ouachita Mountains, and singularly enough, these are all simple troughs tilted up at one end, or both ends, and are never complicated in the sense that the large up-folded areas are. These troughs are 20 to 50 miles long by 6 to 10 miles broad and are separated one from the other by huge thrust faults. They are formed of the Stanley and Jackfork formations in some cases, but usually later sediments, up to and including the Atoka formation, are also caught in these basins. These synclines are sometimes over-turned. The strata dip from 30° to 60° toward the central axis in most cases, but frequently the dip is much less—sometimes more. Some of the more prominent of the synclines are: Bethel syncline and Bokokola syncline in northern McCurtain county; Lynn Mountain syncline in northern Pushmataha and southern LeFlore counties; and Caney basin in western Pushmataha County. There are ten or a dozen all told. These large basins and accompanying thrust faults all trend in a southerly or southwesterly direction, and the rocks of which they are composed form the foundation stones of southern Atoka, southern Pushmataha, most of Choctaw, and a part of Bryan counties. I.e., it is on this type of structure and over this kind of rocks that the Coastal Plains deposits were laid in the Red River region. Southern McCurtain County, as previously stated, is underlain by the hard sandstones and especially by the flints and slates which compose the Atoka anticline.

Coastal Plains Stratigraphy

Lying on top and across the steeply dipping, eroded edges of the Ouachita Mountain rocks in southern Atoka, southern Pushmataha, and southern McCurtain counties, and farther south, are thick deposits of yellow sand, red and yellow clays, chalky limestones, and shell beds; also black gumbo clays and marls, which dip toward the Gulf at the rate of 40 to 70 feet per mile. This group of rocks, 1,000 feet in thickness or more in its entirety, comprises the lower Cretaceous (Comanchean) group, and the basal part of the Upper Cretaceous group of sediments. Much has been written concerning the character, thickness, and age of these formations, very largely by J. A. Tarl*, but Stephenson*, Hopkins, Powers and Robinson, Ellisor*, Miser*, and Dane*, have also made notable contributions to our understanding of this area. For present purposes only brief descriptions of the several formations need be given. In order from the top downward or from youngest to oldest these are as follows:

**Stratigraphic Section of the Red River Plain**

*Pecan Gap Chalk (Upper Cretaceous).* Although at present concealed from view beneath a thin covering of river silt and sand, the Pecan Gap chalk and associated shales and sands undoubtedly lie across the southern tip of McCurtain County, and are the uppermost beds of the Cretaceous in this region in Oklahoma. The chalk has a thickness of 400 feet in Bowie County, Texas, where it has been identified in wells drilled there, and doubtless will be found to have a like thickness in the southern end of McCurtain County, Oklahoma (T. 10 S, R. 26 W, and E. 1.) The chalk is exposed at Rocky Comfort, 1½ miles southwest of Foreman, Little River County, Arkansas, just east of the Oklahoma-Arkansas State line. Here it consists of massive beds of pale blue chalk weathering white, and is fossiliferous.

**Brownstone beds (Upper Cretaceous).** The Brownstone is essentially "a blue or gray calcareous clay containing many fossil oysters, and is characterized by the presence of the large oyster, Exogyra ponderosa, whence it has been called the Exogyra ponderosa marl," but there are beds of glauconite, lenses of quartz sand and some sandy shales as well as blue-gray calcareous clays, in this formation. At the top of the marl is a glauconitic, fossiliferous, sandy zone, 100 feet thick, to which the name Wolf City has been applied. It has been recognized in northeast Texas, including Bowie County, and should also be found immediately beneath the chalk in Oklahoma. The clays of the lower portion of the Brownstone weather dark olive green, which is char-

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characteristic of this part of the formation. The total thickness of the Brownstown ranges from 300 to 600 feet. Westward in Texas it grades into the Taylor marl and Austin chalk. In Arkansas the Brownstown beds have been subdivided recently by Dane et al into: (1) Brownstown marl (restricted), below, and (2) Ozan formation, above. The subdivision was made because of the discovery in the middle of the formation of an unconformity and a change in lithology.

Eagle Ford shales (Upper Cretaceous). Below the Brownstown in the wells drilled in Bowie County and west, in Texas, there is found the same type of sand and associated shales as found in the upper part of the Eagle Ford farther west. These strata have a thickness of 250 or more feet, at the top of which is a sand (sub-Clarksville sand). Ordinarily, the Eagle Ford consists of dark bluish or black shaly clay which is gypsiferous and more or less bituminous, but the typical black, bituminous phase of the Eagle Ford shales is missing in this area, according to A. C. Ellisor, and the sub-Clarksville sand and underlying shales grade into the Woodbine (Bingen) below. But, according to L. W. Stephenson, there are no rocks at all of Eagle Ford age in this locality, southwest Arkansas in particular, and a break in the Bingen sand represents Eagle Ford time. In McCurtain County, Oklahoma, the upper Eagle Ford section, if present, should crop out as a narrow east-west band at about the latitude of Haworth or Bokohoma, and dip south. Southeast of Durant in Bryan County, Eagle Ford shales occupy an area of approximately 50 square miles and dip southeast. They apparently occupy the trough of a syncline in this locality.

Woodbine sand (Upper Cretaceous). The Woodbine sand or "Silo sand" which crops out in southern Bryan and southern Choctaw counties, comprises farther east, in southern McCurtain County, the lower part of the Bingen formation. It is the basal formation of the Upper Cretaceous and consists of fine brown sand and sandy clays interstratified. The total thickness is about 500 feet, but erosion removed much of the upper part from the outcrop along the north edge of which strikes through Silo, Durant, and Bennington in Bryan County; through Dulan and Grant in Choctaw County; and through Idabel and Odell in McCurtain County. It lies in an unconformable position upon the Lower Cretaceous strata below, with overlap in a northwesterly direction, so that it is in contact with the Bennington limestone below, in Bryan County and western Choctaw County, but overlaps the Goodland limestone at the east margin of McCurtain County.

Bennington limestone (Lower Cretaceous). The Bennington limestone in the Texas region is represented by from 80 to 100 feet of calcareous, fissiliferous clays according to Taff. Coming northward into Oklahoma they change gradually to a hard dull-blue limestone, the Bennington limestone, 10 feet in thickness, which carries an abundance of small shells, (Brachytera arsenticula). Because of the overlap of the preceding Bingen, the Bennington might not be found in wells drilled along the north edge of the Bingen in parts of Choctaw and southern McCurtain counties. It should be present in Bryan County.

Bokchito formation (Lower Cretaceous). The Bokchito is a formation composed chiefly of clay and sandy clay with beds of friable sandstone, shell limestone, and ironstone conglomerates, aggregating approximately 140 feet. The sandstones are 20 to 30 feet in thickness locally. Because of the overlap of the Bingen to eastward the Bokchito formation might not be present in wells drilled in parts of Choctaw and southern McCurtain counties.

Caddo limestone (Lower Cretaceous). This formation consists of clay and calcareous marls interstratified with white marly limestone and semi-crystalline limestone making a section about 150 feet thick. Oyster shell beds are found at the top similar to those occurring below, at the top of the Kiamichi formation. The Caddo limestone is doubtless present in its proper sequence throughout southern Bryan, southern Choctaw, and southern McCurtain counties.

Kiamichi formation (Lower Cretaceous). The Kiamichi formation includes a few feet of siliceous limestone and shell marl overlaid by 50 feet of blue clay marl with oyster shell beds in the upper part. The oyster shells are large, up to 3 inches in length, and are cemented into firm ledges, one foot thick, by marly lime. This formation crops out south of the Goodland limestone and adjacent to it all across the southern counties.

Goodland limestone (Lower Cretaceous). The Goodland is a massive white limestone 25 to 50 feet thick, and crops out in a slightly south of east direction from the northwest corner of Bryan County to the place where Little River leaves the State in southern McCurtain County. It is a good maker in wells, and is prominent in the field as a maker of cliffs and terraces where it comes to the surface. It should be encountered in all wells drilled south of its outcrop at successively lower and lower depths toward the south.

Trinity sand (Lower Cretaceous). The Trinity sand is the basal member of the Lower Cretaceous group of rocks, and is the beach and near shore deposit of the Lower Cretaceous sea, which encroached upon the land from the southeast and east. The progress of the inundation upon the subsiding land to the north was so slow and its work so complete that all of the Paleozoic rocks: shales, sandstones, cherts, etc., hard and soft lime, were worn down to a nearly level base. Upon this plain, across the eroded edges of the hard rocks, the Trinity was laid down in much the same condition and relative position to the older rocks as we now find it. It consists of local, coarse conglomerates or boulder and gravel beds at the base, covered with from 400 to 600 feet of the fine pack sands, red and yellow clays and, in the east, certain
thin layers of limestone. The gravel beds may be 50 feet thick in central McCurtain County and central Atoka County, or wanting entirely in some places elsewhere. The gravels are composed of chert or flint largely, where thickest. The overlying sand is soft, poorly cemented, and upon exposure yields great quantities of loose sandy soil. Occasionally silicified fragments of wood and thin layers of lignite or carbonized wood are found in the Trinity sand. This material is drift wood which floated in the Trinity sea for a time, but was finally buried. The Trinity formation crops out in a belt about 10 miles broad, covering southern Atoka County, southern Pushmataha County, northern Choctaw County, and a portion of central McCurtain County. It should be found in all wells drilled south of the outcrop at progressively lower and lower depths in a southerly direction.

Coastal Plains Structure

It has been pointed out that the Ouachita Mountain rocks and structures extend beneath the Cretaceous cover in a southerly direction and that the Cretaceous rocks have been deposited across the upturned eroded edges of these old rocks. It has also been said that the Cretaceous sediments dip to the south and southeast at an average rate of 40 to 70 feet per mile, which is approximately the rate of dip of the old sea floor. It remains to call attention to some of the details of this general structure.

The most prominent anticline in all the Gulf Coast area of southeast Oklahoma is the Preston anticline, the axis of which strikes southeast diagonally across Marshall County, Oklahoma, and continues southeast into Grayson and Fannin counties, Texas. This is a very large, plunging structure, plunging southeast, and has been fully described by Stephenson, Hopkins, Powers, and Robinson, whose works have been referred to above. The axis passes down Red River, in the southwest part of Bryan County, after it leaves Marshall County, and continues on as far as the big bend south of the village of Kemp, where the river turns northeast. The Cretaceous strata dip sharply south, (approximately 100 feet per mile) south of this axis, and almost as sharply northeast (95 feet per mile) north of the axis. The northeast dip prevails as far out as the village of Achille, in Bryan County, then flattens out in the bottom of a syncline.

There is another anticline in Marshall County, known as the Madill anticline, which also has a trend in a southeast direction and plunges southeast. 11 This anticline enters Bryan County at the middle west line of the county, west of Durant, but it is a very much smaller structure than the Preston anticline, and probably does not extend farther east and south than some point near Allison, south of Durant. The surface rocks dip away from the Madill axis south and northeast, as


in the case of the Preston anticline, but at a less rapid rate,—about 50 feet per mile.

The axis of the syncline, which lies between the Preston anticline and the Madill anticline, passes north of the village of Colbert to about the position of Achille. This syncline, of course, also plunges southeast. On map No. VIII, the structure contours, copied from Hopkins, Powers, and Robinson, indicate the position of the Preston and Madill anticlines and the intervening syncline in western Bryan County. The presence of these structures is also indicated by the outcrop of the Goodland limestone in Marshall County (See map of Marshall County). North of the Madill anticlinal axis the strata dip northeast for a short distance (possibly five miles) and are then reversed and rise gradually to the outcrop still farther north. Judging from the strike of the Goodland limestone Durant lies in a shallow plunging syncline, plunging southeast, and the rocks farther north all dip south into it.

Figure 24.

The details of the structure in eastern Bryan County are not known, but there are probably no important flexures in the general area, else they would be indicated by curves in the outcrop of the Goodland limestone. The outcrop is straight, except for minor irregularities, due to drainage. Neither are the details of the structure in Choctaw and southern McCurtain counties known. The outcrop of the Goodland limestone, which is fairly straight, however, shows no pronounced irregularities in the general south dip of the rocks, and the depths at which the Goodland limestone is reached in the wells drilled
indicate only minor wrinkling, so far as can be determined. In southern Atoka and southern Pushmataha counties there is every indication that the Trinity sand dips directly south and merges into the structure as outlined for Bryan and Choctaw counties.

No attempt has been made to assemble the data in northern Fannin, Lamar, and Red River counties, Texas, from which it might be possible to tell something about the structure there, but there is included on map No. VIII the locations of all the wells that have been drilled and are drilling in this region, and their total depths are recorded. The logs of these wells show a gradual south dip of the rocks, but data are lacking upon which to base any further statement.

In Bowie County, Texas, and in southern Little River County and Miller County, Arkansas, the Pecan Gap chalk serves as a convenient datum for structural mapping, and as the well records and elevations of the wells drilled there were available, a general structural map, Fig. 24, has been made of this region. In general the rocks dip slightly east of south at the rate of about 70 feet per mile over all of Bowie County and contiguous territory. Several wells in this area have penetrated the Goodland limestone, and two or three of them have probably reached the Paleozoic rocks, but in the absence of samples these horizons are difficult to recognize. However, in the Arden No. 1 well, drilled by Hermann L. Grote, in the NE. corner of Sec. 2, T. 13 S., R. 31 W., eight miles west of Ashdown, Arkansas, the Goodland limestone was encountered at about 1,156 feet in depth; in the Taylor No. 1, drilled by the Tri-State Oil Company, at Whaley station, five miles east of New Boston, Bowie County, Texas, a gypsiferous limestone, which I presume is the Goodland, was found at a depth of 2,300 feet; in the Red River Petroleum Company's well drilled in the NW. 1/4, NE. 1/4, SE. 1/4 of Sec. 15, T. 8 S., R. 26 E., McCurtain County, Oklahoma, the Goodland limestone was reached at 485 feet in depth; and in a well drilled on the Bromway farm in the edge of Texarkana, in Sec. 31, T. 15 S., R. 28 W., Arkansas, the Goodland was reached at 2,650 feet. The location of the outcrop is also established. Using these data there is observed to be a uniform dip of 70 feet per mile south also on the Goodland in this general region. This evidence, so far as it goes, is counter to the possibility of finding any anticlines or synclines of importance here, and there probably are none.

**ASPHALTS AND RELATED SUBSTANCES**

That Grahamite veins and oil saturated sandstones crop out in various places in southeastern Oklahoma is common knowledge. Some of these occurrences were described by Taff in 1909, and others by Hutchinson in 1911. Two or three of the larger deposits were known early in the nineties. Grahamite was mined, intermittently, for a number of years at Jumbo in Pushmataha County, beginning in 1891 and continuing until about the year 1915, when an explosion of gas in the mines killed several men. A fissure vein of Grahamite at Sardis, near Tuskahoma, also in Pushmataha County, was opened in 1907 and operations continued there for about 15 years. Grahamite has been mined also at Daisy in Atoka County, and at Page in LeFlore County. Asphaltite has been dug and blasted from a pit at Valliant in McCurtain County, only very recently. There is an asphalt deposit north of Idabel on the banks of Little River, and others farther east in Arkansas. In the Chickasaw Creek country and in the valley of McGee Creek, around Stringtown and Redden, in Atoka County, there are extensive outcroppings of sandstones which are now saturated with heavy residues of black petroleum and some asphaltum. A number of shallow wells, 600 feet deep, have been drilled at Redden and near by. These, when drilled into the sandstones, partly filled with a heavy black oil, which was used by the farmers and ranchers in that neighborhood for various uses. There is asphalt in the Potato Hills, west of Talihina, and in the cherts at Stringtown, and doubtless in numerous other places, as yet undiscovered, in the Ouachita Mountains.

The occurrences mentioned are of two general types: (1) fissure veins, and (2) impregnated sandstones. The veins have resulted from the solidification or drying up of liquid petroleum, which welled up from beneath, and for a time flowed from cracks or crevasses in the ground, but which eventually ceased to flow and that which remained in the cracks and near the surface became hard. The crevasses were widened by the flow of the oil and asphalt, locally up to 50 feet, but usually the width is from two to four feet, pinching out gradually to zero. The length of such veins may be one mile, as in the case of the Sardis occurrence, but any single, continuous body of Grahamite or gilsonite ordinarily does not extend more than 100 yards or two hundred yards at the outcrop. The veins are vertical or nearly so and are usually parallel with the bedding of the shales and sandstones in which they occur. All the known veins of large size are found in the Stanley formation of Carboniferous (Mississippian) age. The Jumbo asphalt vein and the Sardis vein are typical of this class.

The asphaltites or impregnated sandstones, which make up the second class of the two general types of asphalt deposits, occur most conspicuously in the valley of McGee Creek near Redden, where ledges of sandstone, 4 to 6 feet thick, saturated with asphalt, come to the surface dipping at fairly steep angles, up to 45°. It is possible to follow these along the creeks and at intervals through the woods in places 100 yards or more. If continuous outcrops could be observed the actual length of the asphaltite deposits, in outcrop, presumably would be seen to be somewhat greater. As above mentioned the sandstones at a depth of 600 feet contain fluid oil, which indicates that the present dried out, exposed edges of the sand bodies were at one time the source of much exuding petroleum. (The grahamite veins are said also to become soft in depth). It is not known whether these sandstones are the original
oil sands which have been tilted up and eroded, or whether they constitute a means of escape of the oil in other, deeper, broken strata—a subject to be taken up later on page 102. The exposed strata which include the ashalites of McGee valley are Stanley sandstones and shales—the same rocks that contain the grahamite and gilsonite veins elsewhere.

The asphalt deposits at Valliant and Idabel are also of the second class, being sand or sandstone which has been saturated with petroleum, but the sands in these cases belong to the Trinity formation of Lower Cretaceous age, and the oil has come up from below, accumulated beneath the overlying hard limestone (Goodland limestone), and there, after a long period of erosion and exposure, has partially evaporated. The oil is thought not to be indigenous to the Trinity sand, but to have come up from the older (Paleozoic) rocks which lie buried beneath.

The residues of petroleum in the Potato Hills, in northern Pushmataha County, and in the Talihina chert at Stringtown are accumulations in the jointed chert and are of minor importance quantitatively. That which is seen in the fresh, deep exposures in the quarry at Stringtown is in part a very fluid oil, and emits an odor.

We come now to the question of the origin of this asphalt, which, as has been pointed out, occurs as vertical fissure veins and as impregnations in sandstones in the Stanley (Mississippian) formation, as deposits in the cracks in the jointed Talihina (Ordovician to Devonian) chert; and as impregnations in the Trinity (Lower Cretaceous) sands and sandstones.

Origin of the Asphalt

Since the Trinity sand is largely non-fossiliferous, and contains practically no carbonaceous nor wooden matter, and no bituminous black shales, which might be considered as sources for petroleum, the asphalt found in the Trinity sand is thought to have been derived from seepages from the Carboniferous rocks beneath. The Carboniferous rocks contain asphalt and oil-saturated sandstones, and are inclined with their broken edges tilted up against the bottom of the overlying Trinity, which itself dips at a moderate rate. The situation is thus favorable for the migration of petroleum from the older rocks into the Trinity sand. This is the condition of the rocks in question all across the southern border of the Ouachita Mountains of southeast Oklahoma and southwest Arkansas, and is believed to be fundamental to the occurrence of the asphalt in the Trinity.

Taff and Reed\(^{14}\), in discussing the probable source of the oil in the Madill oil pool of Marshall County, Oklahoma, state the case as it occurs to them as follows:


The Trinity sand is known to contain petroleum or bitumen, a residue of crude petroleum at various localities in southwestern Arkansas, southern Oklahoma, and Texas. At all localities where this crude petroleum or its residue has been found the Trinity sand is several hundred feet thick. This sand is a beach or shallow-water deposit of siliceous sand with local comparatively thin beds of clay. It contains exceedingly scanty remains of organic life, either vegetable or animal. Here and there thin shell limestones in layers occur in the central part of the formation, and widely separated localities silicified wood has been found, but nowhere is there sufficient evidence of the occurrence of organic matter to warrant the assumption that the oil originated in the formation that contains it.

In southwestern Arkansas and in northern Texas, as well as in southern Oklahoma, thick deposits of Carboniferous rocks that contain oil residues underlie the Trinity sand. Furthermore, the Carboniferous beds are tilted in such a manner that their edges project against the base of the Trinity sand. Any oil in the Carboniferous strata beneath the Trinity would in the course of time be conveyed upward and would either lodge in that sand or find an exit through it to the surface. There seems at present no other reasonable explanation than that the oil of the Madill pool had its source in the underlying Paleozoic strata.

Miser and Purdue\(^{15}\) have described seven asphalt deposits occurring in the Trinity sand in Pike and Sevier counties in southwest Arkansas, concerning the origin of which the following statement is made by them:


The Trinity formation contains petroleum and asphalt at many places in northern Texas and southeastern Oklahoma. The asphalt in these two states and in Arkansas, as in other regions, is doubtless a residue of crude petroleum, whose lighter and more volatile parts have escaped by evaporation. The petroleum yielding the asphalt in Arkansas is believed by the writers to have been derived from the Carboniferous rocks underlying the Trinity formation, near the base of which the asphalt is found. In support of this belief is the fact that there are small amounts of asphalt in the sandstones of the Atoka formation of Carboniferous age, which crops out in two narrow belts with a north of east trend in Pike County, a few miles north of Pike and Murfreesboro. Asphalt is also found in Carboniferous and older rocks near Reno, Arkansas, and in southeastern Oklahoma. The Carboniferous rocks pass beneath the Trinity formation, and the beds are tilted in such a manner that their edges project against the base of the Trinity. Any oil in the Carboniferous beds, would, in the course of time, work its way upward into the Trinity. It could not go higher than the lower limestone of the Trinity, because of the impermeable character of this limestone and the associated clays. As the Trinity has a gentle dip to the south, the oil would be conveyed up the dip to the surface. There is, however, no direct proof that some or all of the petroleum did not originate in the basal part of the Trinity formation, which contains some fossiliferous limestones.
Hopkins, Powers, and Robinson in their discussion of the Madill and Preston anticlines, give a similar view of the origin of the oil and gas in these folds, when they say:

The high grade of the oil now found in the Trinity, the absence of organic matter in the formation, and the distribution of the oil in it prove fairly conclusively that the oil has migrated into the Trinity from the underlying Paleozoic formations, either from the Caney shale or from the Glenn formation, both of which are salted to underlie this area. Thus, wherever the Trinity is in contact with either of these formations an adequate source of oil is probably available. But they are in contact with the Trinity only under abnormal structural conditions, where they have been folded or faulted and deeply eroded before the Trinity was deposited. Such a condition is not likely to exist in this area except near crests of major anticlines like the Preston, Madill and Oakland folds. Accordingly it is unlikely that oil will be found in paying quantities in the Trinity anywhere in this area except on these folds, a conclusion that is corroborated in a measure by the drilling that has been done. The Trinity has yielded prominent showings of oil and gas in this area only on these anticlines. Because of the intensity of the pre-Cretaceous folding and the depth to which these folds were eroded before the deposition of the Trinity, it is rather unlikely that much oil will be found in that formation even under favorable structural conditions. Over a broad area in Texas the Trinity constitutes an enormous reservoir of fresh potable water; in the area here considered the Trinity contains a large supply of water, but the water is more or less salty, doubtless owing to its stagnant character.

The asphalt and heavy residues of petroleum in the exposed Carboniferous rocks of the Ouachita Mountain area may also be thought of as having had a deeper seated origin, especially since there are so many fissure veins of large size in the lowermost formation of the Carboniferous, i.e., the Stan ley shale, and since a certain amount of these materials, asphalt and oil, is actually found in Ordovician to Devonian rocks, namely in the Talihina chert. The asphalt vein at Page in LeFlore County occurs in the Jackfork sandstone, above the Stanley, and there is one small deposit of asphalt in the Atoka formation above the Jackfork in the valley of McGee Creek, Atoka County, but both of these veins extend in depth, doubtless into the Stanley shale beneath. The bulk of the asphalt is seen to be in the Stanley.

The Stanley shale has been described as a deposit of dark colored, fine grained sandstone, and dark, carbonaceous shale, 6,000 to 10,000 feet thick; as being practically non-fossiliferous, except for plant remains; and as having been laid down in shallow water. The plants are pieces of Lepidodendron, fragments of Calamites and fern pinules. All of the carbonate matters of microscopic sizes in the shales and sandstones seem to be macerated woody and other plant material which was reduced to these fine particles by the work of waves. Because of the presence of the plants, and the almost total absence of marine fossils in this thick formation, and because also of its general lithologic character and limited geographic distribution, it has been further described as a delta deposit, which was laid down on the margin of the ocean near land, and at least partly in fresh water.

Geologists at present are not inclined to think of petroleum as originating in coal or woody substances, nor as forming in marshes or delta deposits of fresh or brackish water accumulation. Thus, while the Stanley is carbonaceous it is not bituminous, hence not inherently petroliferous. The Jackfork sandstone, 6,000 feet thick, superimposed on the Stanley is also non-fossiliferous, except for plants, and has also been described as deltaic in origin. It is in fact the upper one-half of the same delta which was begun in Stanley time, and like the Stanley, was laid in fresh or brackish waters, apparently. At any rate there is nothing about the Jackfork sandstone that would indicate an accumulation in marine waters, and no part of it has, as an essential quality, a petroliferous nature. This cannot, however, be said of the Atoka formation, which is at least in part marine and which is locally petroliferous.

When the section of rocks beneath the Stanley shale is examined, flints and slates are found throughout central McCurtain County, in northern Pushmataha County, and in western Atoka County. Certainly these are not the source beds of the petroleum in question. There is, however, a formation known as the Caney shale lying on top of the Woodford chert and shale in northern Atoka County and in southern Pittsburg County in the Ouachita Mountains, and this formation is marked by its own fossiliferous, and may be considered as a likely source for petroleum. In central Atoka County, where there is much of the asphaltic sandstone, as well as veins of asphalt, in the Stanley, the Atoka formation lies adjacent to the west, separated from the Talihina-Stanley succession only by the Choctaw thrust fault. Beneath the Atoka lie the Wapanucka, Caney and older formations which normally make up the Arbuckle Mountain section. These rocks are all marine, in part petroliferous, and some of these have furnished asphalt. The rocks east and west of the Choctaw fault are badly broken, and stand on edge, partly overturned, for two miles or more either side. The upthrow side of the fault is the east side, and the Talihina chert is at the surface in contact with the Atoka formation, which crops out along the west side of the fault. Under these circumstances, petroleum from the broken rocks of the Atoka formation, and possibly from older petroliferous rocks (Wapanucka, Caney) should find its way into the Talihina chert and Stanley shales and sandstones, which have been thrust against and upon the petroliferous series. But granting that the asphalt in Atoka County could have originated in the manner suggested, it is still difficult to see how the Jumbo and Sardis asphalt veins and other veins still farther east could be derived from so distant a source.


OIL AND GAS IN OKLAHOMA

THE OVERTHRUST THEORY

The rocks which are exposed in the Ouachita Mountains are very different from those of the same age which appear at the surface in the Arbuckle Mountains. This difference is so marked throughout these two areas, and up to the present time they have not been satisfactorily correlated. Because of the marked contrast in lithology in the two regions, lying adjacent to each other, it has been suggested, first by C. I. Dale, that an enormous overthrust fault, the displacement measured in scores of miles, may have crowded the Ouachita facies from the south or southeast far to the northwest, over the Arbuckle facies. 

The rocks of the Ouachita facies have been folded and thrust-faulted throughout the full length and breadth of the Ouachita Range, and this mountain mass has been crumpled and broken by a force that moved in a northerly and northwesterly direction. These facts are obvious from the areal geologic map of the region, but whether the Ouachita Mountain rocks have been shoved bodily scores of miles north and northwest into Oklahoma, from an adjoining territory outside, presumably from a region in Texas and Arkansas, as Dale has suggested might be the case, is difficult to prove. However, if such a force has operated to bring the Ouachita Mountain formations up and over the Arbuckle formations, then the Arbuckle limestone, Simpson formation, Viola limestone, and younger rocks of the Arbuckle facies may lie buried beneath the Talihina chert in the Ouachita Mountains, and these Arbuckle rocks may be considered as a source for the asphalt now found in the Talihina chert and in the Stanley and Jackfork formations. It may be assumed, of course, that the Arbuckle facies normally should extend some distance to the east of their present outcrop in the Arbuckle Mountains—at least as far east as the eastern boundary of Atoka County. There may be Carboniferous rocks (Atoka formation) beneath the Stanley and Jackfork or beneath the Talihina chert according to this theory, and the Atoka then could furnish petroleum for the dikes of asphalt in the Stanley and elsewhere.

The outcropping sandstone ledges in the vicinity of Redden above referred to (p. 98) which are saturated with asphalt and which at a depth of 600 feet carry fluid petroleum may be, thus, only a means of escape of oil which in reality is coming from the Atoka formation, buried beneath, or from the Hunton limestone or "Wilcox sand", and not from the formation in which the oil is found. If this condition exists the outcropping sandstones (Stanley), which dip at high angles, up to 45 degrees at the surface, may extend downward, possibly a mile or more, to a low-angle fault plane, and beneath the fault there might be present a petroleum-bearing formation of the Arbuckle facies, in contact with the faulted-off edges of the outcropping sandstones. Sandstones, structurally so related, should permit the escape of oil at the surface, in the same manner in which oil is supposed to escape from the Carboniferous rocks into the Trinity sand farther south, and as explained above. But, again, it is easier to think of these relationships of old rocks in the vicinity of Redden, in Atoka County, or even at the Jumbo asphalt mine in western Pushmataha County than farther east. Moreover it is not to be assumed that the Arbuckle facies was necessarily deposited as far east as the Sardis asphalt vein in northern Pushmataha County, certainly not necessarily as far east as the Page asphalt vein in southern LeFlore County. Nevertheless, carrying out the idea of a large overthrust fault, and recognizing that some of the Carboniferous rocks (the Atoka) are locally petroliferous, there is the possibility that the Sardis asphalt and the Page asphalt came up from an over-ridden mass of Atoka formation, if not from some other Paleozoic rock.

I do not propose here to discuss the possibility or impossibility of such an overthrust as suggested by Dale. The idea has been favorably received by all of several geologists with whom I have had occasion to discuss it. It is a subject as Dale has said, that is worth considering at least. Since there appears to be no adequate source for petroleum in the Stanley and Jackfork shales and sandstones and none in the Talihina chert, Arkansas novaculite, nor any of the older rocks in the Ouachita series, the idea is very welcome as a means to explain the presence of these large asphalt veins or dikes. Indeed the argument may be turned around, and we may say, that since there is no adequate source for petroleum in the Stanley-Jackfork sequence and none in the Talihina chert, Arkansas novaculite, nor any of the older rocks of the Ouachita series, these dikes and seepages of asphalt must be leakage from the over-ridden and deeply buried petroliferous beds of the Arbuckle facies. But, there are arguments touching upon the mechanics of such an overthrust, both for and against,—a presentation and discussion of which would be entirely out of place in the present instance. I would state at this time, in conclusion, that if the asphalt in question is not derived from some deeply buried petroliferous rocks of the Arbuckle facies, I see no reasonable explanation for it. So far as asphalt is concerned it is not necessary to assume that the overthrust extends farther south than approximately the valley of Kiambi River above the town of Antlers, for any asphalt south of that latitude, so far as known, in Oklahoma, occurs in the Atoka formation where it might be indigenous, or is found in the Trinity sand derived as seepages, presumably from the Atoka.

DEVELOPMENT

There have been, up to the present time, about 80 wells drilled in the five counties of southeast Oklahoma (Atoka, Pushmataha, McCurtain, Bryan, and Choctaw counties); and there have been drilled about 40 others which might be considered border wells, bordering this area. Most of these are located in the Red River Plains area, but in Atoka County most of them were drilled in the mountains. Many of

the wells encountered “shows” of oil, gas and asphalt, but none, including the nearby wells in Arkansas and Texas, has found production in paying quantities.

The discovery of the Madill oil pool and the Lark and Enos gas fields, in Marshall County, in 1906 and later, led to the drilling of wells in Bryan County, where it was hoped other fields might be found. In Atoka County it was the asphalt that attracted the prospector, and the wells drilled there are located near the asphalt. Elsewhere wells were located on anticlines, or what were reported to be favorable structures, or were located for no reason at all, except that the country looked like oil country, or appeared to be worth a test for oil.

By reference to map No. VIII, it will be seen that very few of these holes are more than 2,000 feet deep, and that most of them range from a few hundred feet to around 1,700 feet. In the Ouachita Mountains the sandstones are so hard that it is impossible, with standard equipment, to drill much below 1,700 feet, and this at great cost of time and money. In the Plains regions, south of the Mountains, drilling is fairly easy in the Cretaceous sediments, but as soon as the older rocks are reached difficulties commence, and the wells are then abandoned.

There are only three very deep holes in the entire region. One of these is in the SW 1/4, NE 1/4, NW 1/4, sec. 7, T. 2 S., R. 9 E., and was drilled by the Wapanucka Oil and Gas Company to a depth of 4,928 feet. It was begun in May, 1922, and completed in May, 1926. At the top, in this hole, there were 1,417 feet of Atoka sandstones and shales, below which were found the Wapanucka limestone and older rocks of the Arbuckle facies, all of which could be drilled, whereas hard sandstones of the Ouachita Mountains facies, had they been encountered, could not have been drilled by the ordinary drilling equipment.

A second deep hole was drilled in the SE 1/4, NW 1/4 of sec. 17, T. 4 S., R. 11 E., by Ed. Hansen, et al., to a depth of 4,065 feet. There were rocks of the Arbuckle facies encountered in this well also, from comparatively shallow depths to the bottom of the hole.

The other very deep hole is located in the SW 1/4, SE 1/4, NW 1/4 of sec. 7, T. 6 S., R. 19 E., drilled by the Oklahoma-Colorado Oil and Gas Company, with standard tools to 2,618 feet and completed with a diamond drill to a total depth of 4,970 feet.

In the northern part of Grayson, Fannin, Lamar, Red River, and Bowie counties, Texas, few attempts have been made to go below the Woodbine sand. So far as known, none has reached the Paleozoic rocks. In southern Little River County, Arkansas, two fairly deep tests have been drilled and both seem to have reached Paleozoic rocks. These are: (1) The H. L. Grote test in the NE 1/4, NE 1/4 of sec. 9, T. 13 S., R. 31 W., Arkansas, drilled to a total depth of 3,863 feet; and (2) The Goodrun Trust Company’s test in the NW 1/4, NW 1/4 of sec. 13, T. 12 S., R. 30 W., Arkansas, drilled to a total depth of 3,835 feet.

As a rule, in southeast Oklahoma, the logs of the wells drilled are fragmentary and, in the absence of samples, unreliable. Few samples have been saved. No attempt has been made, therefore, to identify the Paleozoic formations in any of the deeper tests. Except for the attempted identification of the Goodland limestone of the Lower Cretaceous and the Pecan Gap chalk of the Upper Cretaceous (Bowie County, Texas), no satisfactory correlation of the logs is possible. From the rate of dip of the Goodland limestone and the chalk, we may assume, however, that the Paleozoic rocks drop rapidly south from their outcrop in the mountains to Red River and beyond.

RECOMMENDATIONS

The authors of all the early reports on oil and gas in Oklahoma wrote favorably of the southern Oklahoma Cretaceous area, which includes southern Atoka, southern Pushmataha, southern McCurtain, and all of Bryan and Choctaw counties. Hutchinson, who was one of the earliest to go into this region and to write about it, refers to it as “possible” oil field territory. All the maps and reports of the Oklahoma Geological Survey, up to and including Bulletin 19, show the Cretaceous area as “likely” or “probable” oil territory.

The Ouachita Mountains, on the other hand, have always been regarded as too sharply folded and faulted to produce oil or gas in economic quantities, and this area was therefore described by Hutchinson and by all later workers up to 1917, as non-productive, or was left blank on the maps with the understanding that it was not in an oil country.

In 1923, after spending several years studying the general geology of the Ouachita Mountains, C. W. Honess came to the conclusion that it was “useless to drill into the Paleozoics anywhere in the eastern half of Choctaw County, or anywhere in the southern half of McCurtain County, Oklahoma, excepting an area of about 300 square miles in the extreme southern part of McCurtain County, and that very little oil indeed would be found in the Catoosa sediments (of eastern Choctaw County and southern McCurtain County) in the southern part of the state 300 square miles or so of country in the extreme southeastern part of McCurtain County.” A part of the territory of southeastern Oklahoma formerly regarded as in an oil country was thus transferred to a region designated as impossible of production. Nothing was said of western Choctaw County and the territory farther west, but a corner of southeast McCurtain County was left in the original classification as “possible of production.” At the same time, on the other hand, Honess pointed out that the Smithville anticline in northeast McCurtain County, in the Ouachita Mountains proper as “possible of production.” At any rate he was unwilling to classify the ground covered by the Smithville structure along with the rest of the southern part of the

Ouachita Mountains, as entirely impossible of production, and thus removed a small strip of country from an area which had always been thought of as one "impossible of production" to a classification of "possible of production."

During the past five years several reports have come from the press dealing with the stratigraphy and structure of parts of this area and adjacent areas, and numerous wells have been drilled in the region and bordering it. Two wells of moderate depth have been drilled in southeast McCurtain County in the area described as "possible of production," and a shallow (1,755 feet) test has been made of the Smithville anticline. But, as yet, no production has been found in the general region nor near it. Showers' of gas and oil are commonly found in both Paleozoic rocks and Cretaceous strata, but in all cases these seem to be small residues of former pools of oil which have escaped, for the most part, to the surface, and no longer exist as pools.

Most of the oil which is found is black and of a low grade. It is sometimes described as "dead oil," which indicates that it is not found under pressure, and does not have a sustained flow. Gas, when found, is usually in small amounts, and soon exhausted. One exception, however, is the one-quarter million feet of gas found in the well in sec. 16, T. 3 N., R. 22 E., in LeFlore County, Oklahoma, in a sand 1,128 to 1,178 feet deep, and with a rock pressure of 175 pounds per square inch. This well, drilled in 1920, was allowed to flow for several months, but was later shut in. Gas was escaping through the valve in March, 1927. In all probability the well would still produce if opened.

When one considers that there are large asphalt dikes, residues of heavy black oil, and gas in widely separated areas in the Ouachita Mountains and south in the Red River Plain, one hesitates in condemning this territory as an oil producing territory. In spite of the facts that in the mountains the rocks are thrust-faulted, partly overturned, and metamorphosed, and supposedly lie in a region of high carbon ratio, if there be any truth in the theory of overthrust, there may still be oil pools below the overthrust sheet, and if the thickness of the mass which was thrust over the Arbuckle facies is not too thick, there may yet be Hunton and Simpson production found in certain areas in the Ouachita Mountains. The most likely places to look for the Arbuckle section would be, of course, nearest the Arbuckle exposures, and the shallowest depths at which the Arbuckle facies may be expected should be where the Ouachita facies is known to be thinnest, i.e., where the Talihina chert is exposed. Possibly some of the areas of Stanley shale are not too thick to be pierced by the drill. Conditions of subsurface structure also should be considered, for where the overthrust mass is thinnest, granting there is an overthrust mass, there may be Tishomingo granite, or some other non-petroleum rock beneath. In this matter it would be logical to prospect in the localities where asphalt and oil seeps occur, because at those places there must be a source of some kind, the most likely being, in the absence of the Glenn formation, the Hunton or Simpson.

Referring to the new map of the State of Oklahoma, compiled by H. D. Miser of the U. S. Geological Survey, and published by the United States Geological Survey, it will be seen that certain areas of eastern and northern Atoka County and a part of northern Pushmataha County appear attractive. The region of the Jumbo asphalt deposit, and the valley of Kiamichi River, north of Kosoma, in western Pushmataha County, may also be considered. There are numerous localities in the general region farther north, in southern Latimer and southern Pittsburg counties, which, if there has been an overthrust, may be considered favorable for prospective oil and gas regions. But, has there been an overthrust? If so, is it possible to drill through the overthrust sheet? What are the chances of hitting upon an oil pool beneath, granting there has been an overthrust, and granting that it can be pierced by the drill? Also, what should be the degree of metamorphism of the buried Arbuckle facies in this region? It is not possible for the writer to answer any of these questions. This much has been said on the subject that the reader may know why it is not possible to classify the Ouachita Mountains of Oklahoma definitely and conclusively as lands impossible of oil production.

In regard to that part of the Ouachita Mountains east and south of Kiamichi River (except the Smithville anticline), this can be done with a much greater margin of safety, than for the country west and north of Kiamichi River, in the Ouachita Mountains. It would be well to state also that while the Ouachita Mountains west and north of Kiamichi River cannot be condemned as an oil producing country, because of the theory of overthrust, neither can this region be highly recommended, or even recommended at all, to anyone who has not large sums of money to squander, and in the event of failure can nevertheless go on rejoice.

Any drilling operations whatsoever that may be undertaken in the Ouachita Mountains should be preceded by thorough and exhaustive field studies over wide areas, for it may be that such studies have been completed it will not be necessary to drill at all. The entire situation hinges on the question of overthrust, which at the present writing is only a theory.

Finally, as a warning to the inexperienced, and as giving the writer's own personal opinion, it seems that the Ouachita Mountains is one of the last places in the United States where one may expect to find petroleum in commercial quantities. As a last resource, sometime in the future, when gasoline is selling for 50 cents a gallon it might be worth while to study the Ouachita Mountains. Meanwhile there are too many other places and better places in which to drill prospect holes.

Much of what has been said in regard to the Ouachita Mountains applies also to the Red River area (including Bryan and Choctaw coun-

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23. The Smithville anticline in northeastern McCurtain County, which is south of Kiamichi River, may be considered, at present, as the same area referred to, and having the same prospects as the lands north of Kiamichi River. This particular structure was originally described as an area having some slight possibilities. At this writing, and with all the facts considered, it is still impossible to absolutely condemn it.
ties and the southern parts of Atoka, Pushmataha, and McCurtain counties, because the old (Paleozoic) rocks of the mountains extend in depth, beneath this area. It is recommended, therefore, without further discussion, that wells be not drilled into the old rocks beneath the Cretaceous sediments at any place in the area discussed in this paper.

In the Cretaceous rocks of southeast Oklahoma only two anticlines are known. These are the Preston anticline and the Madill anticline, both of which are productive of oil or gas in Marshall County, but have been proved unproductive farther east. These anticlines have been described above and are shown on map No. VIII. They are plunging structures, plunging southeast; and it is to be expected that they should produce from the higher westward portions if at all. These structures probably have by now been fully exploited.

In the remaining Cretaceous area of southeast Oklahoma, which includes eastern Bryan County, all of Choctaw County, southern McCurtain County, and the southern parts of Atoka and Pushmataha counties, the structure is unfavorable to oil and gas accumulation so far as known. The rocks dip uniformly south or slightly east of south throughout this region—a type of structure which should permit the escape of any oil or gas which might otherwise accumulate here. Apparently then, there is not a single attractive locality to be found in this region. Indeed there is no place anywhere in the five counties of southeast Oklahoma that can be recommended with any assurance that oil may be found in commercial quantities.

PONTOTOC COUNTY

By

R. A. Conkling

Introduction

The author, in attempting to write this report, has encountered many difficulties due to lack of sufficient data. It is practically impossible to get all the information together in the time available, so this report must be read with the understanding that much of the data will be enlarged upon or disproved. Although we have a fair grasp of subsurface conditions of the county, the area is near the Arbuckle Mountains which have undergone numerous orogenic movements with the resulting unconformities, so that every well encounters something new.

Fig. 25.—Map of Oklahoma showing location of Pontotoc County.

ACKNOWLEDGMENTS

The author wishes especially to acknowledge the work of Geo. D. Morgan in Bulletin 2, Bureau of Geology, from which the description of the formations has been copied verbatim, since the major portion of the Stonewall quadrangle lies within Pontotoc County. He also wishes to thank J. B. Umpleby, F. W. Dakin and John Fitts for information and assistance. Mr. Frank C. Greene of the Skelly Oil Co., has kindly furnished the structure map of the county.

LOCATION

Pontotoc County is in the south-central part of the State. Its northern boundary is the Canadian River. It extends from T. 1 N., to T. 6 N., inclusive, and from R. 4 E., to R. 8 E., inclusive. The

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county contains 17 whole townships and parts of 6 others. The total area is 716 square miles.

TOPOGRAPHY

Most of the county lies within the Sandstone Hills region. The extreme southern part lies within the Arbuckle Mountain region. The topography of the northern part of the county is the result of weathering of alternating sandstones and shales that have rather low dips. More or less parallel escarpments follow each other at great distances, which have been dissected by streams, giving to the whole surface a broken appearance. Most of the northern part of the county is wooded. Farther south limestones predominate, and flat or rolling prairie is the type of topography.

Canadian River forms the north boundary of the county, and together with its tributaries drains approximately the northern half. Blue River and Boggy Creek drain the southern half of the county.

The elevation of the surface in Pontotoc County ranges from 645 feet to 1,300 feet. The lowest elevation is found where Clear Boggy Creek crosses the eastern line of the county, in sec. 25, T. 2 N., R. 7 E. The highest elevation is found near the NE. cor. sec. 18, T. 2 N., R. 4 E., about 1½ miles north of Dolberg.

GENERAL AND HISTORICAL GEOLOGY

The strata exposed in Pontotoc County range in age from upper Cambrian to Recent. However, there are many gaps, due to either unconformities or faulting, so that the entire section is incomplete at the surface.

Because of the rapid variation of the formations both along the outcrops and beneath the surface and the absence of many at the surface, it is difficult to give any estimate of the average thickness of any of the formations or the total thickness of all the formations at any given place over the county.

At the southeast corner of Pontotoc County where the Arbuckle limestone outcrops, there is less than 4,000 feet of sedimentary strata while in the eastern edge of the county there is probably 10,000 to 15,000 feet of these formations. These formations are also quite thin near the town of Center where an anticline is imposed upon a northwest plunging subsurface high.

The sediments in general become very clastic toward the top of the section and also they become coarser toward the Arbuckle Mountains. The formations below the top of the Hunton Terrane are dominantly limestone while the succeeding Woodford and Caney formations are largely composed of black shale. The Wapanucka limestone, although shaly at the base, carries considerable limestone near the central portion, but from there the succeeding formations are largely shales, sandstones and conglomerates with very little limestone.


PONTOTOC COUNTY

The following description of regional structure and stratigraphy is by Morgan as published in Bulletin 2, Bureau of Geology, Norman, Oklahoma.

The structure of the area is complex and is evidently the result of numerous movements that were quite variable both as to type and point of origin.

The movements which resulted in the structure may be summarized as follows:

1. Slight warping movements initiated in the Arbuckle area at an early date, possibly in the later Cambrian or early Ordovician period.

2. Warping and slight oscillation continued through Ordovician time.

3. In early Silurian time arching movements in the Arbuckle area became more decided and the Arbuckle axis was defined.

4. Magnitude of periodic arching movements increased during the Devonian and Mississippian so that by Pottsville time the Hunton and possibly Viola, Simpson, and Arbuckle formations were exposed near the southeast end of the present mountains.

The crustal movements of these four periods were not persistently upward throughout the area of the Stonewall quadrangle, as is indicated by the fact that during the time at which they were going on there were deposits in the Arbuckle area between 7,000 and 10,000 feet of sediments. It is probable that the movements during the Cambrian and Ordovician were very slight and irregular, and that during the time at which they were going on there was a gradual increase in the relief between the top of the Arbuckle basin and the surface of adjoining land masses. This relative vertical divergence (whether caused by sinking of the basin, uplift of the adjoining land areas, or by both processes) also continued through the Silurian and Devonian periods, but after the movements became decidedly positive with the resulting establishment of the Arbuckle axis, the axial area was probably more progressively above than below sea level.

5. Near the close of Atoka time there was uplift followed by peneplanation and subsequent overlapping deposition of the Hartshorne, McAlester, and at least part of the Savanna formations. Toward the close of Savanna time the Stonewall quadrangle was subjected to a period of uplift and block faulting which resulted in the emergence of all the area with the possible exception of the Franke graben. Peneplanation of the uplifted area followed and all formations down to the Wapanucka and Caney formations were stripped off of it. The eastern part of the Franke graben, near the quadrangle line, was near or below base level during this time and was unaffected by erosion. Following this period of peneplanation the Boggy shale and later formations, to near the top of the Wewoka, were then laid down unconformably on the peneplaned surface and across the Franke graben. That a part of the Arbuckle axis remained above sea level during all the time from Wapanucka to near the close of the Wewoka is indicated by the fragments of Caney, Woodford, Hunton and Viola formations that are contained in the strata of the Wapanucka to late Wewoka formations inclusive.

Progressive northward thrusting of the Ouachita area was initiated near the beginning of Devonian time, and it is probable that this area contributed largely to all the sediments of the Stonewall quadrangle that lie between the base of the Woodford and the top of the Vamoosa formations.
From Devonian time gradual uplift characterized the Arbuckle axis, and at the present time the older strata exposed there have a northward inclination that amounts to nearly 4,000 feet from the southern edge of the quadrangle to near its center. A little before the close of Wewoka time the Ouachita area was strongly uplifted. This movement resulted in the Choctaw fault which borders that area; it caused a general northwest tilt of all the Pennsylvanian strata of the Conigut and Stonewall quadrangles, and was accompanied by some faulting in the latter area. The fault along the northern side of the Lawrence uplift was formed at this time and the one along the southern side was renewed so that the intervening area was lifted high above the surrounding region. The uplift of the Lawrence block was differential, being greatest toward the west. This general period of uplift and faulting was followed by peneplanation, which at the western or highest part of the Lawrence uplift stripped off all the beds down to the lower part of the Boggy formation, and in the western end of the Franks graben removed all strata down to the top of the Boggy. On the less uplifted eastern portion of the Lawrence area, in the low lying region to the north of this area, and in the eastern part of the Franks graben peneplanation was only slightly effective.

The period of erosion was followed by the transgression of the sea and the later Wewoka beds (about 30 feet thick) and subsequent strata, including the Vamoosa formation, were laid down. At the western end of the Lawrence uplift the Wewoka strata were deposited on the eroded edges of lower Boggy beds, and in the western end of the Franks graben the upper part of the Wewoka was laid down, probably on upper Boggy strata. Throughout all this period of deposition a great deal of angular chert conglomerate was brought into the Stonewall quadrangle. This type of sediment also characterizes the formations eastward toward the Ouachita Mountains and is thought to have been derived from that region. Portions of the Arbuckle axis were maintained above sea level during this period of deposition as is indicated by the limestone conglomerates in the Wewoka, Holdenville, and Francis formations, especially in their outcrops over the area of the Franks graben.

8. Near the close of Wamoosa time there was an unusual uplift of the Arbuckle axis that affected all the area embraced in the Stonewall quadrangle. The uplift resulted in subtle renewal of movements along the already established fault lines and formed several new ones. The flexing and slight faulting of the late Wewoka, Holdenville, Seminole, and Francis formations along the northern side of the Lawrence uplift occurred at this time. The block faults that cut the Hunton and overlapping Holdenville formations in the northwest quarter of section 34, west of Franks, were probably also caused by the movements as were the block faults east of Byng.

The first result of this uplift was the peneplanation of much of the Stonewall quadrangle. This was followed by unconformable deposition, over most of the area, of a mantle of sediments, largely composed of limestone conglomerates (Ada formation). The source of the conglomerates was the Arbuckle Mountains.

The removal of this large amount of material from the Arbuckles exposed the granite core of the mountains which thereafter, to the close of Pontotoc time, contributed an abundance of arkosic material to the formations being deposited in the Stonewall quadrangle. After the granite of the Arbuckles was exposed it apparently eroded faster than did the bordering limestone to the north so that near the time at which the sandstone at the base of the Asher formation was deposited the granite surface had been reduced below the level of the bordering limestone. The granite then no longer contributed arkosic material to the sediments that were being laid down to the north of the mountains.

The uplift at the close of deposition of the Vamoosa formation, and the subsequent peneplanation of the area occurred in late Pennsylvanian time. The Permian period began during the subsequent time of deposition. The base of the Permian system is placed at the bottom of the Hart limestone member of the Stratford formation and, northeastward from it point at which that member is thought to be overlapped at the base of the Konawa formation.

All of the Permian formations of the Stonewall quadrangle have been slightly folded indicating movements in the area during or subsequent to that period. Mesozoic and Tertiary strata are not represented in the Stonewall quadrangle.

During the Pleistocene the Guertie sand was laid down, probably as a river deposit. In recent time a thick sand deposit has been laid down in the Valley of Canadian River.

**STRATIGRAPHY**

**ARBUCKLE LIMESTONE**

In the northwest corner of sec. 25, T. 1 N., R. 6 E., near the top of the formation, is a thin chert conglomerate which carries pebbles up to three inches in length. Most of the pebbles are angular, but a few appear to be waterworn. A crossed-bedded, conglomerate sandstone was also observed in the north-central part of sec. 29, T. 1 N., R. 7 E. The pebbles here contained are mostly chert and sandstone, and ordinarily are not more than two inches in length.

Taff also noted conglomerates in the basal part of the Arbuckle limestone. The lower conglomerates were not observed by the writer. It is possible that all the clastic beds represent re-worked portions of the Arbuckle itself. The fragments which constitute the higher conglomerates, however, indicate a source outside of the immediate area. The variation in sedimentation shown by the tabular conglomerates suggests warping movements within the area during the time at which the formation was being deposed.

**SIMPSON FORMATION**

The thickness of the Simpson has been given as ranging from 1,200 to 2,000 feet.

The variation in thickness is explained by Taff as being the result of the local absence of the basal portion of the formation, so that here again there is evidence of a probable early warping movement of the Arbuckle Mountain area.

Near the center of the formation is a thick sandstone member (100 to 200 feet) which is more persistent than the others.

Regarding the general character of the formation Taff says:

OIL AND GAS IN OKLAHOMA

In the northern portion of the region, and especially on the northern side of the Arbuckle mountains west of Washita River, the Simpson formation is found to be much thinner than in the southern portion. This is due chiefly to the absence of the lowest beds, which have an aggregate thickness of several hundred feet. The upper division of the formation is found to become thinner northward, owing to the decrease in the quantity of lime and clay. With the decrease in the amounts of lime and clay northward there is a general increase in the abundance of sand, the whole formation becoming more siliceous. The absence of the lower portion of the formation toward the north and the more elastic nature of subsequent portions of the formation in that direction, suggest an Ordovician land mass to the north of the Arbuckle area over which the Simpson sea gradually encroached. The possibility of a land mass in that same general region is again suggested by a similar northward variation in the formations comprising the Hunton terrane.

VIOLA LIMESTONE

The thickness of the Viola is between 500 and 750 feet. The following section was measured across portions of secs. 12 and 13, T. 1 N., R. 6 E.

Section of the Viola limestone as exposed in secs. 12 and 13, T. 1 N., R. 6 E.

<table>
<thead>
<tr>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue and white limestone with some chert</td>
<td>100</td>
</tr>
<tr>
<td>Gray and blue limestone with little or no chert</td>
<td>90</td>
</tr>
<tr>
<td>Massive limestone bed</td>
<td>10</td>
</tr>
<tr>
<td>White argillaceous limestone</td>
<td>5</td>
</tr>
<tr>
<td>Massive blue limestone bed</td>
<td>10</td>
</tr>
<tr>
<td>Medium to thin-bedded limestone</td>
<td>35</td>
</tr>
<tr>
<td>Limestone with sand lentils</td>
<td>15</td>
</tr>
<tr>
<td>Limestone with interbedded shale and lentils</td>
<td>15</td>
</tr>
</tbody>
</table>

The limestone in this portion is white or whitish-gray on fresh exposures, but weathers to a dark gray and through differential weathering develops a rough pitted surface.

Fossilliferous limestone with some chert           | 25   |
Thin-bedded limestone with chert                   | 90   |
Thin-bedded limestone without chert                | 30   |
Massive blue limestone                             | 4    |

Granular white limestone. This portion of the formation is platy near its upper limit and there weathers more rapidly so that streams and gullies often mark the zone.

Shale with thin beds of limestone                  | 120  |
Very fossiliferous limestone bed                    | 45   |
Argillaceous limestone                             | 5    |
Thin-bedded limestone and shale                    | 10   |
Dense white limestone (Base of formation)         | 3    |

No other sections of the Viola limestone were measured, but the evidence afforded by wells drilled in the western and northern

PONTOTOC COUNTY

portions of the quadrangle indicates that the formation thins in that direction. In the well at Vanoss (sec. 34, T. 4 N., R. 4 E.) there is apparently 660 feet of limestone assignable to the Viola, while in the Denn well (sec. 20, T. 5 N., R. 8 E.) there seems to be only 190 feet of the formation.

SYLVAN SHALE

The thickness of the Sylvan, according to Taff, increases from 60 feet at the east end of the Arbuckle uplift to approximately 300 feet west of Washita River.

In the quarry, just east of Lawrence a full section of the Sylvan is exposed and here totals approximately 120 feet. Complete sections are also available from the logs of two wells drilled in the Stonewall quadrangle. In the first of these located in the center of sec. 12, T. 5 N., R. 7 E., the Sylvan has a thickness of 151 feet and in the other, situated in the northeast corner of sec. 29, T. 5 N., R. 4 E., it is 145 feet thick.

On fresh exposures the Sylvan shale is generally green or greenish-blue in color. Because of the lack of resistant beds within the formation it weathers rapidly, resulting quite commonly in under-cutting of the succeeding Chimneyhill limestone, so that an abrupt escarpment often marks the contacts of the two formations. This is the case east of Lawrence.

Hunton Terrane

CHIMNEYHILL LIMESTONE

This formation takes its name from Chimneyhill Creek (South Fork of Jack Fork Creek on most maps) at the confluence of three small creeks in sec. 4, T. 2 N., R. 6 E. The formation is easily recognized by its pink-crenoid and oolitic members. The Chimneyhill limestone is especially well exposed in the region east of Lawrence where it forms a westward-facing escarpment of Sylvan shale. The contact is one of unconformity. Good exposures of the limestone are also common farther southeast where several formations of the Hunton terrane extend along the northeastern flank of the main mass of the Arbuckle Mountains.

HENRYHOUSE SHALE

According to Reeds the Henryhouse shale rests unconformable upon the Chimneyhill limestone. It is thickest in the western part of the Arbuckle Mountains and thins eastward so that in the Stonewall quadrangle it is entirely absent between Canyon Creek and the southeast corner of the quadrangle. Thinning toward the north is apparently less rapid because the fossils secured from the well in sec. 4, T. 4 N., R. 5 E., indicate its presence at that point.

As is indicated by its name the Henryhouse shale consists largely of shales. Within these, soft marly limestones are interbedded, and there are occasional resistant limestone beds which, due to differential weathering, stand out as small ridges.

HARAGAN SHALE

In the Stonewall quadrangle the Haragan shale is apparently absent on the Lawrence uplift, but is very well exposed in the outcrop of the Hunton formations in the southeastern part of the quadrangle.


Lithologically the Haragan greatly resembles the underlying Henryhouse shale and in the absence of fossils it is very doubtful whether the two could be distinguished.

BOIS D'ARC LIMESTONE

The Bois d'Arc is locally absent and in such places the succeeding Woodford formation rests directly upon the older formations of the Hunton terrane. Reed's mentions such a place in the vicinity of Honey Creek near Washita River. Other localities in which such absence has been observed are sec. 29, T. 1 N., R. 7 E., at which point the Woodford apparently rests directly upon the Haragan shale, and along the northern flank of the Lawrence uplift in secs. 29 and 30, T. 3 N., R. 6 E. A well drilled in the center of sec. 10, T. 3 N., R. 6 E., indicates that there is only 80 feet of Hunton there. It appears, therefore, that in addition to absence of the Haragan shales from the Lawrence uplift, 40 feet of the Henryhouse and 40 feet of Henryhouse with the Woodford chert resting on the latter.

WOODFORD FORMATION

In the southern and western parts of the Arbuckle Mountains the Woodford contains near its base a considerable thickness of cherty strata. These are apparently entirely lacking in the Stonewall occurrences which may constitute an explanation of the lesser thickness of the formation here. In the present investigation the formation was found, in the majority of cases, to consist of brown and black chert and shale with local bands carrying concretions of varying size. The greatest number of concretions are round and about the size of a marble. Some, however, are elongate and variation in size up to a diameter of a foot was noted. As a rule the lower part of the formation is darker and more sandy than the upper portion. In some places the upper strata are quite sandy and on exposure weather to a grayish or greenish-blue color. Such occurrences closely resemble portions of the Caney shale. In fact, the general lithologic similarity of the two formations is so close as to make it quite difficult to distinguish between them where only this criterion is used.

SYCAMORE LIMESTONE

In the Stonewall quadrangle the formation has not been observed to have a thickness of more than five feet. The average, however, is less than this and probably does not exceed two feet. In view of the extreme thinness of the formation in the Stonewall quadrangle, as compared with the occurrence in the southern and western portions of the Arbuckles, it might be expected to have a considerable variation in character in the two localities. This is the case, however, as Taff's original description agrees very closely with the character of the Stonewall exposures. For the most part the formation is a tough, hard limestone, slate-blue on fresh exposure, and weathering to a very characteristic bright yellow. Where the formation is as much as four or five feet thick the lower portion is generally slightly sandy and in some places it seems to grade laterally into shale.

The shale at the bottom of the Canyon Creek section has a lithology appearance somewhat similar to that of the underlying Caney Creek, but the two were easily distinguished by the following features:

1. The basal shale of the Wapanucka carries a very prolific fauna which is characteristic of the formation.
2. The Caney shale is less calcareous and slightly the darker of the two, also it is often more sandy.
3. The upper part of the Caney shale, although fossiliferous and although carrying a fauna somewhat similar to that of the Wapanucka—in that they are both Pennsylvanian—has a barren zone of some 60 feet at its upper limit.
4. Flintstone concretions, characteristic of the upper Caney, occur in this barren zone.
5. The fauna of the fossiliferous portion of the upper Caney has only a few forms which are common to the Wapanucka formation.

**ATOKA FORMATION**

The Atoka consists of alternating sandstones and shales with a few impure limestones near its base. The latter are to be observed on Canyon Creek, a short distance north of the Wapanucka outcrop. A chert bed known as the Hickachoc chert lentil occurs in the lower part of the formation where it outcrops in the southern part of the Coalgate and the northern part of the Atoka quadrangle. This chert lentil was not observed in the Stonewall exposure. Taff mentions another type of strata which occurs within the Atoka formation. In describing these beds he says:

"Prominent local beds of conglomerate composed of fine brown sand and sub-angular chert pebbles make high ridges and hills immediately west and southwest of Stringtown. Conglomerate beds of similar nature occur also in the upper part of the formation west of North Boggy Creek and north and west of Atoka. A peculiar feature of this chert conglomerate is that its limit in range north and south corresponds with the occurrence of Silurian chert (mapped as Talihina Chert) in Black Knob Ridge."

These conglomerates are important in that others of a very similar character are common in practically all the formations later than the Atoka which are present in the Stonewall quadrangle. Their greatest development, however, is in the formations above the Wetchumska shale.

The thickness of the Atoka in the Coalgate and Atoka quadrangles, as given by Taff in the folios covering those areas, is 5,000 feet. In the Stonewall area, however, the exposed section is very much less and is estimated to be only 800 feet.

**HARTSHORNE SANDSTONE**

From the western edge of the Coalgate quadrangle, to which point the formation was mapped by Taff, there is a continuation into the Stonewall quadrangle of several brown sandstones with interbedded shales. This group of strata resembles erosion somewhat better than the more shaly beds above and below it and for that reason is generally expressed as a low, rounded ridge. It is thought that these strata represent the westward extension of the Harshorne sandstone.

Further east the Hartshorne sandstone has a thickness of as much as 200 feet, but in the portion of its outcrop here discussed the formation is only about 100 feet thick. It consists of brown or yellowish-brown sandstones with interbedded shales.

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**Figure 26.**
Oil and Gas in Oklahoma

McAlester Formation

In its Stonewall exposure the upper part of the McAlester consists very largely of dark colored shales, which, however, carry a few thin beds of sandstone. In the portion below the coal, sandstone is prominent, but even here the strata consists largely of shales. The most important bed, geologically, in the McAlester formation is a thin red limestone which occurs 15 feet below the Lehigh Coal. This bed was traced almost continuously along the outcrop mapped in the present survey and contributes quite conclusive evidence as to the relation of the McAlester with the formations above and below it. Where the red limestone outcrops just south of the strip pit in section 14, it is approximately 2,000 feet above the Wapanucka limestone, but at its last observed western exposure, along the eastern edge of sec. 3, T. 7 N., R. 6 E., it is only 465 feet above the Caney shale; the Wapanucka, Atoka, and Hartshorne formations being there absent. This condition is taken to indicate (1) that the McAlester is an overlapping formation; (2) that the top overlaps the base, probably thus accounting for at least part of the supposed westward thinning mentioned by Taft; and (3) that in the Stonewall quadrangle the overlap of the upper part of the formation continues to such an extent that it projects across the beveled edges of the older formation and, in the region just south of Franks, rests on the Caney shale.

In its eastern extent the exposed portion of the McAlester formation carries numerous beds of conglomerates. On the west bank of Canyon Creek there is such a stratum which rests unconformably on limestone beds of the lower part of the Atoka formation. This conglomerate is largely composed of reworked fragments from the Caney and Woodford formations, but also carries a few pieces of the uppermost exposed limestone of the Atoka. The absence of the conglomerate from the eastern edge of the Arkabutla strata older than the Woodford suggests that the conglomerates were not exposed in the immediate vicinity at the time the conglomerate was deposited. The importance of this observation is the fact that in the Atoka quadrangle, 5 miles to the southeast of the eastern county line, a conglomerate, found at the top of the Wapanucka formation, which contains both Atoka and Arkabutla limestones, has been removed. This conglomerate was deposited in the Vicksburg strata, and is part of the Arkabutla formation. The natural conclusion, therefore, is that the Arbuckle Mountains were first uplifted at some point to the south of their present highest portion. This conclusion is substantiated by the fact that at the southeastern edge of the mountains all of the thick section of early Paleozoic rocks has been removed, thus exposing granite, while in the area just south of the point at which the Arkabutla conglomerate bed is exposed in Canyon Creek, several thousand feet of these older rocks are still present above the granite.

Further west, later conglomerates in the McAlester carry fragments of Hunton limestone and numerous well preserved specimens of Camarocerasus which were very probably derived from either the Henryssor or Harscan shales. The red limestone which occurs below the Lehigh Coal also becomes more elastic westward and just north of the road and house, one-half mile south of the NW. cor. of sec. 6, T. 1 N., R. 7 E., contains limestone pebbles up to an inch in length. Fragments of coal were also observed in the limestone at this place. The conglomerates in the western extension of the McAlester formation were included by previous workers as part of the Franks conglomerate.

Savanna Sandstone

A section measured along the east line of T. 1 N., R. 7 E., shows a thickness of Savanna amounting to approximately 1,900 feet. Westward, however, the exposed portion of the formation is greatly decreased because of the combined effect of two overlaps. A section measured about two miles southeast of Franks shows only 400 feet of Savanna.

The formation consists of alternating shales and sandstones, with occasional thin impure limestones. Toward the western end of the outcrop conglomeratic beds become prominent. These carry fragments of oolite and pink-erinooidal limestone from the Chinneyhill formation. Other limestone fragments included in the conglomerates closely resemble strata from the Viola and Arbuckle. The conglomeratic phase is a part of the Franks conglomerate of previous investigations of the Arbuckle area.

Jolly Limestone Member

Near the bottom of the Savanna there is a thin limestone bed which is important in that it shows clearly the overlapping nature of itself, and the strata above it, across the basal beds of the formation. This bed is very well exposed in the road in front of J. C. Jolly's house, 300 yards east of the northwest corner of sec. 8, T. 1 N., R. 7 E.

Boggy Formation

The formation consists of sandstones, shales, and a few limestones. Of the three, the kind of strata which constitute by far the greatest thickness, but at the top of the formation, the thin elastic beds are quite prominent. These grade from sandstones and fine grained conglomerates at the eastern edge of the area to coarse limestone conglomerates near the town of Franks. In the latter area Boggy strata constitute a large part of what has previously been called the Franks conglomerate.

The maximum thickness of the formation along the border of the Stonewall and Coalgate quadrangles amounts to less than 1,500 feet. If the upper part of the formation were present in the region south of Stonewall, however, it is probable that the thickness there would amount to as much as 1,500 feet.

In the vicinity of Franks only the upper part of the formation is exposed, but it is thought that wells drilled there would encounter a full section of at least 1,500 feet. On the eastern end of the Lawrence uplift the lower part of the Boggy is in unconfined contact with the Caney shale and the Wapanucka limestone. On the northern flank of the uplift, near Lawrence, it overlaps all lower formations from Caney to Viola, inclusive.

Thurman Sandstone

A complete section of the Thurman formation in the Stonewall quadrangle is about 100 feet. Several beds of conglomerate and conglomeratic limestones occur in the basal part of the section. The pebbles in these beds are worn and consist of chert and limestone. Some of the conglomerate fragments greatly resemble the pink erinooidal member of the Chinneyhill limestone and are thought to have been derived from that formation.

Brown and yellowish-brown sandstones are very prominent in the formation and alternate with dark colored shales.

Fifteen feet below the base of the formation occurs the very characteristic Camarophyllum-bearing limestone mentioned in the discussion of the Boggy formation.
This bed is easily traceable and clearly defines the base of the Thurman. The top of the formation, however, is not so easily determined. In the Coolgate field the upper limit coincides with the outcrop or rather a heavy sandstone, and although there are other sandstone beds above this one, it was taken as the top of the formation and mapped westward into the Stonewall quadrangle as the upper limit of the Thurman.

**STUART SHALE**

The thickness of the Stuart shale is approximately 80 feet. It consists of dark shale ranging through shades of grey, blue, and black, and near its top and bottom also carries a few thin beds of sandstone. About 15 feet below the top of the formation is generally a zone of brown concretions, which were of assistance in mapping.

**SENOARA FORMATION**

In a section measured through the central part of secs. 3 and 10, T. 3 N., R. 7 E., the Senora was found to be 125 feet thick. At the base of the formation there is about 35 feet of sandstone with only a few thin beds of interstratified shale. This series of beds is much more resistant than the underlying Stuart shale and the differential weathering of the two results in the formation of a steep, southward-facing escarpment. The Stuart shale occupies the steep face of the escarpment and the basal Senora beds extend along the crest.

Above the basal sandstone, to the top of the formation, shales are prominent, but interbedded with these are brown and yellowish-brown sandstones.

In the basal sandstones there is locally a thin, arenaceous limestone that is quite fossiliferous. This bed is of assistance in mapping as it is also the zone of concretions fifteen feet below the base of the formation.

**CALVIN SANDSTONE**

A section measured in the central part of sec. 3, T. 3 N., R. 7 E., near the western end of the outcrop shows a thickness of only 49 feet for the Calvin.

Where this section was taken the beds assigned to the Calvin consist of coarse-grained, brown and grayish-brown sandstones. With these are interbedded a few thin layers of shale. The beds are slightly more resistant than the shales of the upper Senora and lower Wetumka, and for that reason weather out as a low, rounded ridge.

Farther northeast, and typically in the northeast corner of sec. 36, T. 4 N., R. 7 E., some of the sandstones are very thin beds. Associated with these are occasional red shales. Such a red shale occurs in the road one-half mile south of the corner just mentioned.

**WETUMKA SHALE**

In sec. 24, T. 4 N., R. 7 E., the Wetumka shale has a thickness of between 150 and 175 feet, while a section measured in sec. 3, T. 3 N., R. 7 E., shows a total of 250 feet. As pointed out in the discussion of the Calvin formation this apparent difference in thickness is probably due to the fact that in section 3, some of the upper shaly strata of the Calvin have been mapped as basal Wetumka. The contact between the two formations is gradual and, at least in the Stonewall quadrangle, it would probably be more advisable to map the formations together. They extend only a short distance into the area, however, and in an endeavor to preserve the stratigraphic subdivisions used in the Coolgate field a separation of the formations has been attempted.

There are a few thin sandstones near the top and bottom, but for the most part the formation consists of almost unbroken shale.

The slight resistance offered to erosion by this shale results in its being undercut from beneath the resistant sandstones in the base of the overlying Wewoka formation, and in the formation of a prominent southeastward-facing escarpment.

**WEWOKA FORMATION**

Several sections measured in the Stonewall quadrangle show a total average thickness of 400 feet for the Wewoka. The top and bottom of the formation are marked by definite sandstone beds that were mapped without difficulty. The basal sandstone, as well as several other members locally grades into chert conglomerate.

**HOLDENVILLE FORMATION**

The Holdenville formation consists largely of shale, but also contains numerous sandstone beds and two mappable limestone members. Some of the sandstones locally develop into massive chert conglomerates that are lithologically identical with the conglomerate at the base of the Seminole in the type area of that formation.

In the northeastern part of the quadrangle the Holdenville is approximately 235 feet thick. It thins southward, however, and at its southern extremity, where it is overlapped by the Seminole, does not exceed 100 feet.

**Saskanwa Limestone Member**

The upper of the two limestones occurs 35 feet below the top of the formation. Its outcrop passes through the town of Saskanwa and the member is named after that town. The bed is especially well exposed in the railroad cut and quarry about one-fourth mile south of Saskanwa.

**Homer Limestone Member**

This limestone lies below the Saskanwa limestone and is also best developed in the northeastern part of the quadrangle.

In the northeastern part of the quadrangle the Homer limestone is approximately three feet thick. It occurs 70 feet below the Saskanwa limestone and has a chert of Chaetetes. The color of the limestone in this area is dark gray or almost black. The reef-like character of the stratum is maintained southward to the vicinity of Homer school where the quantity of Chaetetes begins to diminish and a few specimens of Fusulina appear.

**SEMINOLE FORMATION**

Although defined by Taft the upper limit of the Seminole was not mapped by him. In order to establish what he considered as the limits of the formation his brief description and definition of the formation is here quoted in full. He says:

"About 50 feet of the lower part of the Seminole conglomerate is exposed in a small area in the northwestern corner of the Coolgate quadrangle. This part of the formation is composed of
laminated or stratified subangular chert, with a sprinkling of quartz pebbles from three inches in diameter to small grains in a cement of fine brown and usually ferruginous sand. The coarser conglom erate in the beds at the base is loosely cemented and on weathered surfaces it breaks down into rounded boulders and loose gravel. Forty to 30 feet from the base the conglomerate grades into brown sandstone which continues upward about 100 feet to the top of the formation. The Seminole formation crops in a rugged hilly country northwestward in the Seminole Nation, making rough timbered lands.

By definition then, the Seminole of the type area has a thickness of about 150 feet. Since no definite bed is named as marking the top of the formation there can be no question as to the original measurement and the definition must be taken literally.

**FRANCIS FORMATION**

In the type area and northward the Francis formation has a thickness of 500 feet. In the vicinity of Ada and southward only the lower part of the formation is exposed, the upper part being overlapped by the Ada formation.

At the base, but within the Francis formation, is the DeNay limestone member, the lower part of which marks the top of the Seminole formation. Above this limestone is an interval of about 30 feet that is represented by dark blue and black shales. These grade upward into sandstones which on the creek bluff northwest of Sanakwa have a thickness of nearly 20 feet. This is the sandstone that outcrops in the railroad cut below the viaduct in the northeastern part of Francis and is also correlated with the sandstone in the road cut just north of the brick plant and railroad crossing near the southeast corner of Ada. Above the sandstone member is a series of thick, dark and sometimes calcareous shales. The average thickness of this part of the formation is 250 feet.

Above the shale series is a thickness of almost 100 feet within which coarse brown sandstones and chert conglomerates predominate.

The upper part of the Francis formation is a shale that is about 100 feet thick. This part carries a few thin sandstone and one rather persistent conglomeratic limestone.

### DeNay Limestone Member

The DeNay limestone formation has an average thickness of a little more than one foot. In the region north of the Canadian River the bed is rather dense and breaks out in longted blocks. In the road about one-half mile east of Francis the bed is slightly eroded. Crinoid stems become more abundant in the stratum toward the southwest and in the region south of Ada it is often almost entirely composed of these organisms. In the northeastern part of T. 5 N., R. 5 E., the crinoids become less abundant and the limestone develops a bright yellow color. The latter characteristic must be used with discretion, however, because there are in the area several beds of this color.

### FRANKS CONglomerATE

In the vicinity of Franks, conglomeratic strata are exposed through a section of approximately 1,500 feet. Many of the beds are fossiliferous, and (contrary to Tuff's statement, as given above, that the Franks conglomerate of this area is nearly flat) all are highly folded and locally faulted. The conglomerates are largely composed of limestone fragments which vary in size up to a diameter of four or five inches. Toward the east and northeast the fragments diminish in size and quantity within any given stratum; the beds becoming sandy or grading into shale in these directions.

### BELLE CITY LIMESTONE

The formation has an average thickness of 30 feet. It is composed of two limestones of varying thickness with an intervening shale. The upper limestone is generally thicker and much more massive than the lower. Its range in thickness is from one foot as just south of Byng, to as much as 15 feet near Canadian River. The beds range from white or light gray in color and is often characterized by well developed stylolites. Pronounced weathering along joint cracks is common and in the eastern part of sec. 34, T. 6 N., R. 6 E., results in the formation of small sink-holes at the intersection of a few of the prominent joints.

The lower limestone bed is buff colored. Its range in thickness is from one foot, as in the vicinity of Byng, to as much as five feet near Canadian River and northward. At variance with the massive character of the upper member of the formation the bedding of this stratum is relatively thin.

The interval between the upper and lower limestones is composed of shale that ranges in color through shades of green, blue and black. Its average thickness is 12 feet.

### VAMOSA FORMATION

Where all of the formation is exposed the entire section has an average thickness of 260 feet. At the base is about 30 feet of dark shale that might easily be mapped as a separate formation. Dark limestones were made from this member, but they are probably fossiliferous. The main mass of the formation is above this shale and has a maximum thickness of about 230 feet. It consists in large part of chalk conglomerates, of massive, coarse, red and brown sandstones, and red shales. The clastic material is finer near the top and the red coloration is there also less pronounced.

### ADA FORMATION

The average thickness of the Ada formation is about 100 feet. Limestone conglomerates and coarse sandstones are very prominent along the greater portion of the outcrop. Clastic material becomes less toward the north, however, and in the vicinity of Vamosa is very scarce. With the decrease in the amount of clastic material northward the formation becomes thinner and at the northern edge of the sheet has a total thickness of only about 60 feet.

One very characteristic feature of the formation is the asphalt which it contains. This is always associated with the conglomerates or coarse sandstones many of which are often highly saturated. One mile west of Ada, asphalt-bearing sandstones and conglomerates are quarried for paving purposes.

### VANOS FORMATION

The Vanos formation consists of alternating sandstones, conglomerates, shales and a few thin limestones. All of the strata are arkoses, some of the sandstones so much so that at the first glance a few of them might be mistaken for true granites.

Near the center of the formation there are several thin limestone beds. These were not observed north of Canadian River, but appear intermittently along the outcrop to the south of that stream. They are generally argillaceous and subject to rapid
gradation into shale. Where freshly exposed the limestones are light gray in color and relatively soft, but on weathering become hard and white. Several of these beds are well exposed at the eastern edge of the town of Center. Good exposures are also common in the region about one mile east of Vanoss. The limestones are less arkosic than the associated sandstones, but some of them carry an appreciable amount of feldspathic fragments.

In the upper part of the Vanoss formation sandstones are less prominent than they are near the base. The shales which constitute the greater part of this upper portion are generally of light color, ranging through shades of green and gray. Occasional red shales are also present. With the decrease in sandstone there is also a decrease in the quantity of the arkose. Locally, however, there are beds that are almost entirely composed of this material.

The upper limit of the Vanoss formation is marked by the base of the Hart limestone member of the Stratford formation. The thickness of the Vanoss formation increases southward. The exposed portion east of Konawa totals only about 250 feet, while near the southwest corner of the quadrangle there are about 650 feet of strata within the formation.

STRUCTURE

The structure of Pontotoc County is very complex due to the fact that it lies on the north flank of the Arbuckle Mountains and is sharply folded and faulted, especially in the older formations. See map No. IX). In general it might be stated that beds younger than Boggy dip to the northwest while the regional dip of the lower beds is to the northwest, north, northeast and east as controlled by the northward plunging axis of the Hunton arch.

There are many minor changes in this general dip and important ones, so far as the possibility of oil and gas is concerned, will be pointed out in the following statements.

First, there are three general lines of subsurface "highs" which affect the oil possibilities of Pontotoc County. One is a subsurface "nose" which seems to be an outshoot of the Arbuckle folding running in a northwestward direction and passing just west of the town of Center and plunging to the northwest. The second is an east-west subsurface fold beginning on the eastern edge of the county just north of Allen in T. 5 N., R. 8 E., and extending westward through T. 5 N., Rs. 6-7 E. This fold plunges toward the east. The exact trend of the axis of this fold is not definitely defined as yet. For a better understanding see the map of Pontotoc County on which is given the depths at which the Hunton and Simpson formations were encountered in many wells over the area. The third is the Lawrence uplift running through the northern part of T. 2 N., and the southern two-thirds of T. 3 N. The big basin lies between this and the second high mentioned above.

still in the Viola. It will be noted from the above that the Hunton
and Viola were found at very great depths although the well was drill-
ed near the top of the surface fold. It is extremely unlikely that the
Simpson will produce oil in paying quantities under this anticline.

![Subsurface Map of Northwest Allen Pool](image)

**Figure 28.**

**NORTHWEST ALLEN POOL**

Another pool has been discovered recently by the Homoka Oil
Company in sec. 16, T. 5 N., R. 8 E. The pool has been extended
far across the western edge of sec. 16 and to the west across the south
half of section 17 and through section 20 by some 17 or 18 wells. C.
B. Shaffer has also brought in a well in sec. 36, T. 5 N., R. 7 E., but
as yet it is impossible to say whether this is a separate structure or an
extension of the northwest Allen pool. A subsurface map showing the
structure as far as the author is able to work it out from wells drilled
will be noted in Figure 28. The author believes that the production
here is coming from the basal Wapama and the upper part of the
Caney. In other words, there are several good sands in the next
two or three hundred feet below which should produce considerable
quantities of oil. There are many who believe that this is the Savanna
horizon, in which case the Wapana and upper Caney series are still
to be penetrated with very good possibilities for oil. This pool should
be the most important pool in Pontotoc County.

**BEEBE ANTICLINE**

The axis of this fold extends from the southeastern part of sec.
36, T. 4 N., R. 5 E., to the southeastern part of sec. 28, T. 4 N., R. 5
E. This is not a closed structure on the surface, being open to the
northwest. The production here comes from what is thought to be the
base of the Boggy from 1,200 to 1,750 feet, and the Caney shales are
penetrated at about 1,800 feet. A little farther to the northeast, in sec.
28, a well was drilled to the Hunton lime at 2,185 feet on what is
thought to be a separate structure from that at Beebe. At 2,548 feet
a production of 155 barrels was had and the well has held up remark-
ably well although both direct offsets were dry. One of these was
drilled to the Simpson and found it contained water.

**CENTER ANTICLINE**

The Center anticline lies just west of the town of Center and is
about five miles southwest of the Beebe anticline. This anticline shows
a closure at the surface and a well drilled in the NE. 1/4 sec. 144, hit
the Hunton lime at 1,400 feet and the Simpson at 1,940 feet. Although
the wells had small showings in two or three of the Simpson sands, these
sands were found to contain a heavy hydrostatic head of sulphur water
and no commercial production was had. It is not certain, however, since
this is the only well drilled on the structure, that this was on the highest
point in the subsurface, and although we believe that it is doubtful that
the Simpson will produce commercial quantities of oil from this
structure yet no definite statement can be made.

**FAULTING EAST OF BYNG**

Morgan mapped two surface faults just east of the town of Byng.
This is thought to account for the accumulation of the oil and gas in
sec. 34, T. 5 N., R. 6 E.

11. Below the Thurman sandstone and near the top of the Boggy shales is a
prolific red shaly member. There is often included in the shale a fine
grained angular gray sandstone bed whose thickness ranges from one to
twenty feet. In the old Allen field this sandstone is found at a depth of
700 feet to 800 feet and is known locally as the Allen producing sand.
To the northwest of the old Allen field a new field has been recently dis-
covered. Here the Allen sand is found at a depth of 900 feet or more.
A study of the samples from the producing horizon in the new field is not
the Allen sand, however, but a sandstone that is found at a depth of
2,300 or 2,400 feet. This sandstone is approximately 100 feet thick and can
be quite definitely correlated with the Savannah sandstone which outcrops
to the southeast of Allen in Coal County, Oklahoma. It is likely that this
new field is not far from the northwestward limit of Savannah deposition.

**GRO. S. BUCHANAN.**
STRUCTURE OF THE ADA GAS FIELD

The Ada gas field is located in secs. 8, 9, 16 and 17, T. 4 N., R. 6 E. The subsurface structure is shown in Figure 29. There have been wells drilled on this dome to the Simpson formation which found the sands to be water-bearing.

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THE SLICK WELL IN SEC. 21, T. 5 N., R. 6 E.

This well came in for some four or five thousand barrels in the Hunton limestone which was reached at 2,555 feet and penetrated to a depth of 138 feet. As yet it cannot be stated as to whether this is a closed subsurface structure or not, but the author is inclined to believe that it will not have much closure, and therefore, believes the possibility of Simpson production below is very slight.

FUTURE POSSIBILITY OF OIL AND GAS OF NORTHWEST ALLEN STRUCTURE

The striking of oil at 2,500 feet in sec. 16, T. 5 N., R. 8 E., by the Homoaoka Oil Company has caused a revival of interest in Pontotoc County, especially in the northeastern part. If the author's correlation is correct, the production from this well was found in the basal part of the Wapanucka formation or the very top of the Caney formation and it shows an uplift of approximately 800 feet from the center of sec. 33, T. 5 N., R. 8 E., to sec. 16, T. 5 N., R. 8 E. (See footnote, page 129). As there has not been enough development to the west as yet to show whether this has a large closure in that direction, it is hard to state what the possibilities in the Simpson formation below might be. There are undoubtedly very great possibilities in the lower sands above the Simpson, however, and this structure would be worthy of a Simpson test should closure be found to the west. If this does not produce in the Simpson, the author does not believe there is any very great possibility of future production from this series. There will be many shallow pools developed, no doubt, some of which will have a considerable commercial value, and it is likely that the Hunton will produce over a considerable area. However, the history of the Hunton production is that it is more or less spotted.
WASHINGTON COUNTY

By

Everett Carpenter

LOCATION

Washington County is located in the northeastern part of the State. It borders Kansas on the north and is about 65 miles west of the Oklahoma-Missouri line. It extends from T. 23 N., to T. 29 N., inclusive, and from a line about 1½ miles west of the east side of R. 12 E., to the middle of R. 14 E. It is about 10½ miles wide and 40 miles long and includes about 420 square miles. (See Fig. 30).

Figure 30.—Map of Oklahoma showing location of Washington County.

It is traversed from the north to south by the Atchison, Topeka and Santa Fe Railroad, and from northeast to southwest by the Missouri, Kansas, and Texas Railroad. Bartlesville, the county seat, is situated in the northern part of the county. It is a town of about 20,000 population and is the location of several important industries.

TOPOGRAPHY

The topography of Washington County may be classed as rolling. East of Caney River it is a prairie plain varying in altitude above sea level from 700 to 860 feet. The lowest point is on the Caney River in the southeastern part of the county in sec. 28, T. 23 N., R. 14 E., where the elevation is 590 feet. The highest point is in the northeastern part of the county in sec. 6, T. 29 N., R. 14 E., where an elevation of 960 feet is reached. West of Caney River the topography is more hilly. Along the western border of the county, an escarpment

(Originally published as Bulletin 40-V, January, 1928).
ranging from 150 to 200 feet in height, rises conspicuously above the plain.

The county is drained by tributaries of the Arkansas River, the largest of which is Caney River which flows in a southeasterly direction. It has cut a broad alluvial filled valley which contains excellent agricultural land.

GEOLGY

Surface Formations

The rocks exposed at the surface in Washington County are of Pennsylvanian age. They occur about the middle of that system and consist of sandstone, shales, and limestone. The subdivisions from oldest to youngest are Coffeyville formation, Hogshooter limestone, Nellie Bly formation, Dewey limestone, Ochelata formation, and Ne-

gonoy formation. (See Map No. X.)

COFFEYVILLE FORMATION

The oldest and lowest formation occurring in Washington County is the Coffeyville. It outcrops in the southeastern part of the county, where it has an exposed width of about ten miles. The lowest portion of the formation consists of bluish to greenish homogenous shale containing a calcareous member near the base, known as the Checkerboard limestone. The upper portion is sandy with numerous exposures of pure sandstone. The thickness of the formation as a whole is about 970 feet, not all of which is exposed in Washington County.

HOGSHOOTER LIMESTONE

The Hogshooter limestone rests conformably upon the Coffeyville formation. It is a single bed of massive gray lime and has a thickness of 6 to 8 feet, in T. 26 N., R. 14 E. However, it becomes thin bedded and argillaceous and thins to about 4 feet at Ramona and Vera. Along Hogshooter Creek it is exposed over a wide area but the breadth of its outcrop gradually narrows southward to Ochelata, where it becomes less conspicuous and must be indicated on the map by a single line.

NELLIE BLY FORMATION

The Nellie Bly formation consists of alternating shales and hard sandstones, the latter ranging from a few inches to several feet. This formation is about 18 feet thick at the Kansas line but thickens southward to 200 feet in southeastern Osage County. Throughout its exposure in Washington County, it averages about 75 feet.

1. The data for the nomenclature used in this report have been taken from Bulletin No. 35, Oklahoma Geological Survey. The data for the geologic map have been compiled from information furnished by the Oklahoma Geological Survey and several oil companies and consulting geologists. Among those whose contributions have been of assistance are: Foster Petroleum Co., Wood Brothers, Gypsy Oil Co., Phillips Petroleum Co., Robert E. Garrett, Prairie Oil and Gas Co., and The Wolverine Oil Co.

WASHINGTON COUNTY

DEWEY LIMESTONE

The Dewey limestone, which rests upon the Nellie Bly is bluish gray in color, semi-crystalline, and often shaly, although it is not infrequently massive. It is three feet thick at Wann, but thickens southward until it is 20 feet thick east of Dewey, where it has its greatest areal extent. It thins slightly toward the south.

OCHELATA FORMATION

The Ochelata is essentially a shale formation containing several sandstone and limestone members. The Avant limestone member, a ferruginous limestone 5 to 7 feet thick, occurs in the south end of the county about 300 feet above its base. It is about 400 feet thick and outcrops in a band about 12 miles wide. The Stanton limestone member is exposed in the north end of the county. It is hard and white and is about ten feet thick, but thins rapidly to the south. It is the Piqua limestone in the Independence quadrangle of Kansas.

NELOGONY FORMATION

Only the basal part of the Nelogony formation is exposed in Washington County. It occupies the tops of the hills northwest of Bartlesville, and attains its greatest thickness in the northwest corner of the county, where its exposures are chiefly shales interstratified with sandstone.

Subsurface Formations

East of Washington County, older Pennsylvanian strata outcrop. These formations contain the sands from which the oil and gas in this area are obtained. From oldest to youngest they are: Cherokee shales, Ft. Scott limestone, Labette shale, Pawnee limestone, Bandera shale, Altamont limestone, Cologah limestone, and Nowata shale. East of northern Washington County the Lenepah limestone occurs between the Nowata shale and the Coffeyville formation.

Subsurface formations in Washington County.

<table>
<thead>
<tr>
<th>Formation</th>
<th>Outcrop Thickness (in feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherokee shale</td>
<td>450 to 960</td>
</tr>
<tr>
<td>Ft. Scott limestone</td>
<td>50</td>
</tr>
<tr>
<td>Labette shale</td>
<td>100 to 120</td>
</tr>
<tr>
<td>Pawnee limestone</td>
<td>40 to 100</td>
</tr>
<tr>
<td>Bandera shale*</td>
<td>0 to 100</td>
</tr>
<tr>
<td>Altamont limestone</td>
<td>60</td>
</tr>
<tr>
<td>Nowata shale</td>
<td>130</td>
</tr>
<tr>
<td>Boone chert</td>
<td>450</td>
</tr>
<tr>
<td>Chattanooga shale</td>
<td>5 to 40</td>
</tr>
<tr>
<td>Arbuckle limestone (Siliceous lime)</td>
<td>25 to 1,500 (f)</td>
</tr>
</tbody>
</table>

2. The Bandera shale thins from the Kansas line southward until it permits the Pawnee and Altamont limestones to unite forming one formation known as the Cologah limestone.
The last three formations are of older age and sometimes yield oil and gas.

The following well logs penetrated all formations from the surface to the granite.

Log of Empire Gas & Fuel Co's. Maggie Thompson No. 1, sec. 22, T. 29 N., R. 13 E.

<table>
<thead>
<tr>
<th>Formation</th>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>lime</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>sand</td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>lime</td>
<td>350</td>
<td>275</td>
</tr>
<tr>
<td>sand</td>
<td>350</td>
<td>200</td>
</tr>
<tr>
<td>slate</td>
<td>850</td>
<td>600</td>
</tr>
<tr>
<td>lime</td>
<td>850</td>
<td>550</td>
</tr>
<tr>
<td>sand</td>
<td>850</td>
<td>550</td>
</tr>
<tr>
<td>sand</td>
<td>850</td>
<td>550</td>
</tr>
<tr>
<td>slate</td>
<td>850</td>
<td>550</td>
</tr>
<tr>
<td>lime</td>
<td>850</td>
<td>550</td>
</tr>
</tbody>
</table>

Log of Barnsdall Oil Co's. Wm. Rigdon No. 7, SW. 1/4 sec. 30, T. 28 N., R. 13 E.

Commenced 7-24-20; Completed 12-20-20

<table>
<thead>
<tr>
<th>Formation</th>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>soil</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>sand</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>lime</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>slate</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>sand</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>slate</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>lime</td>
<td>145</td>
<td>40</td>
</tr>
<tr>
<td>sand</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>lime</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>shale</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>lime</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>sand</td>
<td>880</td>
<td>550</td>
</tr>
<tr>
<td>slate</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>sand</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>shale</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>lime</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>sand</td>
<td>880</td>
<td>550</td>
</tr>
<tr>
<td>slate</td>
<td>87</td>
<td>46</td>
</tr>
<tr>
<td>sand</td>
<td>87</td>
<td>46</td>
</tr>
</tbody>
</table>

(Continued on page 137)
The position of these sands is shown graphically in Fig. 32, which illustrates the columnar section encountered in drilling.

STRUCTURE

The strata of Washington County have a northeast-southwest strike and a northwest dip of 20 to 25 feet per mile. The geologic map (No. X) shows the strike and outcrop belts of the formations exposed at the surface. The normal structure is in general a northwestward-dipping monocline, but the normal westward inclination of the strata is interrupted in places to form local anticlines, terraces, and "noses."

Anticlinal folding is generally associated with the accumulations of oil and gas, although it is not always the only controlling factor in such accumulations. The producing sands are more or less lenticular. In places these lenticular bodies of sand furnish all the requirements for accumulation that are provided by closed anticlines, so that pools are sometimes found that are not on structures.

DEVELOPMENT

Owing to its relationship to the producing fields of Kansas where oil and gas were first developed in the Mid-Continent field, what is now Washington County received early attention from the oil producers. The Cudahy Oil Co. obtained leases in the vicinity of Bartlesville and drilled a well in 1897. The location of this well is now in Johnstone Park within the city limits of Bartlesville. It was the first commercial oil well drilled in the county and is still producing. (See Plate II.)

Active development was retarded until 1904 on account of the necessity of obtaining the approval of the Secretary of the Interior for Indian allotted leases. The period of years between 1904 and 1907 saw the most active development. Most of the pools of the county were discovered and drilled during those years. Wells with an initial production as high as 1,000 barrels of oil and 75 million cubic feet of gas per day were drilled. The peak of production was reached in 1906, from which date there has been a slow but steady decline, until at present (1927) the average per well per day is probably not more than one barrel.

As a whole, the area has been productive. Probably a greater proportion of the acreage within the county has produced either oil or gas than any like area in the Mid-Continent field. Every township in the county has had some production although T. 23 N., Rs. 11-13 E., have had very little.

BARTLESVILLE—DEWEY POOL

The Bartlesville-Dewey pool occupies an area extending across the county from the north line of T. 27 N., to, and including, the north tier of sections in T. 25 N. It was formerly thought that the oil in this area lay in separate pools, but many former pools have since been
united. There are many nonproductive spots in this area but only a few sections which do not have some producing wells.

Perhaps the most prominent structure is known as the Bartlesville anticline. The apex of this structure is in sec. 17, T. 29 N., R. 13 E., but it plunges westward under Bartlesville and into Osage County. The structure of this anticline is shown in Figs. 33 and 34 which show the structure of the Dewey, Peru, and Bartlesville sands and the Mississippi lime.

Data are not available to show the structural conditions obtaining in all parts of the county. Most of the pools were discovered and drilled before geologists were commonly employed in exploration work for the oil companies. This area has not been subjected to that intensive study that many other oil producing areas have been.

The Bartlesville-Dewey pool was the earliest discovery in the county. Development was very active during 1904, 1905, and 1906. Some of the wells drilled during this period had an initial production of 1,000 barrels per day. In 1906 the average initial production per well was about 73.2 barrels. This average gradually decreased from that time and in 1914 it was only 10.4 barrels. At the close of
1914 there were 4,816 producing oil wells in this field. The high price paid for oil in 1915, stimulated development to such an extent that most of the inside and edge locations were drilled. Many wells were operated profitably that were abandoned when the price of oil declined. The initial daily production ranged from a few barrels to about 60 barrels, the average being about 20 barrels.

This pool has developed a number of prolific gas wells. The Burgess sand encountered at a depth of 1,400 to 1,500 feet was the chief gas sand. The gas lay near Bartlesville, though a narrow belt extended toward the northeast, to, and beyond Dewey. Some wells were brought in with an average initial open flow volume of 15 million cubic feet per day, and an average rock pressure of 464 pounds. In most cases wells of such capacity were among the first wells drilled in the field. By the latter part of 1911 the pressure on these wells had declined to 219 pounds, and the open flow to about 9 million cubic feet.

Drilling record and initial production of wells in the Dewey-Bartlesville pool, 1906-1915.

<table>
<thead>
<tr>
<th>Year</th>
<th>WELLS COMPLETED</th>
<th>INITIAL PRODUCTION (Oil)</th>
<th>Average per.</th>
<th>Barrels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Oil</td>
<td>Dry</td>
<td>Gas</td>
</tr>
<tr>
<td>1906</td>
<td>790</td>
<td>606</td>
<td>123</td>
<td>61</td>
</tr>
<tr>
<td>1909</td>
<td>415</td>
<td>390</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>1910</td>
<td>443</td>
<td>420</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>1911</td>
<td>483</td>
<td>455</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>1912</td>
<td>1,120</td>
<td>980</td>
<td>71</td>
<td>69</td>
</tr>
<tr>
<td>1913</td>
<td>(a)948</td>
<td>839</td>
<td>75</td>
<td>44</td>
</tr>
<tr>
<td>1914</td>
<td>(a)520</td>
<td>441</td>
<td>55</td>
<td>24</td>
</tr>
<tr>
<td>1915</td>
<td>90</td>
<td>80</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>4,819</td>
<td>4,201</td>
<td>396</td>
<td>222</td>
</tr>
</tbody>
</table>

(a) Includes Hogshooter.

Future Drilling

In early drilling no attention was paid to the shallower horizons, because of greater yield from deeper sands. The smaller wells at shallower depths will, as the deep sands are drained and the price of oil advances, become more and more important. It seems probable that as oil becomes scarce, shallow drilling will offer the best inducement in this region and that the life of the pool, will be extended a number of years by such work.

COPAN POOL

Location and Extent

The Copan pool is located in T. 38 N., R. 18-13 E., and occupies an area of about 8 square miles. It is almost continuous with the
Bartlesville-Dewey field to the south, and extends into Osage County to the west.

Development

The Copan field was opened in 1907 and development soon became very active. The average initial production of the wells in 1907 was 54.4 barrels and in 1910 it was 33.7 barrels. This average gradually decreased from that time. A few small oil and gas wells were the result of development in 1915.

**Drilling record and initial production of wells in the Copan pool, 1909-1915.**

<table>
<thead>
<tr>
<th>Year</th>
<th>WELLS COMPLETED</th>
<th>INITIAL PRODUCTION (Barrels of Oil)</th>
<th>Average Per Well</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oil</td>
<td>Dry</td>
<td>Gas</td>
<td>Total</td>
</tr>
<tr>
<td>1909</td>
<td>45</td>
<td>17</td>
<td>35</td>
<td>95</td>
</tr>
<tr>
<td>1910</td>
<td>121</td>
<td>22</td>
<td>65</td>
<td>208</td>
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<tr>
<td>1911</td>
<td>216</td>
<td>45</td>
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<td>282</td>
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<td>1912</td>
<td>482</td>
<td>50</td>
<td>41</td>
<td>573</td>
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<tr>
<td>1913</td>
<td>393</td>
<td>50</td>
<td>26</td>
<td>469</td>
</tr>
<tr>
<td>1914</td>
<td>294</td>
<td>80</td>
<td>76</td>
<td>450</td>
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<tr>
<td>1915</td>
<td>76</td>
<td>10</td>
<td>10</td>
<td>105</td>
</tr>
<tr>
<td>Total</td>
<td>1,625</td>
<td>274</td>
<td>283</td>
<td>2,182</td>
</tr>
</tbody>
</table>

(a) Includes also Wann and Canary pools.

The gas wells which originally had a rock pressure of 450 to 530 pounds had been depleted so that during the fall of 1911 the pressure was not more than 25 pounds, mainly because the sand was coarse and the drain rapid. Probably the maximum capacity of the field was about 300 million cubic feet per day. In 1914 the capacity of the field was probably not more than 50 to 75 million cubic feet. The table above gives the development from 1909 to 1915.

**Sands**

The wells begin in the Ochelata formation, a shallow sand which is encountered at 700 to 800 feet and is probably the Peru sand. The Bartlesville sand, which has a thickness of 29 feet, occurs at a depth of about 1,300 feet and is oil producing. The interval between it and the top of the Ft. Scott limestone is about 350 feet. The Burgess sand produces gas and occurs at a depth of about 1,500 feet. On page 146 is a log which is thought to be typical of this region.
Log of William Miller No. 5, sec. 3, T. 28 N., R. 13 E.

<table>
<thead>
<tr>
<th>Formation</th>
<th>Top</th>
<th>Bottom</th>
<th>Formation</th>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>soil</td>
<td>680</td>
<td>730</td>
<td>lime</td>
<td>720</td>
<td>820</td>
</tr>
<tr>
<td>shale</td>
<td>30</td>
<td>130</td>
<td>shale</td>
<td>820</td>
<td>920</td>
</tr>
<tr>
<td>sand</td>
<td>130</td>
<td>180</td>
<td>lime Ft. Scott</td>
<td>920</td>
<td>1010</td>
</tr>
<tr>
<td>shale</td>
<td>180</td>
<td>220</td>
<td>shale</td>
<td>1010</td>
<td>1020</td>
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<td>1040</td>
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<td>1130</td>
<td>1220</td>
</tr>
<tr>
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<td>500</td>
<td>shale</td>
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<tr>
<td>lime</td>
<td>570</td>
<td>610</td>
<td>oil</td>
<td>1300</td>
<td>1343</td>
</tr>
<tr>
<td>shale</td>
<td>610</td>
<td>720</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CANARY POOL

Location and Extent

The Canary pool lies in the extreme northeastern part of the county in T. 29 N., Rs. 13-14 E. The productive area was formerly approximately 10 miles square, with the long axis extending northeast-southwest. In as much as the gas has been exhausted the pool is now limited to the oil producing area.

Sands

The wells in this area start in the Ochelata formation. The productive horizons are the Bartlesville at 1,175 feet and the Burgess at 1,450 feet. The Bartlesville sand which is about 50 feet thick, is productive of oil and some gas. The Burgess was a prolific gas sand.

Development

The northeast part of the field is principally oil producing, with a few scattered gas wells. The reverse is true farther southwest. The average initial production per well is given by the United States Geological Survey as 54.4 barrels for 1909, and 33.7 barrels for 1910.

WANN POOL

The Wann pool produces from two small areas in the west side of T. 28 N., R. 14 E. The larger of the two areas is immediately west of Wann and the other about 4 miles southwest of Wann.

The general conditions of the pool are similar to the Canary and Copan pools. The wells start near the base of the Ochelata formation. The Bartlesville sand, which is the chief oil producing sand, is found at a depth of about 1,000 feet and the Burgess sand at about 1,200 feet.

HOGSHOOTER POOL

Location and Extent

The Hogshooter pool is located in T.s. 24-26 N., R. 14 E., and lies on both sides of Hogshooter Creek in the southeastern part of Washington County. The developed area includes a strip of about 12 miles long from south to north, and from a fraction of a mile to about 4 miles in width. It is contiguous to the Dewey-Bartlesville field on the north.

The wells on the east side of Hogshooter Creek and south of Oglesby begin on, or near, the horizon of the Coffeyville formation. The wells on the west side of this creek begin near the horizon of the Hogshooter limestone.

Development

The Hogshooter pool was opened in 1907 and during that year development was very active. Some of the larger wells had an initial production as high as 500 barrels per day, and the gas wells ranged from 5,000,000 to 16,000,000 cubic feet per day.

The Hogshooter pool was one of the important gas areas of its time. Although it was not large in comparison with some of the later discoveries, it led to the construction of several large gas lines. The gas was transported as far as Hutchinson, Kansas, St. Joseph and Joplin, Missouri, and was used in the industries at Bartlesville, Dewey and Miami. The demands of these lines were greatly increased by the depletion of the Kansas fields, so that the field had a rapid decline. It is no longer a factor in the gas business for the amount now produced hardly meets the demands of the powers on the oil leases.

Sands

The sands in this pool are encountered at the following depths: the highest sand, the Peru sand, is about 40 feet below the “Big Lime” —the Pawnee; the Bixler sand which is just below the Ft. Scott limestone, occurs at about 710 feet; a productive oil sand, the Squirrel, is found 200 feet below the Ft. Scott, or at a depth of 880 feet; the Bartlesville, which is the main producing oil sand of this pool, lies about 400 feet below the Ft. Scott, or at a depth of 1,080 feet; the Burgess is encountered at a depth of 1,160 feet.

VERA POOL

The Vera oil and gas pool is located in the extreme southeastern corner of Washington County. The principal producing area lies near the corner of Tps. 22 and 23 N., Rs. 13 and 14 E. It was discovered in 1915 and had its principal development in 1915 and 1916. The production is both oil and gas. The initial production of the oil wells ranged from a few barrels to 350 barrels, and the gas wells from 2 to 18 million cubic feet per day.

The geologic conditions encountered are quite similar to those obtaining in the Hogshooter pool. The Bartlesville sand is the main producing horizon.

SUMMARY

Washington County is in completely developed oil and gas territory. The surface rocks are Pennsylvanian and generally dip to the
west at a low angle. The oil and gas accumulations are largely associated with folding, but some pools produce from lenticular sands. The county includes several important oil and gas pools. Development began early and has continued intermittently up to the present time. The production of all of the fields has declined until the average production per well per day, is probably not over one barrel, but more oil remains in the sand than has ever been removed. New and improved methods of extracting the oil still remaining in the sand will provide several years of production. Considerable territory has been developed, but there are still areas which have not had a test well drilled. The productive horizons are fairly shallow, ranging from 500 to 1,700 feet.

McINTOSH COUNTY

By

Robert W. Clark

ACKNOWLEDGMENTS

In the preparation of this report use has been made of information already published in Bulletin 19, Pt. II, and Bulletin 17, of the Oklahoma Geological Survey. I am deeply indebted to Robert H. Dott of the Mid-Continent Petroleum Corporation, for information relative to the surface formations and general structure of the western part of the county and to the Geological Department of the Sinclair Oil and Gas Company for correlations in a well south of Eufaula proving the synclinal condition of the south part of the county.

Figure 35.—Map of Oklahoma showing location of McIntosh County.

LOCATION

McIntosh County is located in the east-central part of Oklahoma. The Canadian River forms its southern boundary line and its northern line is the north line of township twelve north. From east to west it lies in ranges 13 to 18 inclusive. There are fifteen whole townships within its boundaries, the east half of T. 12 N., R. 14 E., and fractional parts of eight townships bordering on the Canadian River. Its total area is approximately 724 square miles.

(Originally published as Bulletin 40-W, January, 1928.)
McIntosh County, for the most part, presents a rather rugged topography except for an area about three townships wide extending from Eufaula northward to the county line. This area lies in Rs. 15, 16, and 17 E., and is gently rolling and mostly open country. Its surface rocks are shale and shaly sandstone. Over the rest of the county the surface rocks are largely massive sandstone which cause the rugged topography. The relief may be as much as 350 feet in one-half mile.

The Canadian River borders the county on the south. The North Fork of the Canadian River crosses the county from west to east. It enters the county near the southeast corner of T. 10 N., R. 13 E., and flows northeastward to the middle of T. 11 N., R. 14 E., thence eastward to the southwest quarter of T. 11 N., R. 16 E., and thence southeastward and joins the Canadian River about three miles south of Eufaula. The Deep Fork of the Canadian River enters the county in the southeast part of T. 12 N., R. 14 E., and, after flowing east and southeastward, joins the North Fork about six miles north of Eufaula. The extreme northeast part of the county is drained by small tributaries of the Arkansas River.

STRATIGRAPHY

Surface Geology

The surface formations embrace that part of the Pennsylvanian included between the Savanna sandstone and the Senora as described by Taff. The Savanna sandstone outcrops in the northeast part of T. 11 N., R. 18 E., and the southeast corner of T. 12 N., R. 18 E.

BOGGY SHALE

The Boggy shale is next above the Savanna. There are several sandstone beds, some of them quite massive, in this formation. These sandstones give rise to the rugged topography in the southern part of the county, especially along the Canadian River. Toward the north the sandstones become more shaly and even disappear, giving rise to the more open prairie type of country north of Eufaula. From logs of wells drilled in R. 14 E., and starting about the top of the Boggy or in the Thurman sandstone above it, the thickness of the Boggy appears to be about 1,000 feet.

THURMAN SANDSTONE

The Thurman sandstone lies above the Boggy and outcrops in a narrow belt across the county from north to south. It nearly covers the east half of T. 12 N., R. 14 E., the major part of Tps. 9, 10, and 11 N., R. 14 E. The width of the outcrop increases toward the south due in large part to the presence of some large domes in its southern area. It is about 75 feet thick and forms a very rugged topography. In the extreme northern part of the county it becomes somewhat shaly and a less rugged topography results.

STUART SHALE

The Stuart shale, lying above the Thurman, consists of a series of red and gray clay and sandy shales with some rather massive sandstone ledges near its base. In T. 10 N., R. 13 E., it underlies the Senora which caps the big outlier through the center of the township. It covers the most of the rest of the township except the southeast corner and along the river. It extends southward across Tps. 8 and 9 N., R. 13 E., and froms a strip of territory of the prairie type contrasting with the rugged topography of the sandstone areas on either side of it.

SENORA FORMATION

Only the basal part of the Senora formation is exposed in this county. It is composed of massive sandstone which caps the big outlier in the central part of T. 10 N., R. 13 E. Its full section is developed in Okfuskee and Okmulgee counties to the west near Henryetta where it is important economically on account of the coal beds.

QUATERNARY AND RECENT

Along the rivers there are deposits of sand and silt of Quaternary age while in the vicinity of Texanna is quite an extensive deposit of dune sand.

SUBSURFACE GEOLOGY

In the western part of the county the subsurface formations are the same as are found in Okmulgee County adjoining it. The productive horizons in descending order are: the Salt sand, the Booch, the Morris, Glenn of Morris, and the Fields sands. The last three are in the Dutcher group of Pennsylvanian age. The Lyons-Quinn sand, near the base of the Pennsylvanian, is a productive horizon in the western part of the county. The Salt sand and the Booch sand are found throughout the county and correspond respectively to the Savanna and the Hartshorne with the intervening McAlester sale. This shale attains a thickness of 600 feet in the eastern part of the county whereas it is only 250 feet thick in the vicinity of Morris in Okmulgee County. The formations below the Booch are not uniform. The Atoka formation varies in thickness from 500 feet in the northwest part of the county to more than 2,000 feet in the southeastern part. In some places several sands are reported in the Dutcher series while in other places only one or even none are reported in this group. The Lyons-Quinn sand is reported in nearly all logs in the county where the wells have been drilled to a sufficient depth but its thickness and position in the lime

2. Dott, Robert H., personal communication.
are not uniform. The Mayes lime, or black lime above the Wilcox, is also reported in all logs that have been drilled deep enough for it. Its thickness, however, is variable and it is often broken. Occasionally a white lime is reported directly beneath the Mayes, which is probably the Boone. With few exceptions 40 to 60 feet of Chattanooga black shale are reported below the Mayes and then 10 to 25 feet of Hunton lime. Below the Hunton are 50 to 60 feet of Sylvan shale and under that the Viola lime, which varies in thickness from 35 to 60 feet and is often sandy according to the logs. The two wells in secs. 3 and 11, T. 11 N., R. 18 E., show 213 and 225 feet of white lime above the Wilcox sand. This is not due to careless logging, then the Viola lime is thickening up to the east and approaching the thickness shown at the outcrop at Marble City. Below the Viola is the Wilcox sand, which has been penetrated in several tests in different parts of the county.

**SURFACE STRUCTURE**

In the eastern part of McIntosh County the surface formations dip normally to the southwest but on the western side they have a normal northwest dip conformable with the normal dip of the surface rocks in Okmulgee County. The regular dip varies from 40 to 60 feet to the mile. A large structure known as the Warner anticline extends, according to Snider, from the northeast corner of sec. 35, T. 12 N., R. 18 E., southwestward to the center of the SE 1/4 sec. 5, T. 11 N., R. 18 E. On the western side of the county there are surface structures of considerable magnitude. A fault extends nearly north and south in R. 14 E. The downthrow is on the east side but the amount has not been measured accurately because of the nature of the beds involved. It has been found in places across Tps. 11 and 12 N., R. 14 E., and the northern part of T. 10 N., R. 14 E., and probably extends further south. It also shows in the subsurface formations (see Wilcox sand structure map, No. XIII). In this range on either side of the fault are large surface structures or closed domes. Other minor structural features are observable throughout the county.

**SUBSURFACE STRUCTURE**

Small domes and noses occur in the subsurface formations and are the immediate cause of accumulation of oil and gas. Frequently location of these subsurface structures is marked by a surface dome, nose, or terrace but often there is no discernable surface structure overlying one of these small subsurface domes.

The major subsurface features of this county are very interesting and are shown on Map No. XIII. The south part of the county lies in the Porum syncline, the axis of which is south of the Canadian River and outside of the county. The Atoka formation has thickened up greatly in this area. A well near Texana in sec. 17 T. 10 N., R. 18 E. top-ped the Atoka at 1,493 feet and was abandoned at 3,190 feet, still in it. A well is now drilling across the river south of Rufaula in sec. 32, T. 9 N., R. 16 E., which at 3,400 feet was still in the Atoka formation. In a twin hole to this an equivalent to the Lyons-Quinn sand was found at 4,500 feet. The Wilcox sand should be about 700 feet deeper or about 5,200 feet. A well in sec. 16, T. 10 N., R. 15 E., was drilled to 3,815 feet. The last 500 feet were black shale and slate. It is believed that the Wilcox sand would be at least 4,200 feet deep here.

As a subsurface structure the Warner anticline extends all the way across the county from east to west about through the middle of the county. The gas fields south of Checotah lie on this structural ridge. A dry hole to the Wilcox sand in sec. 27, T. 11 N., R. 15 E., and another in sec. 22, T. 11 N., R. 14 E., indicate that this ridge extends westward across the county.

North of the Warner anticline and about parallel to it is a syncline extending all the way across the county in T. 12 N. This is called the Hitchita syncline. The Porum syncline, the Warner anticline and the Hitchita syncline form a series of major folds parallel to the Choctaw fault and the folds north of it. They mark out the northern limit of the influence of the Ouachita thrust, as no such folds occur in Okmulgee and Muskogee counties to the north.

A series of nearly north-south faults cut across the Hitchita syncline and the Warner anticline. Their southward extent cannot be determined because of lack of drill holes to furnish information. One of these faults lies in R. 14 E., another in R. 15 E., and a third in R. 16 E. The fault in R. 14 E. has a downthrow on the east side of nearly 200 feet, while the one in R. 15 E. has a downthrow on the west side of nearly 500 feet. Thus the area between these two faults is a huge graben, the east side of which has dropped more than the west side and which is again faulted through the middle by the fault in R. 15 E. This latter fault is not as extensive as the other two nor does it have anywhere near as much throw. The axis of the Warner anticline is nearly level between these two faults while to the east of the fault in R. 16 E., this axis dips steeply to the west.

There have apparently been two periods of deformation in this area and, because of the difference in the nature of the cause of these disturbances, the results are decidedly different. First there was the folding due to the Ouachita thrust from the south. This caused the Porum syncline, the Warner anticline and the Hitchita syncline. Then the Ozark uplift to the northeast caused the north-south faults cutting across the already existing folds.

**DEVELOPMENT**

The greater part of McIntosh County has not yet been tested for oil or gas. Pools have been developed in six different townships and a few dry holes are widely scattered over the county.
A small gas pool was opened up in 1915 about half way between Checotah and Eufaula. The gas occurs in sands at depths of about 650 feet, 1,950 to 2,000 feet, and 2,400 feet. The wells had an initial capacity up to 35 million cubic feet. Another little gas pool was found in sections 17 and 18 of this township. The sand occurs at 775 to 800 feet and another sand about 1,800 feet deep. This pool was discovered in 1919. In 1925 some gas was found in section 2 in a sand about 800 feet deep. Only two gas wells were completed here as they were just small wells.

T. 12 N., R. 16 E.

Shows of oil and gas have been found in some wells in section 12, but other tests in this township have not been productive.

T. 11 N., R. 15 E.

In 1920 oil was found in section 27 in a sand 1,080 to 1,096 feet deep. Five oil and gas wells were productive of small amounts in this pool but deeper drilling afforded only dry holes. This is the only production in this township.

T. 12 N., R. 15 E.

Gas has been encountered in several different sands in many widely separated parts of this township. The Beggs Oil and Gas Company has a pool around the section corner of 2, 3, 10, and 11. The Booch sand at 1,250 feet and sand at 1,765 feet are productive of gas. A good oil show was found at about 1,850 feet but the well was drilled to the Wilcox sand without results. Gas was also found and produced at 725 feet in the SE. cor. SW. 1/4 section 16 and at about 700 feet near the SW. cor. section 26. In the SW. cor. NW. 1/4 section 29 shows of gas were found in every sand and 15 million feet were encountered at 2,340 feet. A test to the Misener sand offsetting this was dry. Shows of oil and gas have been found in several other tests in the township but none were productive.

T. 12 N., R. 14 E.

Only the east half of this township lies in McIntosh County and there is not very much production in it although the west half has been productive of several good pools. There is a little oil pool in the NW. 1/4 section 2 and the NE. 1/4 section 3. Two sands are productive, the Morris, at around 1,700 feet, and the Fields sand at about 1,800 feet. The wells were small. In the SW. cor. section 3, oil is produced from the Fields sand, and gas from the Salt sand, at a depth of about 800 feet. In the west half of section 10, several wells are producing gas from the Salt sand. A well near the center of section 10 was dry in all sands to the Wilcox. In the SW. 1/4 section 15, the Salt sand produces gas. Near the SW. cor. section 22, there is a small oil well in the Lyons-Quinn sand at 2,115 feet. The pool lies across the line in Okmulgee County. Other wells drilled in the east half of this township were not productive.

T. 11 N., R. 14 E.

In 1913, gas was discovered in section 6 and since that time drilling has continued in the northwest quarter of this township. A few oil wells have been developed on the north side of sections 5 and 6, in an 1,800 foot sand but gas is the chief product of this township. The principal gas sands are the Salt sand at 700 feet, and the Booch sand at about 1,400 feet deep. A few wells scattered throughout the township failed to find any production below 1,900 feet.

RECOMMENDATIONS

There are several major structural features in this county which are favorable for oil and gas accumulation. With the exception of a few wells in the northwest corner of the county, and in section 27, T. 11 N., R. 15 E., all the production to date has been gas, but shows of oil have been found in several places and there is reason to believe that more oil and gas pools can be developed in this county by careful study and prospecting in the areas of the major domes and anticlines.

Log of well drilled in NW. cor. SE. 1/4 sec. 22, T. 11 N., R. 14 E.

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<td>Top of Salt sand</td>
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<tr>
<td>white lime</td>
<td>1960</td>
<td>1985</td>
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(Continued on page 156)
OIL AND GAS IN OKLAHOMA

**Log of well in cen. of NE.¼ NE.¼ sec. 18, T. 11 N., R. 17 E.**

Graham Brothers Oil Company

<table>
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**Log of well drilled in SW. cor NW.¼ SW.¼ sec. 35, T. 12 N., R. 15 E.**

Gillinace Oil Company

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<tr>
<td>sandy shaly</td>
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<td>249</td>
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<tr>
<td>sand (Salt sand)</td>
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<tr>
<td>broken sand</td>
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<td>736</td>
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<td>shaly sand</td>
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<td>995</td>
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<tr>
<td>sandy shaly</td>
<td>995</td>
<td>1161</td>
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</tbody>
</table>

(Continued on page 157)
PAYNE COUNTY

By

A. H. Koschmann

ACKNOWLEDGMENTS

In the preparation of this chapter the writer has availed himself of information in Bulletin 19, Part II, of the Geological Survey. L. L. Foley, of the Mid-Kansas Oil Co., kindly correlated the formations in the well logs shown in Plate I and A. F. Truex, of the Twin State Oil Co., furnished the surface and core drill structure maps of the Ripley field, and well logs of this field with the important formations correlated. W. J. Allen, of the Shaffer Oil and Refining Co., furnished the structure map of the Mehan field. C. G. Carlson, of the Peerless Oil and Gas Co., kindly read the manuscript and offered many valuable suggestions, which the writer gratefully acknowledges.

Figure 36.—Map of Oklahoma showing location of Payne County.

LOCATION

Payne County is located in the north-central part of the State, extending from R. 6 E., to R. 1 W., and from T. 17 N., to T. 20 N. It is bounded on the north by Pawnee and Noble counties, on the east by Creek County, on the south by Lincoln and Logan counties, and on the west by Logan and Noble counties. It includes an area of approximately 716 square miles. Stillwater, with a population of 6,000, is the county seat.

TOPOGRAPHY

Payne County has a general surface slope to the southeast, with a range in elevation from 1,140 feet in the western part, to 800 feet in the valley of the Cimarron River in the eastern part. This river is the chief drainage channel of the county, and Stillwater Creek its chief tributary. The county is well drained by the tributaries of these two streams.

The well developed drainage has carved the topography into a rolling plain; however, the western part is in general of greater relief than the eastern, as the streams are here more deeply incised. Payne County lies with the Sandstone Hills region, excepting the extreme western part, which is in the Red Beds Plains. In the eastern part of the county several limestone ledges form small escarpments. Twin Mounds, limestone capped hills, 10 miles east of Ingalls, form the most striking topographic feature of the county.

GEOLGY

Stratigraphy

Surface Formations

The surface rocks of Payne County are basal Permian (Stillwater and Wellington) and upper Pennsylvanian (Neva to Buck Creek). These formations represent the transition between the marine, non-red Pennsylvanian and the non-marine, red Permian. The color change does not follow the strike of the beds but transgresses the strike at an angle, which results in both red and non-red Pennsylvanian and Permian beds. The contact is here assumed to be the base of the Cottonwood limestone, following Prosser.¹ The Cottonwood limestone thins out at the north line of the county, but its equivalent horizon is found just west of the Neva limestone outcrop running almost north-south through R. 4 E. As a result Permian rocks cover about two-thirds of the area of the county, while the eastern one-third is occupied by Pennsylvanian beds.

WELLINGTON FORMATION

The Wellington formation, according to Aurin, Officer, and Gould,² is composed of gray to blue drab shales with numerous thin beds of gray "mudstone" to red sandstones and shales as the color-change line between the red and non-red sediments is crossed. This color change area is a zone or belt several miles wide running in a northwest-southeast direction across Payne County from Glencoe to Cushing.

The formation, which outcrops in the western part of the county, is approximately 600 feet thick. The Besdor, Tonkawa and Blackwell sand horizons of the fields to the north of Payne County are found in


the lower half of the Wellington. The formation in Oklahoma is equivalent to the Wellington shale and the Marion formation of the Kansas section.

STILLWATER FORMATION

The next oldest formation, the Stillwater, is the basal Permian formation in the classification used in north-central Oklahoma. Like the Wellington, this formation is found in the area of change of color of the sediments. North of the county the formation contains many prominent limestone members, which, with a few exceptions, thin out and disappear southward. The highest of the persistent members which are found in this area, the Fort Riley limestone, is found approximately in the center of the formation. It can be traced across the county to the Cimarron River just east of Perkins. The limestone has not been mapped south of this point. The Cottonwood limestone, which marks the base of the Stillwater, has been traced across western Pawnee County, south to the Payne County line. Here the horizon of the Cottonwood is made up of drab and red shales and shaly limestones, so that the limestone as described farther north is not found in this area.

ESKRIDGE SHALE

Following the classification of the U. S. Geological Survey and the Kansas Geological Survey, the Eskridge is the highest Pennsylvanian formation, lying just below the Cottonwood limestone. In this area the Eskridge, like other associated formations, changes in color and character from gray, green and brown shales to red sandstones and shales as the beds are traced southward.

NEVA LIMESTONE

Immediately below the Eskridge shale is a series of thin limestones and limy shales, aggregating 10 to 15 feet in thickness in this area. In Payne County the Neva limestone is red to gray in color, with many chert concretions in the lower portion. The formation has been traced south to the county line, and a few miles into northern Lincoln County, but farther south it loses its identity, changing from limestone and shale into sandstone and shale south of the Cimarron River.

ELMDALE FORMATION

The Elmdale is composed of interbedded shales and thin limestones, the latter being usually less than three feet in thickness. The formation has been mapped only in the northeastern part of the county as it loses its identity to the south where it merges into undifferentiated red beds. The most prominent limestone, the Cushing member, occurs just below the middle of the formation and has been traced as far south as the North Canadian River in northern Pottawatomie County. The formation has an aggregate thickness of approximately 100 feet.
SAND CREEK FORMATION

The Sand Creek formation is made up of about 180 feet of limestone and shale, with some sandy shale near the center. The largest limestone bed, the Foraker member, approximates 100 feet in thickness and is found at the top of the formation. The base of the Sand Creek is marked by the thin Grayhorse limestone, four feet thick.

BUCK CREEK FORMATION

The oldest surface formation in Payne County, the Buck Creek, is a series of shales and limestones with two sandy zones near the top. Its aggregate thickness is about 175 feet, the limestones making up half of this amount. The top is marked by the base of the Grayhorse limestone and the base by the base of the Bird Creek limestone. The thickest member of the Buck Creek, the Stonebreaker limestone, is found just above the center of the formation and is about 20 feet thick.

Subsurface Formations

Pennsylvanian

The remainder of the Pennsylvanian section, as revealed by well cuttings, is composed predominantly of shales with interbedded limestones and some sandstones. The base of the Pennsylvanian, as shown in wells drilled near the Pennsylvanian-Permian contact is about 3,600 feet deep. This places the Bartlesville sand at about 3,400 feet and the Layton sand at about 2,400 feet in depth. (See cross-section, Map No. XVII).

MISSISSIPPIAN

The Mississippi lime lies immediately below the Cherokee shales and is, on the average, 85 feet in thickness.

Below the Mississippi lime and resting unconformably upon all older Paleozoic rocks, is the Chattanooga shale. The pre-Chattanooga period of uplift and erosion has resulted in the tilting and beveling of these older rocks so that the Chattanooga rests on successive older formations from Hunton to Sylvan. The Chattanooga is a black fissile shale averaging less than 40 feet in thickness in the county.

The Misener sand, where present, lies directly beneath the Chattanooga shale and forms one of the minor producing horizons of the county. Its occurrence is "patchy," and drilling has not entirely defined its occurrences. Its thickness varies from 0 to 25 feet. The sand is very pure, the grains well sorted and rounded, very much resembling the Wilcox, from which it is believed to have been derived by wind action during the pre-Chattanooga period of erosion.


PAYNE COUNTY

Silurian-Devonian

The Hunton formation in this area consists of limestones and calcareous shales which are difficult to differentiate in well cuttings and so are logged as Hunton lime. It is present in the southwestern part of the county, but its exact limits have not been determined. The Twin State Oil Co.'s well in sec. 23, T. 18 N., R. 11 E., penetrated the Hunton at 4,798 feet. The formation has been encountered in several wells south of this area in Lincoln County.

Ordovician

The Sylvan shale is found over the greater part of the county, being absent only in the eastern and northeastern parts. This shale may be distinguished from the Chattanooga by its light color, usually greenish or bluish-gray. Because of its uniform character it forms a good key bed. Its maximum thickness is 75 feet in the western part of the county which decreases to zero in the eastern part.

The Viola immediately underlies the Sylvan and is 35 to 75 feet thick in this area. In places where the Sylvan and Hunton have been eroded the Viola is found in contact with the Chattanooga.

The Simpson formation has an average thickness of 250 feet in the eastern part of the county. Post-Wilcox beds have been reported in the Cushing district where they are made up of brown or gray sandy dolomitic limestone interstratified with sandstone and green shale. The Wilcox here is typical of the Wilcox of other areas.

Only a few wells in the eastern part of the county have been drilled sufficiently deep to encounter the Arbuckle limestone (Siliceous lime). No wells have penetrated it entirely so its total thickness is not known. The upper part consists of beds of massive dolomitic limestone and occasional thin beds of sandstone.

STRUCTURE

The formations of this county have a monoclinal west-southwest dip of about 40 to 50 feet per mile (see Map No. XVII) with occasional reverse dips, which form favorable structures for oil accumulation. The "nose" or plunging anticline type of structure is the more common in this territory. These are merely surface reflections of closed structures in depth and belong to the class of parallel folds formed at greater depths at the degree of folding therefore necessarily decreases upward in the vertical column. Fig. 37, showing the Ripley structure, shows the typical surface "nose", whereas Fig. 38, of the same field, shows this same structure on the subsurface Neva limestone obtained by core-drilling, showing a 20 foot closure. There is some shifting of the top of the structures at depth. This shifting is to the northwest and due to the unequal dips on the northwest and southeast sides of the field. The Me' an field, Fig. 39, shows another subsurface structure, contoured on the Viola limestone.
The Cushing, Yale, and Ingals anticlines were the first structures to be developed in the county. They were outlined by the usual field methods, and are located east of the Neva limestone outcrop where there are reliable markers for surface mapping. The fact that all the structures have a general east-northeast trend is noteworthy.

Figure 37.

**PRODUCING SANDS**

The Bartlesville and Wilcox sands are the two important producing horizons, and of these the latter is the most important. There is considerable Misener production in the county, although the pools are small because of the lenticular nature of the sand. The Misener sand is producing in the Olean and Ingals fields, in T. 18 N., R. 5 E., and in the Tidal-Gardner well in the SE. 1/4 SE. 1/4 SW. 1/4 sec. 12, T. 19 N., R. 1 W.

**PAYNE COUNTY**

Figure 38.

**FUTURE DEVELOPMENT**

In the eastern part of the county, east of the Neva limestone, the folds and structures have been largely worked out and development progressed rapidly after the discovery of the Cushing field. In the western part the sediments change rapidly in lithology, both laterally and vertically, so that the surface structures are worked out with a great deal of difficulty, uncertainty and expense. Core-drilling has been re-
sorted to in most cases to check up on suspected structures determined by usual field methods. The Mehan and Ripley fields, the two latest to be developed in this county, were definitely determined by core-drilling and illustrate the importance and even necessity of core-drilling to corroborate surface work.

![Diagram of Mehan Field, Payne County]

Figure 39.

Coupled with the uncertainty of determining structures by usual field methods and the expense of core-drilling is the problem of deep production in the western part of the county. The "Wilcox" is found at about 3,800 feet in the eastern part of the county, but at 4,700 to 5,000 feet in the western part, as shown in Map No. XVII.

The entire county may be considered prospective territory. The eastern part is proved territory and it is quite probable that some new fields will be discovered in the western part. The Mid-Continent well in NW $\frac{3}{4}$ SE $\frac{3}{4}$ sec. 3, T. 19 N., R. 3 E., the Amerada well in SE $\frac{3}{4}$ SE $\frac{3}{4}$ sec. 24, T. 19 N., R. 1 E., and the Tidal-Gardner well in SE $\frac{3}{4}$ SE $\frac{3}{4}$ SW $\frac{3}{4}$ sec. 12, T. 19 N., R. 1 W., have recently been drilled. The Tidal-Gardner well had an initial production of 140 barrels from the Misener sand and is still producing 50 barrels daily. It was drilled into the Wilcox but found water, so it was plugged back to the Misener.

In spite of these dry wells leasing in the county has been active, especially during the last year. Little land remains unleased at this writing, (December, 1927), which is certainly a good indication of the faith held by the oil fraternity in the future oil development of Payne County.
PAWNEE COUNTY

By
Frank C. Greene

INTRODUCTION

LOCATION AND AREA

Pawnee County is situated in the north-central part of the State, forming a triangular wedge between Osage County and the south edge of the "Cherokee Strip." The Arkansas River forms the northern boundary of the county and separates it from Osage County. Included within its borders are all or parts of T. 20 N., Rs. 5-10 E., T. 21 N., Rs. 4-9 E., T. 22 N., Rs. 3-7 E., T. 23 N., Rs. 3-6 E., T. 24 N., Rs. 4-5 E., with an area of 584 square miles.

Figure 40.—Map of Oklahoma showing location of Pawnee County.

DRAINAGE AND TOPOGRAPHY

As mentioned above, the Arkansas River forms the northern boundary and the Cimarron River is not far from the southern boundary, finally entering the county in T. 20 N., R. 9 E., where the junction of the two streams is near the southeast tip of the county. Black Bear Creek crosses the county and empties into the Arkansas River above Blackburn.

The lowest point is at the junction of these two streams, about 650 feet above sea level. The highest point is something over 1,050 feet.

The county is traversed by a series of escarpments capped by sandstones and limestones. In the eastern third of the area sandstones prevail and the country is timbered. In the middle third, ledges and sandstones alternate and there are some prairie belts interspersed with the timber. In the western third, on the red beds, prairie predominates.

(Originally published as Bulletin 40-CC, February, 1928).
Pawnee County

CHATTANOOGA SHALE

Practically the entire area of the county is underlain by the Chattanooga shale with an average thickness of about 50 feet. It is a black homogeneous shale, containing no gritty material, but with much pyrite. It is full of small brown crinkled discs of Sporangites, which can always be found upon careful microscopic examination.

It is the writer's opinion that the original substance of these spores, once spheres, but now flattened into discs, of which there are millions in each cubic foot of shale, is the source of most of the oil found in the Wilcox sand and associated strata.

The Misener sand, locally found at the base of the Chattanooga shale, is an important oil-bearer in Payne County, which joins Pawnee County on the south. In some cases, it is impossible to state definitely whether a given sand is Wilcox or Misener.

“MISSISSIPPI LIME”

The normal thickness of the “Mississippi lime” is about 300 feet but, like the lower formations, it is greatly reduced or absent on top of some of the structural highs. It is variously logged as white, black, gray, and brown lime, with sands or sandy phases.

The upper part, where porous, constitutes the “first break in the lime” of old-time operators. It yields showings of both oil and gas in many cases, and in a few instances, commercial production.

Pennsylvaniaian and Permian

GENERAL DISCUSSION

The formations exposed at the surface include about 2,500 feet of gray and red shales, brown, buff, gray and red sandstones and limestones, mostly of Pennsylvaniaian age, but including some Permian in Ranges 3, 4, and 5 East, according to the adopted classification. There is no break in sedimentation at the contact. In the southwestern part of the county the base of the Pennsylvaniaian is about 4,000 feet deep and in the eastern end about 2,600 feet. The discrepancy is caused by the thickening of the lower Pennsylvaniaian beds to the east. (See Maps No. XVIII and XIX).

CHEROKEE SHALE

Near the base of the Pennsylvaniaian is a widespread “red bed”, present over most of the county, but somewhat irregular in Ranges 8 to 10 East. In places it rests on the “Mississippi lime” and in others, is 100 feet or more above it. In a few places the intervening shale con-
tains a sand, variously termed Tucker, Burgess, Dutcher, or Bartlesville. It is generally believed, however, that the Bartlesville sand is absent in areas where the red bed is present. This sand, by whatever name the operator chooses to call it, has yielded some production. The noteworthy well of the Duquesne Petroleum Company in sec. 8, T. 21 N., R. 6 E., was in this sand. It came in at 600 barrels, but dropped rapidly and did not produce very long.

The Bartlesville sand, as known in the eastern part of Osage County, is present in the eastern part of Pawnee County, 100 feet thick to the east and feathering out to the west. It is an important producer of oil and gas.

The next higher sand is the Red Fork. It is lenticular, but appears in patches in many parts of the area. It is termed "Bartlesville" sand in the western part of the county and probably is the Burbank sand of western Osage County. Another possibility is that the two sands are united in places in eastern Pawnee County and southeastern Osage County, and together are termed Bartlesville sand.

The "Pink lime" appears to be persistent throughout the county and constitutes a reliable marker for correlation and contouring. It is above the Bartlesville sand of the western part of the county and above the Red Fork in the eastern part.

Next above the "Pink lime" is the Skinner sand, an important producer in the eastern part of the county. It is succeeded by the lower or "Little" Oswego lime and that in turn by the Prue sand. The Prue is somewhat lenticular, but is an important sand. In the true application of the term Cherokee, the lower Oswego lime (base of the Fort Scott limestone) marks the top of the Cherokee.

The Cherokee is about 650 feet thick in the eastern end of the county and thins to 350 feet in the northwestern part.  

OSWEGO-BIG LIME

This series of limes is about 150 feet thick, but is rather variable. It consists of limestones and interbedded black shales. The top is rather irregular, and while the series as a whole constitutes a good marker, the individual beds are rather difficult to correlate in many places. For this reason it is not a reliable bed for contouring, although locally it can be used.

As to the proper correlation of the various members of the series of limestones, the writer believes it includes both the upper Oswego and the Big Lime as used by drillers in the Osage, but this question has not been entirely settled.

The upper bed is locally porous and is believed to be the producing formation in the Bement well in sec. 30, T. 23 N., R. 5 E.

INTERVAL FROM BIG LIME TO AVANT LIME

This interval varying from 1,200 feet in the eastern part of the county to 750 feet in the northwestern, contains three important oil sands and several persistent limestones. In the eastern area shale makes up the greater part, while in the western area, the shales not only thin but sandstones and limestones increase. The top is marked by a thick zone of sandstones and red beds with the Avant limestone at the contact.

The lowest sand is the Cleveland, and in places it is divided by a shale parting. In the Keyston pool the upper bed is known as the Dillard sand. It is probable that in many places only one or the other of the two layers is present and that the name Cleveland is applied to it indiscriminately. This sand was named from the early production found in it on the townsite of Cleveland.

Above the Cleveland sand is the Checkerboard lime, a thin but very persistent bed. It is about 300 feet above the Big Lime in the eastern part of the county but only 125 feet in the northwestern part.

The Layton sand (of Bristol and Cushing) is the next higher sand. It is a zone of one or two thick or thin sands. About 30-50 feet above it is the Lost City (Hogshooter) limestone, which is thin and irregular in most of Pawnee County. The Layton sand as here used is believed to be present as a thin sand below the Layton sand of the Watchorn pool (Tps. 22 and 23 N., R. 3 E.) as defined by Carpenter.

The next higher sand is the Peoples sand of the Cleveland district. It is persistent and thick. At the base there is a fairly persistent limestone and locally a thin layer of red shale. There is a thin lime just above it and about 50 feet above it, is the Dewey limestone. This limestone is found in practically every well from R. 4 E., to the east line of the county and constitutes an excellent marker. West of R. 4 E. in the Watchorn pool, it appears to be replaced by sandstone.

According to a long series of correlated logs, it appears that the Peoples sand is the Layton sand of the Watchorn pool and the pools to the northwest in Noble, Kay, Grant, and Garfield counties.

BRISTOW FORMATION

The Bristow formation is 800 feet thick in the eastern part of the county and 1,050 feet in the northwestern part. It consists of three zones of interstratified sandstone, limestone, and red shale, and three zones of blue shale and thin limestone, two of them separating the sandy zones and the third at the top of the formation.

It does not contain any important oil sand in Pawnee County, but correlations indicate that the middle and lower Hoover sands and the Tonkawa sand of Noble and Kay counties belong in the Bristow.

ELGIN SANDSTONE

The Elgin sandstone consists of one or more beds of sandstone with interbedded shales, the whole having a thickness of 50 to 100 feet. It is the upper Hoover sand of the Tonkawa field.

HIGHER FORMATIONS

The following is a section of the outcropping rocks from the Elgin sandstone to the highest beds in the county. Nearly all the limestones furnish excellent beds for surface mapping.

Sections from Pawnee east to Cleveland.

<table>
<thead>
<tr>
<th>Bed No.</th>
<th>Description</th>
<th>Thickness of Bed (feet)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Limestone, fine-grained, siliceous, gray, weathered light brown, has many cavities, lined with calcite; 1-2 feet thick. (Neva)</td>
<td>1 1/2</td>
<td>1 1/2</td>
</tr>
<tr>
<td>2</td>
<td>Sandstone, gray, weathering brown, fossiliferous, calcareous in places, 2-5 feet</td>
<td>3 1/2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Shale, red and gray.</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Sandstone and red and gray shale. At top is “Standpipe sandstone” which is fairly persistent, 10 feet below, section is variable.</td>
<td>40</td>
<td>48</td>
</tr>
<tr>
<td>5</td>
<td>Limestone, gray, nodular, conglomerate, or gray, calcareous, thin-bedded sandstone, 3-8 feet.</td>
<td>5</td>
<td>53</td>
</tr>
<tr>
<td>6</td>
<td>Shale, red and gray, with locally a sandstone up to 5 feet thick near base, 22-30 feet.</td>
<td>27</td>
<td>80</td>
</tr>
<tr>
<td>7</td>
<td>Limestone gray, composed chiefly of small fragments of crinoids and other fossils where exposed near National Hotel at Pawnee; to south becomes impure, sandy and nodular, 2-4 feet. (Red Eagle)</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>Shale, red and gray, and sandstone.</td>
<td>34</td>
<td>117</td>
</tr>
<tr>
<td>9</td>
<td>Limestone, buff, composed of Fusulina, rarely outerops (Top of Foraker).</td>
<td>1 1/2</td>
<td>117 1/2</td>
</tr>
<tr>
<td>10</td>
<td>Shale, gray.</td>
<td>2 1/2</td>
<td>130</td>
</tr>
<tr>
<td>11</td>
<td>Limestone dark-gray, hard, very fossiliferous, especially brachiopods.</td>
<td>2</td>
<td>122</td>
</tr>
<tr>
<td>12</td>
<td>Shale, red and gray, with local sandstone.</td>
<td>3 1/2</td>
<td>161 1/2</td>
</tr>
<tr>
<td>13</td>
<td>Limestone, buff (1-2 feet), underlain by gray, shaly limestone, or calcareous shale 1-2 feet.</td>
<td>3 1/2</td>
<td>165</td>
</tr>
<tr>
<td>14</td>
<td>Limestone, gray, in two layers, upper 8-10 inches, lower 10-12 inches.</td>
<td>1 1/4</td>
<td>166 1/2</td>
</tr>
<tr>
<td>15</td>
<td>Shale, soft, blue, possibly thicker in place.</td>
<td>1 1/4</td>
<td>177</td>
</tr>
<tr>
<td>16</td>
<td>Limestone, gray, in 3 layers, with shale between, locally weathered brown. (base of Foraker).</td>
<td>3</td>
<td>180</td>
</tr>
<tr>
<td>17</td>
<td>Shale, red or gray.</td>
<td>20</td>
<td>200</td>
</tr>
<tr>
<td>18</td>
<td>Sandstone, brown massive, max. 25 feet, locally absent, and shale with 2 or 3 thin limestones in this interval.</td>
<td>25</td>
<td>255</td>
</tr>
<tr>
<td>19</td>
<td>Shale.</td>
<td>5</td>
<td>230</td>
</tr>
<tr>
<td>20</td>
<td>Limestone, gray, upper 1 1/4 feet thick, very fossiliferous on upper surface, shaly limestone below.</td>
<td>2</td>
<td>232</td>
</tr>
</tbody>
</table>

Sections from Pawnee east to Cleveland, (Cont’d.)

<table>
<thead>
<tr>
<th>Bed No.</th>
<th>Description</th>
<th>Thickness of Bed (feet)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Shale, with a thin, slabby, sandy limestone 10 feet below top, and locally a thick sandstone below, shale mostly red.</td>
<td>73</td>
<td>305</td>
</tr>
<tr>
<td>22</td>
<td>Limestone, gray, lineated, 3-5 feet thick; well exposed.</td>
<td>1</td>
<td>306</td>
</tr>
<tr>
<td>23</td>
<td>Shale, red and white, with locally a sandstone occupying lower 25-50 feet of interval.</td>
<td>69</td>
<td>375</td>
</tr>
<tr>
<td>24</td>
<td>Limestone, gray, upper 6-12 inches locally nodular, thin-bedded below, many layers composed of Fusulina—forms a prominent escarpment [Burelanite (?), Kansas]</td>
<td>7</td>
<td>382</td>
</tr>
<tr>
<td>25</td>
<td>Shale, with 1 or 2 layers of buff, shaly, very fossiliferous limestone—Mayalina very abundant. (Possibly Grayhorse).</td>
<td>10</td>
<td>392</td>
</tr>
<tr>
<td>26</td>
<td>Shale, with locally a sandstone up to 35 feet thick, the top of which is 20-25 feet below top of No. 24.</td>
<td>38</td>
<td>430</td>
</tr>
<tr>
<td>27</td>
<td>Limestone, gray.</td>
<td>1</td>
<td>431</td>
</tr>
<tr>
<td>28</td>
<td>Shale, with local sandstone and conglomerate.</td>
<td>19</td>
<td>450</td>
</tr>
<tr>
<td>29</td>
<td>Limestone, nodular, gray mottled with red and green.</td>
<td>2</td>
<td>452</td>
</tr>
<tr>
<td>30</td>
<td>Shale, red and gray, with local sandstone, 25-30 feet.</td>
<td>28</td>
<td>480</td>
</tr>
<tr>
<td>31</td>
<td>Limestone, gray.</td>
<td>1</td>
<td>481</td>
</tr>
<tr>
<td>32</td>
<td>Shale, with calcarious nodules, redish.</td>
<td>4</td>
<td>485</td>
</tr>
<tr>
<td>33</td>
<td>Shale, gray and red, with several thin layers of hard, resistant sandstone in upper half or third.</td>
<td>20</td>
<td>505</td>
</tr>
<tr>
<td>34</td>
<td>Limestone, gray with large Fusulina, jointed shaly limestone at base. (Top of Stonebraker)</td>
<td>2</td>
<td>507</td>
</tr>
<tr>
<td>35</td>
<td>Shale, gray and red, with local sandstone 30 feet thick.</td>
<td>31</td>
<td>538</td>
</tr>
<tr>
<td>36</td>
<td>Limestone, gray in 2 or 3 beds, small Fusulina.</td>
<td>2 1/2</td>
<td>540 1/2</td>
</tr>
<tr>
<td>37</td>
<td>Shale, with limestone nodules.</td>
<td>2</td>
<td>542 1/2</td>
</tr>
<tr>
<td>38</td>
<td>Limestone, gray, with Fusulina.</td>
<td>1 1/2</td>
<td>543</td>
</tr>
<tr>
<td>39</td>
<td>Shale.</td>
<td>12</td>
<td>555</td>
</tr>
<tr>
<td>40</td>
<td>Limestone, gray, mottled with red, or with a conglomeratic appearance. (Base of Stonebraker)</td>
<td>2</td>
<td>557</td>
</tr>
<tr>
<td>41</td>
<td>Shale, red and shaly sandstone.</td>
<td>28</td>
<td>585</td>
</tr>
<tr>
<td>42</td>
<td>Sandstone, probably locally a red shale.</td>
<td>30</td>
<td>615</td>
</tr>
<tr>
<td>43</td>
<td>Limestone, gray to dark-gray, with several shale partings, extremely fossiliferous (Cryptococcon-bearing limestone).</td>
<td>10</td>
<td>625</td>
</tr>
<tr>
<td>44</td>
<td>Shale, sandy shale, and shaly.</td>
<td>20</td>
<td>645</td>
</tr>
<tr>
<td>45</td>
<td>Sandstone, gray or brown.</td>
<td>10</td>
<td>653</td>
</tr>
<tr>
<td>46</td>
<td>Shale, red.</td>
<td>27</td>
<td>682</td>
</tr>
</tbody>
</table>
Sections from Pawnee east to Cleveland, (Cont'd.)

<table>
<thead>
<tr>
<th>Bed No.</th>
<th>Description</th>
<th>Thickness of Bed (Feet)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>Limestone, gray</td>
<td>1</td>
<td>683</td>
</tr>
<tr>
<td>48</td>
<td>Shale</td>
<td>2</td>
<td>685</td>
</tr>
<tr>
<td>49</td>
<td>Sandstone, bedded, even layers</td>
<td>8</td>
<td>693</td>
</tr>
<tr>
<td>50</td>
<td>Shale, red, purple, gray, and green with 2 or 3 thin, hard layers of sandstone that resemble limestone</td>
<td>17</td>
<td>710</td>
</tr>
<tr>
<td>51</td>
<td>Limestone, gray, in two layers. (Bird Creek)</td>
<td>1/8</td>
<td>711 1/2</td>
</tr>
<tr>
<td>52</td>
<td>Sandstone and shale</td>
<td>33 1/2</td>
<td>745</td>
</tr>
<tr>
<td>53</td>
<td>Limestone, upper 1-3 feet gray, even layered, badly cut by joints; lower part dull and composed of Fusulina. (Turkey Run)</td>
<td>2</td>
<td>747</td>
</tr>
<tr>
<td>54</td>
<td>Sandstone and shale, with locally thin layers of nodular limestone, varible</td>
<td>12</td>
<td>892</td>
</tr>
<tr>
<td>55</td>
<td>Limestone, mostly thin-bedded and gray (Lecompton)</td>
<td>100</td>
<td>932</td>
</tr>
<tr>
<td>57</td>
<td>Sandstone, thick base not seen. (Elgin)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>932</strong></td>
</tr>
</tbody>
</table>

**STRUCTURE**

**General**

Structure has played an important part in the accumulation of oil and gas in Pawnee County. This is not shown in the surface structure in all cases, but a careful survey of subsurface conditions will reveal that practically all the pools of the county are on closed structural highs. This condition is in strong contrast to that prevailing in the shallow pools in eastern Osage County and in Washington County, in the Burkhart field, Glenn Pool, and others. This will be discussed further under "Future Development."

**Surface Structure**

The structure shown by the formations exposed at the surface is fairly simple in the western two-thirds of the county and somewhat more complex in the eastern third, all, however, being merely a modification of the westerly dip prevalent in north-central Oklahoma.

The eastern third of Pawnee County is crossed by the belt of folding and faulting that passes through central Osage County and the Cushing field, in Ranges 7, 8, and 9 East, trending slightly east of north and west of south. It is marked at the surface by en echelon faults with a maximum throw of 100 feet and reverse dips of about the same magnitude.

The western two-thirds of the county exhibits a more regular westerly dip, broken in many places by structural noses, terraces, a few en echelon faults, and some isolated closed highs.

**Subsurface Structure**

In general, the structural features shown by the surface beds become more pronounced with depth. (See under Morrison field). After a study of hundreds of graphic logs, it became apparent that the best horizon for contouring the structure of the lower beds is the base of the Chattanooga black shale. (See Map No. XX). As explained in the discussion of stratigraphy, the Chattanooga rests unconformably on beds of Ordovician age.

The structure shown in Map. No. XX is accurate only to the extent to which logs and well elevations are available. Where wells have been drilled fairly close together and the well elevations are reliable, the map presents an accurate picture of the folding. In other areas it is merely a much generalized picture, subject to revision.

Some of the features shown by this map are discernible at the surface, although reduced in degree of folding, others are probably not represented at the surface. On the other hand, there are doubtless many minor surface features not represented on this map.

The belt of surface folding and faulting mentioned as crossing the eastern third of the county exhibits some very steep dips on the base of the Chattanooga shale. This belt considered in its entirety is comparable with the Nemaha or granite ridge of Kansas and Oklahoma in many ways, although in the literature it has not been given the prominence it deserves.

The western edge of this belt is marked both on the surface and subsurface by steep dips beyond which to the west the dips are gentle. As in the surface structure, the subsurface shows a few noses and closures, but mostly a westerly dip.

**DEVELOPMENT**

**Oil and Gas Pools**

**ADAMSON POOL**

**LOCATION:** Secs. 31 and 32, T. 21 N., R. 8 E., and sec. 5, T. 20 N., R. 8 E.

**DISCOVERY WELL:** Not known.

**DATE OF OPENING:** Not known.

**PRODUCING SANDS:** Top Mississippi Lime—2,600-2,650; Turkey Mt. sand—2,880-2,980.

**REMARKS:** Shows in Wilcox and Hominy sands.

**CLEVELAND POOL**

**LOCATION:** Secs. 8, 9, 16, 17, 18, 19, 20, 21, 29 and 30, T. 21 N., R. 8 E.

**DISCOVERY WELL:** Drilled by local capital, Bill Lowery farm, south edge of town.

**DATE OF OPENING:** September, 1904.

**PRODUCING SANDS:** Cleveland sand—1,500-1,700 feet deep, about 20 feet thick; Skinner sand, big gas and some oil—2,100-2,200; Bartlesville sand—2,400-2,450.

The writer realizes that the information given here is very incomplete and probably in some cases inaccurate. In all compilations of this kind, accurate information concerning oil fields is hard to get and all persons having such information are requested to send it to the State Geological Survey at Norman where it can be placed on file and preserved for the future.
OIL AND GAS IN OKLAHOMA

 Remarks: Well in SW 1/4 SE 1/4 SW 1/4 sec. 20, T. 21 N., R. 8 E., made 1 M. gas in sand topped at 560-580. This sand is in lower red beds. The initial production in the Cleveland sand ranged from 25 to 300 barrels. Gravity, 36-37.9°.

 KEYSTONE POOL

 Location: Secs. 24 and 25, T. 20 N., R. 9 E.

 Date of Opening: March 19, 1919.
 Producing Sands: Upper Cleveland sand—1,100-1,200; Skinner big gas—1,690-1,780; Bartlesville—1,950-2,000; Wilcox—2,430-2,500.

 Remarks: Gravity, 36-37.9°.

 HALETT POOL

 Location: Secs. 3, 4, 8 and 9, T. 20 N., R. 7 E.

 Date of Opening: April 6, 1922.
 Producing Sands: The wells in sections 3 and 4 are Cleveland sand—2,100-2,150; the wells in sections 8 and 9 are Prue and Skinner sands; Prue—2,400-2,570; Skinner—2,580-2,700.

 Remarks: Some of the sections listed under the Jennings well are closer to Hallett than to Jennings and may be considered by some operators to be part of the Hallett pool. There is no sharp line between the two areas.

 JENNINGS POOL

 Location: Secs. 15, 16, 21, 22, 23, 26, 33 and 34, T. 20 N., R. 7 E., and south in T. 19 N., R. 7 E.

 Date of Opening: 1916.
 Producing Sands: Skinner sand has some good gas—2,500-2,600; Bartlesville sand has some good oil—2,690-2,750.


 LAUDERDALE POOL

 Location: Secs. 35 and 36, T. 21 N., R. 7 E., sec. 31, T. 21 N., R. 8 E., secs. 1 and 2, T. 20 N., R. 7 E., and secs. 6 and 7, T. 20 N., R. 8 E.
 Discovery Well: Not known.
 Date of Opening: Not known.
 Producing Sands: The Peoples sand—1,170-1,340, has some small gas and oil; Layton sand—1,400-1,600, has some good production; Cleveland sand—1,700-2,100, has some good production; Prue sand—2,200-2,400, has some small production; Skinner sand—2,300-2,450, has some good production; Bartlesville sand—2,400-2,550, has some good production; Wilcox sand—2,522-2,740, has some good production; Turkey Mountain sand—2,575-2,800, has some good production.

 Remarks: Two sands above the Peoples sand have shows of gas and oil. The Cleveland sand is divided into two parts, Upper and Lower, by a shale from 50 feet to 150 feet in thickness. In the highest part of the pool the Turkey Mountain sand is about 30 feet under the Bartlesville.

 MANNFORD

 Location: Sec. 36, T. 20 N., R. 8 E.
 Discovery Well: Gillette No. 1, School Land, NE 1/4 NE 1/4 SW 1/4, sec. 36. I. P. 1,000 barrels.
 Date of Opening: April 5, 1922.

 MARRAMAC POOL

 Location: Secs. 4, 5, 8, 9, 16, 17, 21, 22, 27, and 28, T. 20 N., R. 6 E.
 Discovery Well: Not known.
 Date of Opening: 1920.

 Remarks: Gravity, 38°.

 MASHAM POOL (DONAHOE POOL)

 Location: Sec. 22, T. 23 N., R. 4 E.
 Date of Opening: Dec. 14, 1924.

 Remarks: The first well in this area was a gas well drilled by J. Alex Dingwall exactly one mile south of the discovery well in the NW cor. SE 1/4, section 27. This was dry in the Wilcox sand but made 5½ million gas in a higher sand.

 MINnehoma POOL

 Location: Secs. 13 and 24, T. 21 N., R. 7 E.
 Discovery Well: Minnehoma, No. 3-W. Merrill, SW 1/4 SE 1/4 SW 1/4, sec. 13, T. 21 N., R. 7 E. I. P. 75 barrels.
 Date of Opening: June 30, 1926.
 Producing Sands: All sands had shows of oil and gas but the production came from the Hominy—2,630-2,725.

 MOrRISON (WATCHORN) POOL

 Location: Secs. 32 and 33, T. 23 N., R. 3 E., and secs. 4 and 5, T. 22 N., R. 3 E.
 Discovery Well: Robert Watchorn, Geo. L. Miller No. 1, NE cor SW 1/4 SW 1/4 sec. 33, T. 23 N., R. 3 E. 35,000,000 cubic feet of gas in Tunkawa sand.
 Date of Opening: December 27, 1915.

3. See discussion of Morrison field, by Everett Carpenter, p. 183.
OIL AND GAS IN OKLAHOMA

PRODUCING SANDS: Tonkawa and other gas sands—2,000-2,500 feet; Layton sand—oil, at 2,752 feet, July 14, 1922; Wilcox sand—650 barrels at 3,800 feet, October, 1923.

REMARKS: This pool is on a closed structure which was found by Frank Buttram, employed by the Fortuna Oil Company. The holdings of the Fortuna were later sold to the Magnolia Petroleum Company.

QUAY POOL
LOCATION: Sec. 31, T. 20 N., R. 6 E., sec. 36, T. 20 N., R. 5 E., and extending south in Payne County.
DISCOVERY WELL: Not known.
DATE OF OPENING: 1914.
REMARKS: Gravity, 36 to 37.9°.

RALSTON POOL
LOCATION: Northern part of T. 23 N., R. 5 E.
DISCOVERY WELL: J. M. Critchlow et al., sec. 3, T. 23 N., R. 5 E.
REMARKS: Gravity, 36-37.9°.

SOUTH CLEVELAND (OLNEY) POOL
LOCATION: Secs. 25, 26, 27, 34 and 35, T. 21 N., R. 8 E., and secs. 2, 3, 4, 5, 8, 9, 10 and 11, T. 21 N., R. 8 E.
DISCOVERY WELL: Chas. Page, sec. 34, T. 21 N., R. 8 E., 2 million cubic feet of gas at depth of 1,400 feet.
DATE OF OPENING: 1915.
PRODUCING SANDS: Red Fork—2,300-2,600; Bartlesville—2,400-2,700.

SOUTHWESTERN POOL
LOCATION: Secs. 13, 23 and 24, T. 20 N., R. 8 E.
DISCOVERY WELL: Not known.
DATE OF OPENING: Not known.
PRODUCING SANDS: Layton sand—1,100-1,200; Cleve'and sand—1,-400-1,600; Skinner has some big gas 2,000-2,140; Red Fork, some gas and oil—2,140-2,300; Bartlesville—2,220-2,350; Wilcox—2,750-2,870.

TERLON POOL
LOCATION: Secs. 19 and 30, T. 20 N., R. 8 E.
DISCOVERY WELL: Not known.
DATE OF OPENING: 1912.

WEST QUAY POOL
LOCATION: Sec. 33, T. 20 N., R. 5 E.
DISCOVERY WELL: Marland No. 1, School Land, NW.¼ NW.¼ SE.¼, sec. 33. I. P. 25 barrels.
DATE OF OPENING: February 22, 1922.

PAWNEE COUNTY

REMARKS: The discovery well drilled in sec. 2, T. 22 N., R. 22 E., was not offset until September 29, 1926. This was in the NE.¼ NE.¼ SW.¼ of the section and the third well in the pool with an initial production of 398 barrels. The second well was drilled in August 20, 1926, in the SE.¼ SE.¼ SW.¼ of the section with an initial production of 60 barrels.

MINOR POOLS AND IMPORTANT SHOWINGS
Kelly-Chandler, No. 1 Hill, NE. cor. SW.¼, sec. 1, T. 21 N., R. 5 E., drilled in August 27, 1924, at a depth of 3,379 feet in Wilcox sand, swabbed 200 barrels, 30 per cent salt water, gravity, 48°; Bement Oil and Gas Co., No. 1 Box, SE. cor. SW.¼, sec. 30, T. 23 N., R. 5 E., drilled in May 23, 1925, produced 95 barrels from Big Lime (?) at 2,762-72 feet.

Duquesne Pet. Co., Chas. Colclazier No. 1, SW. cor. NE.¼ SW.¼, sec. 8, T. 21 N., R. 6 E., completed August 21, 1923, at 2,985 feet. I. P. 660 barrels, but soon dropped off and was drilled to Wilcox without production.

Ranch Creek Pool, sec. 20, T. 21 N., R. 7 E. There are a few wells believed to be in the Skinner sand. Drilled in 1915 or earlier by the Uncle Sam Oil Company.


FUTURE DEVELOPMENT
As already mentioned, nearly all the production so far found in Pawnee County is closely associated with structure. Practically the entire area of the county contains outcrops of a type that permits accurate mapping of the ledges and contouring of the structural features. This led to early exploration and development, with the result mentioned.

It is believed that all of the closed structures and most of the prominent structural noses and terraces have been tested. However, the minor features sometimes furnish surprises, and before the structural production possibilities can be said to be really exhausted, all these minor features must be tested. It should be remembered, however, that in considering these, even though they are based on very careful mapping of the beds exposed at the surface, they are only of minor importance.

Of the future of the non-structural production, there is little to be said, but much to be learned. Neither surface nor subsurface structure is an accurate clue to the location of sand lenses or shoe string sands, yet some of the best fields of the Mid-Continent are of this type.

It is believed that future drilling will reveal some pools of this type in Pawnee County and that the future of the county as an oil and gas producer depends on exploration with the drill for non-structural production.
THE MORRISON FIELD, PAWNEE COUNTY OKLAHOMA

By
Everett Carpenter
Bartlesville, Oklahoma

LOCATION

The Morrison field is located in T. 22 and 23 N., R. 3 E., Pawnee County, Oklahoma. It lies southeast of the Kay County district, with which it is closely related as regards structure and producing horizons. It has a producing area of only about 320 acres, but has produced 4,586,500 barrels of oil at the close of 1926.

HISTORY

The history of the Morrison field commences with the year 1915. The structure was discovered in January of that year by Frank Buttram, who was then employed by the Fortuna Oil Company. The first well George L. Miller No. 1, was completed by Robert Watchorn on December 27, 1915, as a 35,000,000-cubic foot gas well in the Tonkawa sand. During the interval between 1915 and 1922 the development was confined to the gas sands found between 2,000 and 2,500 feet, but on July 14, 1922, George L. Miller No. 3 was completed as an oil well in the Layton sand, found at 2,732 feet. This well was deepened to the "Wilcox" sand in October, 1923, and had an initial production of 650 barrels.

STRATIGRAPHY

The rocks exposed at the surface in the Morrison field are of Permian age. They consist mostly of red sand and shale, but two limestones are present. The Fort Riley limestone outcrops in the field and is the datum used in mapping the structure. This formation has lost the calcareous nature it possesses in Kansas and northern Oklahoma, and consists mostly of sand, with a limestone bed about 10 feet thick at its base. The Winfield limestone outcrops west of the field about 100 feet stratigraphically above the Fort Riley. The interval between the two consists of red sand and shale.

SUBSURFACE STRATIGRAPHY

Subsurface correlations in the Morrison field are comparatively difficult, due to the lack of persistent key beds. The Forsaker limestone is found 500 feet below the Fort Riley, but it is not easily recognized. The first dependable correlation to be made is on the Tonkawa sand found at a depth of 2,000 feet. The section between the Tonkawa sand and the Layton sand, found at 2,700 feet, is irregular, and no accurate correlation is possible throughout wide areas. The Layton sand can be correlated in most of the area, and also the Kansas City-Oswego group. The "Mississippian lime" found on the structure at a depth of 5,800 feet below the Fort Riley is always distinguishable; but on account of its variable thickness the depth of the "Wilcox" cannot be definitely forecast.


Figure 41.—Geologic structure of the surface formations, Morrison field. Contours above sea-level. Contour interval, 10 feet.

4. Reprinted by permission of the Bulletin of the American Association of Petroleum Geologists from Volume 11, No. 10 (October, 1927) and by courtesy of the author, Everett Carpenter.

5. Presented by title before the Association at the Tulsa meeting, March 26, 1927. Manuscript received by the editor July 30, 1927.
STRUCTURE

The structure as revealed by the surface rocks is a typical anticline (Fig 41). It has a north-south length of about one mile and a productive width of about ½ mile (Fig. 41). The fold is characterized by a reverse dip of about 40 feet, although probably not all of the core flank is exposed. The south end of the structure is not clearly revealed, due to the lack of exposures of any key horizons.

Several horizons may be used for subsurface mapping with essentially similar results. For the purpose of this study four horizons were used, namely, Tonkawa, Layton, "Mississippi lime," and "Wilcox" sand (Figs. 42, 43, 44, and 45). These formations, except the "Mississippi lime," contain oil or gas, and measurements to them are probably more accurate than others. The structure as revealed by subsurface rocks is similar in outline to that determined by surface exposures. In general the amount of closure increases with depth to the top of the "Wilcox" sand, where there is a closure of about 150 feet.

Production

The production obtained from the Pennsylvanian strata is mostly gas, although oil has been found in commercial quantities in the Layton sand in several wells at a depth of about 2,700 feet. The producing sands are the Tonkawa sand at 2,000 feet, two unnamed gas sands at about 2,500 and 3,000 feet, and the Layton oil sand at 2,700 feet. The Bartlesville sand is probably present on the Morrison anticline, but it is unproductive. Some slight showings were obtained in the upper part of the "Mississippi lime," but they were not sufficient to be commercial.

The production obtained from the pre-Pennsylvanian strata is all from the "Wilcox." It is the best oil-producing formation, and has furnished more than 80 per cent of the oil in the field. It seems that all the oil-bearing horizons have been tested, but several showings in the siliceous lime have been reported in wells drilled off the structure. It is possible that when a deeper well is completed on the top of the dome, additional production may be obtained.

The following production data are from the office of the Corporation Commission and are thought to be accurate:

Production of the Morrison Field

<table>
<thead>
<tr>
<th>YEAR</th>
<th>BARRELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1922</td>
<td>42,318</td>
</tr>
<tr>
<td>1923</td>
<td>97,576</td>
</tr>
<tr>
<td>1924</td>
<td>1,953,080</td>
</tr>
<tr>
<td>1925</td>
<td>2,232,906</td>
</tr>
<tr>
<td>1926</td>
<td>940,830</td>
</tr>
<tr>
<td>Total</td>
<td>4,564,600</td>
</tr>
</tbody>
</table>

At the close of 1926, the average yield for the field was more than 11,000 barrels per acre. The production during the remainder of the life of the field should be almost 15,000 barrels per acre.
Figure 43.—Geologic structure contoured on the Layton sand in feet below sea-level, Morrison field.

Figure 44.—Geologic structure contoured on the "Mississippi lime" in feet below sea-level, Morrison field.
Figure 45.—Geologic structure contoured on the "Wileex" sand in feet below sea-level, Morrison field. Shows location of cross-sections AA' and BB' (Figs. 46 and 47).

Figure 46.—Geologic cross-section AA' as shown by well logs. For location in field, see Figure 45. Depths shown in feet.
Harmon, Greer, Jackson, and Tillman Counties.

By

R. L. Clifton

INTRODUCTION

The four counties of Harmon, Greer, Jackson, and Tillman, occupy the southwestern portion of Oklahoma. Lying as these counties do, on the southwestern flank of the Wichita Mountain uplift, and bordering the north bank of the Red River, they may be said to belong to the Red River district of Oklahoma.

It shall be the purpose of this report to discuss the oil and gas possibilities of the four counties, and at the same time to delineate some of the geologic and other factors found to exist within the limits of the counties. A geologic map is included as a part of this report. (Map No. XXI).

Acknowledgments

The writer wishes to thank C. N. Gould, Director of the Oklahoma Geological Survey, for the helpful suggestions he has given in the preparation of this report. And without specific reference to others, the writer wishes to acknowledge a debt of service to those geologists who have worked in the area of these four counties. This report then, may be considered a composite work, representing the opinions and conclusions of the writer, influenced to a large extent by the writings and the personal communications of other geologists familiar with this area.

General and Historical Geology of the Four Counties

The surface exposures within the limits of the counties of Harmon, Greer, Jackson and Tillman belong, for the most part, to the Permian system. There is a considerable area of Recent sands and alluvium deposits within the counties. Along the northeastern limits of this area there is a more or less attenuated line of pre-Cambrian exposures, consisting of low-lying granite peaks and knobs that rise but a few hundred feet at the most, above the level plain of this area. A correlation table for the oldest to the youngest formations appearing as surface exposures within the four counties, is given below:

Correlation of formations in Harmon, Greer, Jackson and Tillman Counties.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>Oklahoma</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodward</td>
<td>Whitehorse sandstone</td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>Dog Creek shale</td>
<td></td>
</tr>
<tr>
<td>Blaine</td>
<td>Blaine gypsium</td>
<td>Double Mountain</td>
</tr>
<tr>
<td>Cimmaron</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enid</td>
<td>Chickasha</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Duncan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hennesey</td>
<td>Clear Fork</td>
</tr>
<tr>
<td></td>
<td>Garber</td>
<td>Wichita</td>
</tr>
</tbody>
</table>

The historical geology of the four counties is intimately related to the cycle of events included in the history of the Wichita Mountains. The oldest Paleozoic beds were evidently deposited in an area relatively free from orogenic movements. It is probable that the horizontal attitude of the older beds was but little disturbed until about the close of Ordovician or later deposition. It is believed by Taff and others that crustal deformation became pronounced during early Pennsylvanian times, resulting in the elevation of the Wichita Mountains. These mountains then,—as well as the present Wichita Mountains—are but the uplifted peaks of the ancient sea floor, upon which Cambrian and younger sediments were deposited.

Subsequent to the early Pennsylvanian uplift, the upturned beds were subjected to erosion and finally peenplanation to a marked degree and by the close of Pennsylvanian times, this area again became submerged. Detrital material forming the clastic and indirectly the non-clastic beds of the Permian, was deposited on the eroded Pennsylvanian surfaces. An area of deltaic Permian deposits was laid down on the truncated and tilted older beds, as a more or less narrow border or periphery around the Wichita uplift. To the south, away from the Wichita uplift, deposition was continuous from early Pennsylvanian to the close of Permian times, since the evidence of a marked unconformity between the late Pennsylvanian and the early Permian beds disappears rapidly to the south. Later, and after the close of Permian times, the Wichita Mountain area again was elevated to its present height, thus tilting the beds in the area of the four counties southwestward. Subsequent erosion has removed much of the Permian deposits from the immediate area of the uplift, while streams have channelled fairly deep valleys in the beds away from the uplift. The net result of the two primary crustal uplifts has been to tilt the older,—or Pennsylvania beds, as a specific instance—at a higher angle than the younger, or Permian beds were tilted.

HARMON COUNTY

Location

Harmon County is located in the extreme southwestern part of the State. It extends from T. 1 N. to T. 6 N., inclusive, and from R. 24 W. to R. 27 W., inclusive. The county embraces 11 entire townships and the parts of 11 others. The total area of Harmon County is approximately 567 square miles.

Geography

DRAINAGE AND TOPOGRAPHY

The county is drained by Red River and its tributaries, the principal ones of which are Lebo Creek, Salt Fork, and Elk Fork of Red River. The drainage plane slopes in a general southeast direction.

The greater portion of the area of the county lies in the region of the Gypsum Hills. The topography is that of a level plain, dissected by stream and erosion channels. Much of the central portion of the county is covered by an area of sand and alluvium deposits. The northeastern part of the county presents a typical red beds hills topography that is the area of the highest relief in the county.

Geology

STRATIGRAPHY

The rocks exposed at the surface belong to the Permian and to the Quaternary systems. The area of the Permian beds greatly exceeds that for the younger sands and alluvium.
The Permian exposures belong to the following horizons; the Blaine, Dog Creek, and Whitehorse formations. Miser has shown on the recently published state map an area of Cloud Chief exposures appearing at the surface in northern Harmon County, but recent field work does not convince the writer that any Permian beds as young as the Cloud Chief appear as surface outcrops in the county. Accordingly, the map accompanying this report does not include an area of Cloud Chief exposures.

The Blaine Cynsum beds appear as a sort of concentric band of outcrops extending from the southwestern part of the county, thence eastward, along the eastern portion of the county, to the limits of T. 5 N., where, in the north part of the township, the Blaine outcrops extend westward to the Texas line. The Blaine formation presents four or more series of discontinuous beds of gypsum and magnesium-calcium carbonate beds, with interbedded red clays and shale throughout the area of its outcrops. Occasionally the gypsum beds have a tendency to erode locally in a series of low escarpments.

The Dog Creek formation appears as a surface outcrop in T. 5 N., and extends as far east as R. 24 W. In small areas overlying the Dog Creek shale there occurs an area of Whitehorse sandstone beds. Approximately the lower half of the Whitehorse section is represented in the county. To the northeast, this formation has an average thickness of about 425 feet.

In the central portion of the county there is an area of sand and alluvium beds, within whose limits there occur isolated exposures of Permian beds belonging, for the most part, to the Blaine formation.

There is a narrow band of Recent sands along the larger streams of the county. The principal area of such beds is along the Red River.

As formal evidence affording a direct bearing upon the age and correlation of the Permian exposures in the county, it may be stated that the writer has collected fossils of a few specimens from certain dolomitic beds appearing near the top of the Blaine formation. The fossiliferous beds occur in the western part of the county, along the Texas line, in Tps. 3, 5, and 6 N., where a few specimens of Schizodus and Pleuropora were collected. The same fossils were also collected to the west in Texas, from the same series of beds.

**REGIONAL AND STRUCTURAL GEOLOGY**

The strata in Harmon County dip at a low angle to the southwest, and at right angles to the axis of the Wichita uplift. It has been stated by Taff and others that the Wichita uplift occurred during early Pennsylvanian times, although it is believed that the area of Harmon County was subjected to crustal deformations of perhaps lesser intensity from about the close of Ordovician times until the beginning of Pennsylvanian times—all of which have influenced the subsurface beds in this area. Following the first appearance of the Wichita Mountains as such, the area was greatly eroded, and by the close of Pennsylvanian times, the area of the Wichita uplift again became a depositional zone. The Permian deposits, largely derived from the eroded old land mass of the Wichita uplift, were laid down on the tilted and truncated Pennsylvanian and older beds. At the close of Permian times or later, this area was again subjected to uplift, elevating the Wichita Mountains to their present position.

The various crustal deformations have left their influence upon the beds in the area of Harmon County. The older Paleozoic beds are perhaps more tilted and folded than are the younger Permian beds. Folds and structural reversals most likely occur in the subsurface beds. Gould and Lewis' have recently shown that the eastern limits of the Palo Duro Basin may extend as far eastward as the limits of T. 4 N., R. 25 W. The occurrence of this structural feature only stresses the fact that folds and synclines in the subsurface beds are to be expected in the area in which Harmon County lies.

**ECONOMIC GEOLOGY**

At present there is no production of oil and gas in commercial quantity within the limits of the county. Six or more wells have been drilled, some of which have reported showings of oil and gas, yet the net result of the wells drilled up to the present has been very disappointing. However, none of the deeper tests, as for example the three deeper tests drilled in R. 26 W., have penetrated even the full Pennsylvanian section, so while these three wells may have tested much of the Paleozoic section, the fact remains that the older, or Ordovician beds at least remain untested in these wells. It is evident from subsurface studies that these three tests show a well defined monocline dip to the southwest away from the axis of the Wichita uplift and it is possible that no one of the wells was located on a well defined structure. At any rate the deduction based on the results obtained in those wells drilled in the county, that oil and gas will not be found ultimately, is open to question.

**Summary**

Harmon County must be regarded as lying within possible oil and gas territory. To the south in Texas, the lower Permian horizons, and the greater part of the entire Pennsylvanian section are known to be productive of oil and gas. These same beds, or their stratigraphic equivalents underlie the greater part of Harmon County, and it is of course granted that there is some thinning of the Pennsylvanian section, in comparison to the same section to the south in Texas.

Underlying the Pennsylvanian beds, considerable thickness of Ordovician beds most likely occurs. The Arbuckle limestone is possibly extensive over the entire county. It is possible that thin sections of the Simpson formation may be represented as subsurface beds, in much of

the county, since the presence of beds referable to this formation have been reported from Stephens County, 2 Oklahoma, and in other areas' adjacent to the Wichita uplift. Again thin sections, or erosional remnants of the Viola lime might occur within the county. The presence of these other Paleozoic beds, if more than erosional remnants, may be regarded as additions to possible petroliferous beds, or, against these erosional remnants, if present, might serve as buried hills or elevations over which younger beds might be folded or over which compactional forces on younger beds could possibly create slight reversals in the regional dip, which would form the proper structural condition for the accumulation of oil and gas. While the writer believes that the theory of compaction and differential settling in younger sediments over hills or elevation in older rocks to account for major structural uplifts or folds has been much over-estimated by some geologists, yet the fact remains that compaction and differential settling do furnish the possible physical conditions necessary to form the smaller terrace-like types of structures, such as are found to exist in many other areas and which are believed to be present in this county.

Below is given the log of the well drilled by the Auto Oil and Gas Syndicate. This log is fairly representative of subsurface conditions for the south part of the county.

Auto Oil & Gas Syndicate's Gillentine No. 1, sec. 21, T. 3 N., R. 26 W.

Drilling commenced, 1-15-20; drilling completed, 5-12-21.

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(Continued on page 197)

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HARMON, GREER, JACKSON, AND TILLMAN COUNTIES 197

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(Continued on page 198)
given serious consideration in the location of any test. While this is no assurance of ultimate success, it nevertheless eliminates some of the elements of chance against the drilling of dry holes.

**GREENE COUNTY**

**Location**

Greer County is located in the southwestern part of the State. It extends from T. 3 N. to T. 7 N., inclusive, and from R. 20 W. to R. 25 W., inclusive. The county embraces 12 entire townships and parts of 12 others, whose total area is approximately 624 square miles.

**Geography**

**DRAINAGE AND TOPOGRAPHY**

The county is drained by Elm Fork, Salt Fork, and North Fork of Red River. The drainage slopes more or less rapidly to the southeast.

The county lies wholly in the area of the Gypsum Hills and the Red Beds Plains, except for small outcrops of more or less local and attenuated pre-Cambrian exposures, that form the northwestern extension of the Wichita Mountains. There is also a small area of sand and alluvium deposits along the courses of the larger streams. In places the topography is deeply dissected by stream erosion, the Gypsum Hills forming a dominant feature of the relief.

**Geology**

**STRATIGRAPHY**

The surface rocks belong to the pre-Cambrian and the Permian, while along the streams there are to be found areas of Recent deposits of sand and alluvium.

The pre-Cambrian rocks at the surface in Greer County consist of granite for the most part. These exposures are isolated granite knobs or peaks and ridges, of the Wichita Mountains, which rise abruptly a few hundred feet above the red beds plains. The largest of these granite ridges is known as Head quarters Mountain, near the city of Granite. The approximate area of this mountain is three square miles and which has an elevation of about 500 feet above the surrounding plain.

The Permian beds exposed in Greer County belong to the following formations: from the oldest to the youngest: Hennessey, Duncan, and Chickasha, of the Enid group; and the Blaine formation. These Permian formations consist of red clays, shales, sandstones, some calcareous sandstones and shales, gyspum, and dolomite.

The Hennessey formation, or the Clear Fork beds as its Texas equivalent is called, appears at the surface in the eastern part of the county, just west of North Fork of Red River. The Duncan sandstone

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and Chickasha formation appear as surface beds in the northern part of the county. The Duncan sandstone, which is correlative with the San Angelo formation as described by Beebe, can be traced by more or less attenuated exposures through the county southward to the Red River. Excellent exposures of the Chickasha are observed in the county. The purplish-red color of the Chickasha affords a means by which this formation may traced through the county.

The Blaine formation overlying the Chickasha, consists of five or more beds of gypsum and dolomite, interbedded with red clays and shales. The Blaine exposures cover the greater and the western portion of the county.

REGIONAL AND STRUCTURAL GEOLOGY

Greer County lies chiefly on the southwest slope of the Wichita Mountain uplift. The beds here dip at fairly steep angles, away from the axis of the uplift. In the eastern portion of the county the Paleozoic section—chiefly Permian beds—is very thin over the area of this uplift. Southwestward away from the uplift, older Paleozoic beds begin to come in as subsurface formations, and in this area the Ordovician and the Pennsylvanian beds underly the Permian unconformably. The strata dip to the northeast in the northeastern part of the county. It is certain that the Permian beds overlap the eroded and tilted ends of Pennsylvanian beds in the area of the Wichita uplift.

The older Paleozoic beds are much folded and tilted due to the crustal deformations which have taken place in this area since middle Pennsylvanian times. Structural conditions should not be lacking unless subsequent erosion has modified the older beds too greatly by planation.

ECONOMIC GEOLOGY

Greer County lies in probable oil and gas territory. Due to the thinness of the Paleozoic section in the immediate area of the Wichita uplift, it is not likely that oil in commercial quantity will be found. True, oil has been found in small quantities in several wells and at shallow depths in this area. The oil has come from, or else near, the unconformity where Permian beds most likely overlie pre-Cambrian rocks. Away from the uplift a greater Paleozoic section occurs. Given the proper structural conditions, then oil in commercial quantities may be expected.

Development in Greer County began as early as 1901, since that time ten or more wells have been drilled in the county. At the present date it cannot be said that oil and gas in commercial quantities have been found, although several small oil wells have been completed for a production of one to four barrels daily. Gas to the amount of better than 2,000,000 cubic feet was found in one well.
garded as good. Until more tests have been drilled in the western and southwestern parts of the county, deep enough to test the Pennsylvanian and the Ordovician beds, which are believed to be present in this area, Greer County cannot be regarded as an impossible oil and gas area. (See remarks on Harmon County, page 195).

JACKSON COUNTY

Location

Jackson County lies in the Red River area of southwestern Oklahoma. The county extends from T. 2 S. to T. 4 N., inclusive, and from R. 18 W. to R. 23 W., inclusive. It comprises 12 entire townships and the parts of 21 others, the total area of which is approximately 811 square miles.

Geography

DRAINAGE AND TOPOGRAPHY

The county is drained by Red River and its tributaries, chief among which are North Fork, Salt Fork, and Gypscreek Creek. The drainage in general flows to the southeast.

Jackson County exhibits four types of topography, namely, Wichita Mountain, Sand Hills and Alluvium, Red Beds Plains, and Gypsum Hills areas.

The northeastern portion of the county is in the area of the Wichita Mountains, which consist of isolated peaks and ridges of granite rise a few hundred feet above the surrounding plain.

The sand and alluvium area lies principally in the southern and central parts of the county, along Red River and Salt Fork. The Red Beds Plains area includes the greater portion of the county and lies west of the Wichita Mountain area.

To the west of the Red Beds Plains there is a considerable area having a relief dominated by low gypsum hills and escarpments, which gives this portion of the county a typical Gypsum Hills topography.

Geology

STRATIGRAPHY

The surface rocks in Jackson County belong to the pre-Cambrian, Permian, and Quaternary or Recent.

The pre-Cambrian exposures lie in the northeastern part of the county. These consist for the most part of granite peaks and intruded dikes. The granite knobs and peaks appear as low-lying elevations, protruding above the level plain.

The Permian beds appearing as surface exposures, from the oldest to the youngest are the Hennessy, Duncan, Chickasha and Blaine formations.

The Hennessy formation outcrops in the eastern and the extreme southeastern parts of the county. The writer correlates the Hennessy beds as a part of the Clear Fork division of the Texas section.

There occurs, extending through the central part of the county, an area of exposures belonging to the Duncan and the Chickasha formations. Beginning at Red River, near the town of Elmer, the Duncan beds can be traced in a nearly continuous line across the county. The Duncan, or the San Angelo as the Texas equivalent has been called by Dr. Beede, can be seen in the bluffs on the south bank of Red River.

Excellent exposures of the Chickasha appear above the Duncan, in its outcrops across the county. Southwest of Olustee and along Red River prominent exposures of the Chickasha occur.

The western one-third of the county is included in the area of the Blaine gypsums. Due to erosion and possibly solution and slumping, no one of the three or more beds of the Blaine can be traced across the county without difficulty. The Blaine formation in Jackson County presents a series of three or more discontinuous gyspsum beds, with interbedded zones of dolomite, red clay and shale.

In the northern part of the county, the chief streams are bordered by beds of Recent deposits, consisting of sands, gravels and alluvium.

STRUCTURAL GEOLOGY

The county, lying as it does in the area of the Wichita uplift, has a southwest regional dip. In general the beds dip at a low angle to the southwest. In many parts of the county there may be local variations in dip. However, in much of the area of the county, the nature of the surface beds is such that variations from the regional dip are not easy to detect. Structures or folds, or terraces have been reported by geologists who have worked in the county. It is certain that the different orogenic movements related to the history of the Wichita uplift have tilted the older rocks, and perhaps in some instances to have folded them to a marked degree. A study of the logs of those wells that have been drilled in the county shows a marked thickening of subsurface beds away from the Wichita uplift. The degree of tilting for the older beds is much greater than it is for the younger or Permian beds. It may be assumed with some reason that the Pennsylvanian, and older Paleozoic beds may be more greatly folded than the younger beds, and that subsurface structures, in these older rocks—granting that they are present—might have no reflection whatever in the upper or surface beds.

DEVELOPMENT

Six or more wells have been drilled in the county. Apparently, with but one possible exception, those few wells which have been drilled in the southern portion of the county where the thickest Pennsylvanian beds occur, have not been drilled deep enough to test even the full Pennsylvanian section.

It is quite possible that the Douglas Oil Company well, drilled in sec. 20, T. 3 N., R. 20 W., encountered Ordovician beds at an approxi-
mante depth of 3,300 feet. A study of the log of this well indicates that the base of the Pennsylvanian beds occurs at about 3,150 to 3,300 feet. The writer is inclined to refer the beds encountered below 3,345 feet to the Arbuckle formation, on no stronger evidence than that of drillers’ logs. There is, however, the alternate possibility that the beds, or at least the lower part from 3,345 to 3,755 feet, are older than the Arbuckle limestone.

Douglas Oil Company’s Baker No. 1, NW. 3/4 SW. 3/4 SE. 1/4, Sec. 20, T. 3 N., R. 20 W.

Drilling Commenced, 6-14-23; Drilling Completed, 4-25-24.

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Of the six or more wells that have been drilled in the county, at least three of them have reported showings of oil and gas. Development so far has been discouraging and no production of commercial importance has been found in the county.

Summary

Jackson County is within possible oil and gas territory. The scarcity of surface structural conditions cannot be taken as a criterion for subsurface conditions. The Pennsylvanian and older Paleozoic rocks may be very much folded, yet the sequences of the Wichita Mountain uplift, its erosion, submergence, deposition and subsequent uplift might not reflect the folds that may occur in the older rocks in the younger Permian beds. Permian folding should extend downward into the oldest rocks, but it is quite possible that folds in the older rocks do not extend into the youngest Permian beds in the county.

Future drilling ventures should be undertaken in those areas where some evidence of folding is known to exist. The tests located on such geological evidences should be carried deep enough to reach the older, or Ordovician beds, which are certain to underlie the greater part of the county. So far as the writer is aware, but one test has been drilled deep enough to test even the full Pennsylvanian section in the southern portion of the county. No test in the county should be regarded as conclusive, regarding the oil and gas possibilities of any area, until that well has been drilled to at least the top of the Ordovician beds, if pres-
ent in that area. The Arbuckle limestone, or the Ordovician siliceous limestone—as its equivalent to the northeast is called—undoubtedly underlies the greater part of the county in the area away from the Wichita uplift. Above this limestone it is quite probable that a thin section of the Simpson formation might occur. The Ordovician beds should be regarded as possessing some possibilities for oil and gas, then any well drilled in the southern portion of the county should expect to encounter Ordovician beds at a depth varying from 3,300 to 4,500 feet, depending of course, upon the proximity of the test to the Wichita Mountains and the intensity of the fold or structure upon which the particular well is to be drilled.

It may be stated with certainty that with two or perhaps three exceptions, none of the six or more wells that have been drilled within the limits of the county, have completely tested the possibilities of these locations, for the reason that drilling was stopped too soon. In other words, the possibilities of any location has not been tested until the Ordovician or older rocks have been reached by the drill.

TILLMAN COUNTY

Location

Tillman County is located in the southwestern part of the State, in the tier of counties north of Red River and bordering on Texas. It extends from T. 6 S. to T. 1 N., inclusive, and from R. 14 W. to R. 19 W., inclusive. The county includes 18 entire townships and the parts of 12 others, whose total area is approximately 862 square miles.

Geography

DRAINAGE AND TOPOGRAPHY

The county is drained by Red River, the principal tributary of which is Deep Red Run and its branches.

The topography of the county represents generally broad smooth surfaces, over which occur a few isolated hills and divides of low relief, that have been preserved by ledges of more resistant rock. Occasionally, the smooth surfaces of the county are very much dissected by streams, thus affording locally a sculptured “badlands” or Red Beds topography.

Geology

STRATIGRAPHY

The beds exposed at the surface in Tillman County belong to the Permian and the Quaternary or Recent.

The Permian formations appearing at the surface in the county, from the oldest to the youngest are the Hennessey, Garber and Wellington formations, or their Texas equivalents, the Wichita-Clear Fork beds.

The Wichita beds outcrop in the extreme eastern and southeastern parts of the county and represent but a small portion of the area of the county. West of the Wichita beds there is a considerable area of Clear Fork exposures which makes up more than half of the total area of Tillman County. The Wichita-Clear Fork beds in many local places are covered by alluvial deposits so that even in the area of these exposures, the true character of these beds is not readily discernible.

In general the Permian beds consist of red clays, shales, sandstones, and conglomerates, especially mudstone conglomerates. The red clays and shales occur in the north and northeastern portion of the county. The sandstones in this area are limited and appear as small discontinuous beds. In the southern and central portions of the county, the red clays and shales contain interbedded sandstones, which are usually cross-bedded and are often lenticular along the line of outcrops.

The western portion of the county embraces an area of Quaternary or Recent exposures, consisting of sands and alluvium. Occasionally there appear outcrops of Permian beds as isolated exposures within this area.

Along Red River and along the lower courses of Deep Red Run, there are narrow or border-like exposures of Recent sands and alluvium.

STRUCTURAL GEOLOGY

Tillman County lies well within the influence of the Wichita Mountain uplift. The normal dip of the beds is in general to the southwest, with local variations in the regional dip. An example of this variation is to be noted along the axis of the Devol anticline, described by Munn.

Apparently there is a synclinal structure, or probably a series of smaller synclines and anticlines, extending in an east-west direction through the central part of the county. Howell has referred to this structural condition as the red River syncline.

Structural conditions in the Grandfield district have been discussed at some length by M. J. Munn. Other geologists have called attention to the presence of folds and terraces in Permian areas outside of the Grandfield district. It is reasonable to assume that reversal in the regional or normal dip exists in the Permian and older beds outside the limits of Tillman County. The Wichita uplift, as well as the Red River uplift in Texas, has no doubt modified the attitude of the beds with respect to their normal position, so that structural folds or reversals occur in the subsurface beds, even though the nature of the surface exposures increases the difficulty to detect folds.

DEVELOPMENT

Much development has been done in Tillman County and some production has been found, but at the present time there is no producing well of commercial importance. The development has been confined to

the southeastern portion of the county, where in 1920, a shallow field having three producing horizons of small daily output was discovered. This field, known as the Grandfield district, is but an extension of the Burk Burnett Texas field. The few wells in the extension had an initial production of about 100 barrels for a maximum. The main production came from what the writer correlates as the Cisco formation.

Several wells, drilled outside the Grandfield district, have reported showings of oil and gas.

A report of the Armstrong Oil Company's test in sec. 6, T. 4 S., R. 18 W., is included as a part of this report. Though the Armstrong well was drilled with standard tools, most of the drilling in Tillman County has been done with rotary tools.

**Armstrong Oil Company's test in SE. ¼ NE. ¼ Sec. 6, T. 4 S., R. 18 W.**

Drilling Commenced, Aug. 1919; Drilling Completed, May, 1921

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(Continued on page 209)

HARMON, GREER, JACKSON, AND TILLMAN COUNTIES
Summary

Tillman County lies in probable oil and gas territory, and the development up to the present time has not disproved this statement. Within the knowledge of the writer, but one well has been drilled deeper than 3,600 feet. This test did not penetrate the full Pennsylvanian section.

Underlying the greater part of the county, beds of Ordovician age are certain to be found. There is every reason to believe that the older Paleozoic beds, which as yet have never been tested in Tillman County, so far as the writer has been able to learn, may be petrolierous.

Structural conditions favorable for the accumulation of oil and gas are known to occur in the general area in which Tillman County lies. A study of subsurface conditions prompts the statement that the older beds thicken away from the axis of the Wichita uplift. Likewise, the older beds are inclined at higher angles than are the younger Permian or Paleozoic beds. It is quite possible that the older Paleozoic beds are also much more folded and tilted than are the Permian beds. Structures in the general area of the county are certain to increase in depth. In the drilling of any well in the county, it should be planned to carry the development deep enough to test the Ordovician beds, which are certain to underlie the greater portion of the county. No test may be regarded as sufficient until the Ordovician, or older beds are encountered by the drill.

To the north and northeast of the Wichita uplift, the Arbuckle or Ordovician siliceous limestone and the Simpson sand are known to occur. The Arbuckle limestone should be found in the general area of Tillman County, or at the least, in the southern part of the county. It is not improbable that at least thin beds of the Simpson sand may also be found locally in the county. Hence no test may be regarded as conclusive unless the older rocks are tested.

It is presumed that the Arbuckle limestones will be encountered in the southern part of the county at a depth varying from 3,600 to 5,000 feet, depending, of course, upon the proximity of the test to the Wichita uplift and the intensity of the fold or structure upon which the test may be located.

OSAGE COUNTY

By

H. T. Beckwith

INTRODUCTION

This report gives a brief description of the exposed geological formations in Osage County and illustrations of some of the types of surface and subsurface structures. A brief account of the early history of the Osage Indian Reservation is given as well as the location of the first wells drilled. Those not familiar with the rules and regulations concerning the purchase and development of leases in this county should consult, "Regulations to Govern the Leasing of Lands in the Osage Reservation, Okla., for Oil and Gas Mining Purposes," by the Superintendent of the Osage Indian Agency, Pawhuska. No attempt has been made to go into detail concerning the development and production history of the county, as such information can be found in government publications and in the files of the oil trade journals. Production figures, by years, for the county and for the Burbank Pool only are given.

Much information has been published upon the geology, structural features, and development of Osage County. This county has been the training ground for many Mid-Continent geologists. For a report of this kind the difficulty has not been to find material to put into it, but to sort out from the available data that most desirable for a report of this type. It is not claimed that any strictly original information is included in the following pages. Surface structural maps and descriptions of them have been published and are available for most of the county, and many articles have been published describing the more important producing areas.

The information here given has been compiled from many sources, both published and unpublished. The writer has endeavored to give credit to the original author in all cases; if there has been any lapse of such courtesy it has not been intentional. If to some it should appear that important facts concerning the geology and development have been omitted, it is because, in most instances, such information has been published and is available in public libraries and in the libraries of many of the oil companies and geologists.

ACKNOWLEDGMENTS

The writer wishes to express his thanks to the following individuals and companies who have been helpful in compiling some of the data presented in this report: D. P. Coleman, of the Indian Territory Illuminating Oil Company, compiled the east-west section across the north-central part of the county. J. M. Sands, of the Phillips Petroleum Company, furnished the data on the subsurface map of the Burbank pool. Glenn C. Clark, of the Marland Oil Company, furnished the (Originally published as Bulletin 40-T, February, 1928).
maps and data on the Pettit pool in T. 23 N., R. 8 E., and like material on the Wildhorse pool was furnished by G. C. Potter of the Tidal Oil Co. The geological department of the Gypsy Oil Company furnished the maps and cross-sections on a part of the Boston pool in T. 21 N., R. 8 E. Charles F. Leech, of Bartlesville, kindly furnished the data on the early history of the Osage Reservation and of the first wells drilled therein. Drafting on the county map and some of the other maps and cross-sections was contributed by M. K. Jensen, Chief Draftsman of the Indian Territory Illuminating Oil Company.

Publications of the United States Geological Survey, the Oklahoma Geological Survey, and many articles that have appeared in recent years in scientific publications were freely consulted and are, in many cases, quoted. The writer is also indebted to many other geologists, too numerous to mention here, and especially so to Charles N. Gould, Director of the Oklahoma Geological Survey, for friendly criticism and many helpful suggestions.

LOCATION

Osage County is located in the north-central part of Oklahoma. It is the largest county in the State, having an area of approximately 2,350 square miles, a maximum length north and south of 57 miles and a maximum width east and west of nearly 60 miles. It is bounded on the north by the Kansas-Oklahoma state line; on the east by Washington and Tulsa counties (the 96th Meridian) and on the south and west by Arkansas River, except for a short distance along the northwest side where it is bounded by Kay County.

Figure 49.—Map of Oklahoma showing location of Osage County.

Four railroads enter the county and three of them cross it. There are several well graded earth roads crossing the county in different directions and the stretches of hard surfaced or cement pavement are being extended every year. Pawhuska is the county seat and largest town in which is located the offices of the Superintendent of the Osage Indian Reservation. Some of the other important towns are: Barnsdall in T. 24 N., R. 11 E.; Hominy in T. 22 N., R. 9 E.; Fairfax in T. 24 N., R. 6 E.; Burbank in T. 26 N., R. 5 E.; and Grainola in T. 28 N., R. 6 E.

OSAGE COUNTY

TOPOGRAPHY

This county is located in the Sandstone Hills and Red Beds Plains regions of Oklahoma. Regionally it is part of the broad Great Plains area that slopes gently to the east and south. Locally the topography is more varied. The eastern half of the county lies in a belt of alternating sandstones and shales. These beds dip gently in a direction a little north of west and the more resistant sandstone beds form prominent and steep east-facing escarpments with long gentle west slopes. In the western half of the county, which is of the more open and rolling prairie type, there are many alternating beds of limestones and shales which form similar east-facing escarpments that are not as prominent nor as rugged but more numerous than those on the east. Occasionally local folding combined with favorable drainage has formed a few short westward-facing escarpments. In the eastern and southeastern parts of the county the topography is rough and broken, and wherever the sandstone or sandy shale beds are present the hills are usually covered with a thick growth of scrub oak. In many places along the western and southwestern boundaries of the county the bottom lands of Arkansas River are several miles wide and often covered with heavily wooded sand dunes.

The drainage is south and southeast into Arkansas River, or its tributaries. The principal streams in the county are Caney River in the northeastern part, Sand Creek in the east-central part, and Bird and Hominy creeks in the southeastern part. In the western half the streams are not as large nor as well developed, as in the eastern half, the only one of importance being Salt Creek which flows nearly due south parallevling the strike of the limestone beds. All of the larger streams are well developed in the lower part of their courses and, where they cut through the eastward facing escarpments, form many short ridges and hills separated by broad alluvial-filled flood plains. The upper courses of all the streams have a steeper gradient, flow nearly always on bed rock, and near their headwaters show a rather deeply cut dendrict drainage pattern.

The lowest part of the county is near the southeastern corner where Hominy Creek crosses the county line at an elevation of less than 620 feet. The highest part is near the northwestern corner where some of the higher escarpments reach an elevation of over 1,300 feet.

GEOLGY

Stratigraphy

SURFACE FORMATIONS

The surface rocks of Osage County are Pennsylvanian and Permian in age. The Pennsylvanian beds exposed range upward from a little below the Hogshooter limestone in the southeastern corner of the county up to and including the Eskridge shale at the top of the Pennsylvanian series. Beds of Permian age exposed in the county extend from the top of the Eskridge shale up to and including the major part
of the Council Grove group. The Permian and Pennsylvanian systems are conformable throughout and the change from one to the other is a gradual transition. Surface exposures in both systems are made up of beds of sandstone, shale, and limestone. A few limestones occur in the northeastern part of the county but limestones are much more numerous and prominent in the western and northwestern parts. The sandstones are better developed in the eastern half where they form many wooded ridges or escarpments.

The subsurface beds of Pennsylvanian age, which underlie the whole county, are much the same in character as those found at the surface; they consist of alternating beds of sandstone, shale, and limestone, with the shales predominating in thickness. Beneath the Pennsylvanian series are beds of Mississippian age, consisting chiefly of limestone, some cherty limestone and shale, with the Chattanooga black shale at the base. The Mississippian and Pennsylvanian are generally conformable though there are a few local areas, as in the northeastern part of the county, where there appears to be an erosional unconformity. Below the Mississippian there is a pronounced and wide-spread unconformity. At the close of the pre-Mississippian period beds of Devonian, Silurian, and late Ordovician age were uplifted, folded somewhat and then by erosion planed off to a nearly horizontal surface. These pre-Mississippian beds have a rather pronounced dip to the west and southwest and erosion has beveled their edges so that in going up the dip successively older beds come in contact with the base of the Mississippian. These older beds of upper Ordovician age are present only under the southern and southwestern parts of the county where they form a wedge between the gently-dipping Mississippian and the still older, steeper-dipping and unconformable beds of the massive Arbuckle (Carbon-Ordovician) limestone. The maximum thickness of the Arbuckle limestone is not known. Test wells have penetrated it 1,000 and 1,500 feet. Deep tests have encountered granite at several places in the county.

The surface beds have a normal dip of approximately 30 feet per mile in a direction a little north of west. The subsurface dip is more to the west and southwest, but at a slightly less degree owing to the thinning of these beds to the west and northwest. Locally the normal west dip varies, especially in the eastern half of the county where the surface and subsurface beds are warped and bent into small folds or anticlines, domes, and terraces with their complementary depressions. Faulting is common along certain well defined lines of weakness. All of the faults found at the surface are of the normal type having small vertical displacement and usually still less horizontal displacement. They are inclined to occur in zones and were probably formed by torsional stresses set up at or near the surface at the time the warping and folding of the Pennsylvanian strata took place.


The surface formations, as previously mentioned, are of Permian and Pennsylvanian age. (See geologic map, No. XXII.) The boundary between the two is more or less arbitrary as they are conformable and the lithologic change from one to the other is slight. The gradual change noticeable in the color of the shale beds from predominantly gray and gray-blue in the upper Pennsylvanian to the nearly universally red shales of the Permian, is perhaps characteristic in the northwestern part of the county, but farther south the same color change is equally noticeable along the strike of the upper Pennsylvanian beds. Beede places the contact between the two periods at or near the base of the Neva limestone. The U. S. Geological Survey, however, is inclined to place the contact higher in the section at the base of the Cottonwood limestone. The writer is inclined to agree with Doctor Beede’s separation but for the sake of uniformity in nomenclature the U. S. Geological Survey division is here used.

In this area the sediments of Pennsylvanian age cover three-fourths of the county and those exposed vary from 2,000 to 2,200 feet in thickness as measured across the outcrops. Beds of Pennsylvanian age have an aggregate thickness of about 400 feet. As a general rule the limestone beds along the north boundary of the county become thinner and more sandy to the south. Most of the limestone beds in the northeastern part of the county become thin and disappear a few miles south of the State line. On the other hand, the shales and sandstones, with few exceptions, thicken towards the south, and in the eastern half of the county they thicken more rapidly than the limestones thin in the section. This thickening of the section is quite noticeable in the southeastern part of the county. The interval between the base of the Bigheart sandstone group and the base of the Elgin sandstone shows a considerable increase in thickness to the south. Also from the base of the Elgin sandstone to the top of the Pawhuska limestone group there is an increase in the interval from north to south along the strike. Two shale members, however, thin noticeably towards the south. One of these, the Villas shale of the Kansas section, disappears to the south and, lying above the Avant limestone, gives the outcrop of that formation an apparent westward swing. The other, the Bandera shale, is not exposed at the surface, but is mentioned here because its thinning to the south has caused some mis-correlation of the sands at the horizon of the “Big lime”, in northern Osage pools.

All of the beds, limestones, sandstones, and shales, are of marine origin and most of them, especially the limestones contain well preserved marine fossils. In the southeastern part of the county there are a few thin lenticular beds of coal with occasionally some fine, clean, sand-free clays that indicate swamp conditions of deposition. In several places the sandstone beds in particular show well-preserved ripple marks, worm trails, mud tracks, etc., indicating that some of these beds, at
least, were deposited in shallow waters such as tidal flats, or floodplains that were not submerged at all times.

The limestone beds, while more numerous and persistent in the western part of the county, are not uniform in thickness or in character along their outcrops. Usually, however, the more important beds have some distinguishing characteristic that is of aid in their identification. In some it is the color or thickness of the bed compared to those above or below, in others it is the peculiar shape or appearance of weathered fragments along the outcrop, and in still others it is the abundance, or scarcity of fossils, or of some one specimen in one bed as compared to the adjacent beds that is the determining factor in identification of beds. It is noticeable that there is no limestone bed, at least to the writer's knowledge, that carries a representative fossil that is peculiarly characteristic of that bed and no other. Conditions of deposition during the Pennsylvanian and lower Permian times were quite uniform. Changes in the fauna during this period took place gradually and without any abrupt breaks. The vertical range of several of the species extends well across the upper Pennsylvanian into the lower Permian. In the eastern half of the county the limestones are much less numerous than in the western half, and are thin and not at all prominent in the section. Usually, however, they form very desirable and welcome "key beds" among the many lenticular, cross-bedded and short sandstone lenses. In the extreme northeastern part of the county in Tps. 27, 28 and 29 N., and parts of Rs. 11 and 12 E., the writer found several small, thin "irritating" limestone lenses that appear in short poor exposures which have no distinguishing characteristics and whose only value in structural mapping is to lead geologists to regard the thin to massive lenticular sandstones more favorably as horizon markers.

The sandstone beds are, without exception, lenticular, and most of them show pronounced cross-bedding. They vary in hardness and the amount of cementing material, in color and size of grains, and the percentage of heavy minerals. Some of the beds appear to have been deposited under deltaic conditions, show pronounced forsetting and unsorting of grains, as in the extreme southeastern corner of the county; others are made up of fine to medium-sized grains, are highly calcareous and grade locally into rather pure limestones. Few of the individual beds cover a large area or can be traced more than a few miles continuously. As a rule, the sandstone beds do not occur alone but are usually associated with other lenticular beds that occupy a zone in which sandstones predominate. Such zones are separated by comparatively thick shale intervals. Some of these sandstone zones can be traced more or less continuously across the county. The value of the beds in these sandstone zones for structural mapping depends upon the ability of the geologists to distinguish one short lens from another and the varying interval between such lenses. In some cases the fossil content of a bed will aid in its identification, in others the peculiar type of ripple marks, worm trails, concretionary features, or shape of the weathered blocks or fragments will be local characteristics of value in making cor-

relations over short distances. The thickness of any individual bed may be helpful, though some of the thick sandstone lenses vary abruptly in thickness. The shale interval between one bed and that above or below it in a sandstone zone is often helpful, though here again the interval may vary rapidly. At the best, detailed structural mapping, especially in the southeastern part of the county, is difficult and tedious work. In some areas it is doubtful if the results obtained are worth the effort.

The shale beds, except in the extreme western part of the county, are of somber colors, usually dark gray, yellow to drab, dark-blue, and occasionally black. They change in character as well as in color over short distances. A clean gray-blue shale on one hillside may change to a dark brown, sandy shale on the next hill. Some of the shale beds are quite uniform in thickness over a large area and this uniform shale interval is often a great aid in correlating key beds. Most of the continuous shale horizons thicken a little to the south and in the southeastern part of the county some of them become quite sandy.

No attempt has been made to write a description of all the formations or beds exposed at the surface in the county. In the list that follows the writer has endeavored to give a brief description of the more important beds that have been found useful for structural mapping. These are called "key beds." It is not pretended that this list is complete and it is quite possible that some important key beds in local areas have been omitted.

The classification followed is that given by Gould. The only member of this formation that outcrops as a suitable key in Osage County is the Herington limestone. Correlation: Equivalent to the formation of the same name in the Kansas section.

Character: This is a light gray to buff colored limestone 55 feet above the Winfield. In places there are three beds separated by 6 to 14 feet of red shale. The upper two beds are not persistent and only the lower bed about 5 feet thick was used for a key bed. It breaks up into rather massive blocks and is usually underlain by a massive sandstone directly below it.

Occurrence: Outcrops only in the western part of the bend of the Arkansas River in T. 25 N., Rs. 2-3 E., where it closely parallels Winfield limestone outcrops.

CHASE GROUP

The Winfield, Fort Riley, and Wreford limestones form the principal markers in this group in western Osage County. Correlation: Equivalent to the Kansas formations of the same name.

Character: This limestone lies at the top of the Chase group and about 165 feet above the Wreford. It outcrops only in a small area in the extreme western part of the county as a dull, reddish-gray, argil-
laccous limestone 4 to 5 feet thick. Its outcrop is not continuous and is hard to follow. There are one or two similar, but thinner, beds below it and one above it which were not followed.

**Fort Riley Limestone Member**

**Character:** Some 20 to 30 feet above the top of the Wreford limestone in Tps. 25-26 N., R. 4 E., there is another bed of rather massive, buff-colored limestone averaging 6 feet in thickness. It looks much like the Wreford but carries much less chert. To the south it thins and grades into sandstone. It is not shown on the map as in all exposures its outcrop is close to that of the Wreford limestone.

**Correlation:** The Fort Riley is here correlated with the limestone of the same name in the Kansas section.

**Wreford Limestone Member**

**Character:** This member lies from 90 to 120 feet above the Crouse limestone. In the northern part it outcrops as three beds. The middle bed is buff colored and full of chert. The lower bed is gray to yellow in color and decreases in thickness to the south. It contains some limonitized spots, no chert, and locally changes into a calcareous sandstone. The upper bed is gray to light yellow in color, and looks very much like the Crouse limestone. It varies from 6 to 14 feet in thickness and is thickest near the Kansas line.

**COUNCIL GROVE GROUP**

**Character:** The only reliable persistent beds in this group are the Cottonwood limestone at the base and the Crouse limestone at the top. The remaining beds, sometimes called the Garrison formation, consist chiefly of vari-colored shales with a few limestone lentils.

**Correlation:** Equivalent to the Kansas formations of the same name.

**Crouse Limestone Member**

**Character:** This is a thin but rather conspicuous limestone lying from 120 to 140 feet above the Cottonwood limestone. It varies from light gray in the northern part to a light orange color in the southern part of its outcrop. In many exposures it shows small limonitized concretions and this with the large, conspicuous, massive slabs into which it breaks up, are its chief characteristics. Locally it is full of *Fusulina* and usually shows a highly fossiliferous layer near its base. It varies from 2 to 12 feet in thickness, being thickest in the central and northern part of its outcrop. The Crouse limestone occurs as outliers in a few places along the boundary line between Kay and Osage counties in Tps. 27-29 N., R. 5 E., capping escarpments.

**Cottonwood Limestone Member**

**Character:** The Cottonwood limestone is a gray to light yellow, crystalline limestone in the upper part, changing to argillaceous and oolitic limestone in the lower part. It has a slight greenish to pinkish cast, and a rough weathered surface. The thickness varies from 2 to 6 feet and it lies from 80 to 110 feet above the base of the Neva limestone.

This limestone, the Neva limestone, and all the other principal limestone horizons in the Permian section of Osage County, take their names from localities in Kansas and have been described in the reports of the geological survey of that state in considerable detail. It does not form conspicuous outcrops and in places is hard to find.

**ESKRIDGE SHALE**

**Character:** The Eskridge shale consists principally of vari-colored shales, lenticular sandstones, and a few interbedded thin limestones, but none that form reliable horizon markers. Its thickness varies from 40 to 60 feet.

**Correlation:** Same age as the Kansas formation of that name, and equivalent to the top of the Wabaunsee formation in the Kansas section.

**Neva Limestone Member**

This formation is classified by Beede as the base of the Permian, but later work by the U. S. Geological Survey places it in the late Pennsylvanian and it is here so classified.

**Character:** In most exposures the Neva limestone consists of three or more distinct limestone beds separated by shale. The basal bed is from 3 to 5 feet thick of massive limestone weathering white to straw color and with very few fossils. It usually forms the main bench of the series. The middle bed is 6 to 15 feet thick and consists of thin platy, soft, dirty yellow cherty limestone full of *Fusulina*. It does not form any prominent benches, breaks down easily and is separated from the upper and lower members by beds of shale that increase in thickness and become somewhat sandy to the south. The upper bed is from 3 to 6 feet thick, though the full thickness is seldom exposed. It is a hard white limestone, showing some *Fusulina*, and a little chert. Its chief characteristic is that it is very soluble and the upper surface is very sharp and jagged. The following section is from Beede.

**Section of Neva Limestone, 4¼ miles south of Grainola.**

3. Massive bed of hard limestone weathering with extremely jagged surface through solution 6 0
2. Thin bedded soft stone with frequently marly partings not exposed on hill slopes. *Schwagerina* 15 0
1. Massive limestone bed not weathering as rough as No. 3. 4 8

The thickness of the group varies from 20 to 40 feet and it lies from 110 to 115 feet above the Foraker limestone. The Neva limestone forms escarpments in the hills west of Remington in T. 25 N., R. 5 E., and finally disappears under the sand of the Arkansas River Valley near the west side of T. 24 N., R. 5 E., west of Fairfax. In its southernmost exposures the limestone becomes thinner, more sandy and less cherty, while the intervening shales thicken and carry lenses of sandstone.

**Correlation:** A continuation of the Neva limestone of the Kansas section.

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ELMDALE FORMATION

The only good persistent limestone in this formation in Osage County is the Red Eagle limestone.

Red Eagle Limestone Member

Character: A gray limestone that weathers nearly white with occasional yellow spots and streaks due to limonitic material in the bed. In places where the beds are the thickest there are several individual limestone beds separated by shale. It is of variable thickness ranging from 6 to 20 feet, though in the thickest parts only the upper 10 feet or so are visible. It contains few or no fossils, lies 45 to 80 feet above the Foraker and 50 feet or more below the base of the Neva limestone. Because of its position near the Neva limestone its exposures are not very prominent.

Correlation: Equivalent to the upper-middle of the Wabaunsee group of the Kansas section.

This formation is described by Gould7 as follows:

Two prominent limestone members, the Grayhorse, 4 feet thick at the base, and the Foraker, 60 to 110 feet thick at the top, with intervening shales and thin sandstones. Includes at base the Grayhorse limestone member.

Correlation: The formation is equivalent to the middle part of the Wabaunsee group of the Kansas section.

SAND CREEK FORMATION

Character: This limestone or series of limestones, sandstones, and shales make up half the entire thickness of the Sand Creek formation. It is divided into three groups for purposes of description. The aggregate thickness of these groups is from 100 to 110 feet.

The lower group consists of two thin limestones and 35 to 40 feet of shale. The two limestone beds are near the base; the lower one which is about a foot thick, weathers to a dirty yellow, slabbly bed containing Fusulina, a few crinoid stems, and brachiopods. It is succeeded by 8 to 10 feet of dark shale. The upper thin bed is a dense, fine-grained, almost black, slabbly limestone carrying small Fusulina. Both of these limestone beds are resistant to erosion and are often well exposed at the top of the Foraker.

The middle bed contains 2 to 4 feet of dense, fine-grained, dark colored limestone, containing many Fusulina. It is overlain in the southern part of its outcrop by a rather thick, massive sandstone which thins to the south and disappears.

The upper part consists of three distinct limestone beds separated by thin beds of shale. These shale beds vary from a few to 10 or 15 feet in thickness. The limestones are all light colored, the topmost bed weathering with a smooth, light gray surface showing few or no Fusulina. In the other two beds the Fusulina are very abundant. These upper limestones form a steep eastward-facing escarpment. In the northern part of its outcrop two or more beds are shown in places as on the upland prairie the uppermost bed is often so far back from the rim of the escarpment that it cannot be accurately mapped. In the southern part the upper bed was traced as the key bed. The Foraker limestones form some valuable horizons for structural mapping but are often difficult to follow accurately.

Character: It is characteristically a dirty, dark gray, crystalline to conglomeratic limestone from 2 to 4 feet thick. It contains many small pebbles up to one-fourth inch in diameter, mostly of shale, which weather out and give the surface a spotted appearance. It breaks up into large thin slabs but does not form any conspicuous scarp. A species of large Myalina is abundant in it in many places. It lies from 80 to 90 feet above the Stonebreaker limestone. In the area of its outcrop it is a thin, persistent, and easily recognized key bed.

BUCK CREEK FORMATION

This formation takes its name from the Buck Creek limestone in northern Osage County. It includes those limestones, shales, and a few sandstones lying above the top of the Pawhuska formation and below the Grayhorse limestone. The principal key beds are described below. Correlation: Equivalent of the lower part of the Wabaunsee formation of the Kansas section.

Stonebreaker Limestone Member

Character: This limestone takes its name from the Stonebreaker ranch in the western part of T. 29 N., R. 8 E., where it is well exposed. It varies in thickness from 4 to 16 feet in the northern part to 50 feet or more in the southern part of the county. As it increases in thickness to the north it changes in appearance and character to some extent. In the northern part it consists of one to three beds separated by rather thin shale intervals. These beds vary from light to dark gray in color. Fossils are scarce, there are a few Fusulina and some Cryptozoa in a dark colored upper bed that looks somewhat like the Cryptozoa limestone below. In the southern part of its outcrop the Stonebreaker consists of three distinct beds separated by a greater thickness of sandy shale and shale with some persistent ledges of sandstone. Some of these limestone members are 10 feet thick or more. They are usually lighter in color, weather out differently, and are softer. The lower bed has layers that vary in hardness. The middle bed is thickest, quite soft and sandy, and shows a few Fusulina. The upper bed is poorly exposed, lies on top of a persistent sandstone, and according to Bowen and Roundy,8 "A species of large Myalina is sparingly distributed in this bed." In the central part of the outcrop of the Stonebreaker there are some sandstone beds forming prominent ridges and escarpments above the Stonebreaker limestone. Because of its persistence and widespread distribution this limestone forms a valuable marker over a wide belt across the county.

7. Gould, Chas. N., op. cit., p. 79.
OIL AND GAS IN OKLAHOMA

Cryptozoan-Bearing Limestone Member

Character: The Cryptozoan-bearing limestone is similar in appearance to the underlying Turkey Run and Bird Creek limestones and to the numerous thin limestone lenses in the shales immediately above and below it. It is rather dark gray on weathered surfaces and a dark blue-gray on fresh fracture. Its principal characteristic and the one from which it takes its name is the occurrence of numerous Cryptozoa markings which are described by Heald\(^9\) as follows:

The feature which makes it easily recognized is the presence of Cryptozoan, irregular forms that are the fossil remains of organisms whose nature has not been precisely determined. In many of these forms it is possible to detect a bryozoan, a fragment of shell, or a fragment of crinoid stem near the center. These fossil remains were apparently the nuclei around which the Cryptozoa formed.

In the southern part of the area the Cryptozoa forms are more rare but Bryozoa occur more abundantly and are better developed serving to distinguish this limestone from those near it. It varies from 1 to 3 feet in thickness though locally it may be considerably thicker. It outcrops in open grass country usually on a slope below more prominent beds and is difficult to trace as a continuous bed, though it is probably present below the surface soil. Locally there are several limestone lenses and some rather prominent sandstones above and below it in the section that can be used in structural mapping. These sandstone ledges and probably some local unconformities in the underlying shale account for the large variation in interval (10 to 110 feet) between the Cryptozoan-bearing and the underlying Bird Creek limestones.

Character: This limestone is very similar in character and appearance to the Turkey Run limestone, though usually darker in color on both weathered and fresh surfaces. It breaks up into thin slabs or plates and is very brittle. On fresh fracture it is almost black. It is more fossiliferous than the Turkey Run limestone, contains few or no Fusulina but locally shows an abundance of brachiopods of which according to Heald and Mather\(^10\) the brachiopod, Entelletes hemiplicata, is a type fossil. It varies from 1 to 4 feet in thickness. It is well exposed around the head-waters of Bird Creek from which it takes its name. It lies from 50 to 65 feet above the Turkey Run and from 50 to 110 feet below the Cryptozoan-bearing limestone. In the area of its outcrop it forms a valuable bed for structural mapping.

Turkey Run Limestone Member

Character: This member is a thin, persistent, steel-blue, brittle, fine-grained limestone from 1 to 3 feet thick. It outcrops about 30 feet above the "red line" in the northern part of the county and from 40 to 60 feet below the Deer Creek limestone in the southern part. It weathers into rather thin, irregular, wavy fragments of a light gray color. When struck with a hammer it has a light ring. It is less distinguishe from some of the similar limestones above it by the lack of well preserved fossils other than a small species of Fusulina. When once recognized it makes a valuable key bed because it is thin and persistent.

Pawhuska Formation

Character: This formation consists of four or more limestone members separated by intervening shales, some of which are very persistent and others more local in character. Its thickness varies from 110 to 175 feet. The principal key beds in this group are from the bottom up, as follows: the Okeetee limestone lentil of local distribution; the Lecompton limestone, equivalent (?) to the Kansas formation of that name and the most persistent of the entire group; the Plummer limestone, which consists of two thin beds found just below the base of the Deer Creek in the northern part of the area; the Deer Creek limestone, the thickest member and the most variable in character and thickness; the Little Hominy limestone sometimes called the upper Fusulina-bearing limestone and inclined to grade into sandstone to the south; and the Red limestone member here considered the top member of the Pawhuska formation.

Correlation: Equivalent to the upper part of the Shawnee group of the Kansas section.

Red Limestone Member

Character: This member is classed as the highest bed in the Pawhuska formation. The following description is from that of Heald.\(^11\)

The most frequently observed color of the weathered surface of the "red line" is a distinctive brownish gray; that of the fresh surface a blue-gray with a reddish tinge. The greatest observed thickness of this bed is 7 feet, but the maximum thickness may be considerably greater, as the base of the bed is in most places concealed. In fact, as a rule the bed does not appear as a ledge but as a line of disconnected fragments of float. The rock is very hard and brittle and under a heavy blow splits with a sharp, clean fracture. The bedding is massive, and fragments of float may be of considerable size and are characteristically of irregular form. The distribution of fossils in this bed is far from uniform.

Correlation: It is possibly the equivalent of the Howard limestone in the Kansas section.

Little Hominy Limestone Member

Character: A light gray limestone lying from 12 to 30 feet above the Deer Creek limestone. The following description is taken from that of Heald and Mather.\(^12\)

Typically the Little Hominy limestone is light gray on the weathered surface, somewhat darker where freshly broken, and very coarsely crystalline. In many places the uppermost 3 to 6 inches of this member consists of very immature concretionary limestones containing many shell fragments. At certain localities well-preserved Fusulina, brachiopods, gastropods, and other organisms are present, but at most places good fossils are lacking.

This member occurs as a lentil from 3 to 15 feet thick in Tps. 25-27 N., R. 8 E. To the south it becomes more sandy and converges to.

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wards the underlying Deer Creek and finally disappears. It is not shown on the accompanying map, except for a short distance in the southern part of T. 26 N., R. 8 E., as in most places, its outcrop is too near that of the underlying Deer Creek limestone.

**Deer Creek Limestone Member**

**Character**: This is the thickest and most conspicuous limestone of the Pawhuska formation and is the bed to which the name Pawhuska limestone was originally applied. Its type locality is a few miles west of Pawhuska. It is a gray, fossiliferous, thin-bedded limestone which in the hard, more resistant phases forms prominent ledges. Where it is softer or more sandy it forms sloping terraces. The most distinguishing characteristic along the outcrop is where the more resistant lower beds weather out into large irregular white slabs of limestone and the rather persistent dark rusty bands in the upper part. In the southern part of its outcrop it varies rapidly in character and thickness, and seems to converge towards the overlying limestones.

In T. 24 N., R. 8 E., the lower beds become sandy and the upper beds change in appearance and converge towards the sandy overlying Little Hominy limestone horizon. From T. 23 N., R. 8 E., southward, the bed shown on the map as Deer Creek is the one questionably referred to as Lecompton (?) limestone by Bowen, et al. in Tps. 21-22 N., R. 8 E., and sometimes locally known as the "Hominy lime." Because of the gap in Tps. 23-24 N., R. 8 E., this southern correlation is, the writer admits, somewhat doubtful... It is based mainly on intervals and similar lithological characteristics in the two beds. As a rule the Deer Creek forms a poor marker, except locally as in T. 25 N., R. 8 E. The thinner limestones above and below form much better key beds.

**Thickness**: It varies from 8 to more than 30 feet in thickness, thinning and becoming more sandy to the south.

**Correlation**: Probably equivalent to Deer Creek limestone of the Shawnee formation in the Kansas section.

**Plummer Limestone Member**

**Character**: This member usually consists of two thin beds of limestone each about one foot thick, separated by 4 to 7 feet of shale. Both beds are made up of fine, dense limestone, dark gray to steel gray on fresh surface and weathering to brown or yellowish-gray. Except for a lot of small *Fusulina* it is sparsely fossiliferous. It breaks up into sharp angular blocks, and the upper bed as a rule forms the best outcrop. It is usually present in the slope below the bench formed by the Deer Creek limestone that lies 15 feet or less above it. Because of its proximity to the overlying Deer Creek it is not shown on the map. However, locally its upper bed forms a better marker than the thicker overlying limestone.

**Lecompton Limestone Member**

**Character**: This member consists of from one to three beds, separated by beds of shale. It is hard and not very fossiliferous, except in some places. According to Heald the large coral, *Campophyllum torquium*, is the principal fossil. In color it is gray to light yellow on weathered surfaces and breaks up into large blocks that do not disintegrate readily and may be found some distance down from the outcrop. Where two or more beds are present the lower one usually forms the best marker or key bed. This limestone generally outcrops as a low bench near the base of the Deer Creek limestone escarpment and a short distance above the Elgin sandstone. It varies from 3 to 15 feet in thickness.

**Okej Limestone (1st evil) Member**

**Character**: A thin gray to buff limestone in the lowest part of the Pawhuska formation, and usually not more than ten feet above the top of the Elgin sandstone. It has little value as a key bed in the areas where the persistent Lecompton limestone member is present. Not shown on the map with this report.

**Elgin Sandstone**

**Character**: The Elgin is a massive, medium- to fine-grained sandstone and the most persistent individual sandstone bed in the county, extending entirely across it from north to south. In some places it outcrops in one massive bed 60 feet thick or more. It varies in thickness and usually where this member is thickest it also has the greatest number of included shale lenses. Most of these shale lenses are varicolored, being bright red, light crimson, olive green, etc., and they are also very variable in thickness. Usually they are from 1 to 10 feet in thickness but occasionally a lens 30 feet or more thick occurs separating the massive sandstone outcrops into two well defined benches. This sandstone gets more shaly to the north and in Kansas finally grades into shale.

**Thickness**: It varies in thickness from about 140 feet of massive slightly sandy sandstone near the town of Elgin, north of sec. 14, T. 29 N., R. 10 E., to over 220 feet in parts of T. 23 N., R. 8 E. In this last area a measured section showed over 30 per cent of included shale.

**Correlation**: Equivalent to the basal part of the Shawnee formation of the Kansas section.

**Remarks**: Though the outcrop of the Elgin sandstone is not shown on the accompanying map, in Tps. 25, 26 and 27 N., R. 9 E., it crosses these townships in a wide belt of scattered sandstone outcrops. In T. 24 N., R. 9 E., there is a thick persistent shale lens 45 feet thick or more which runs across most of T. 23 N., R. 8 E. This separates the massive sandstone into distinct beds each of which forms prominent escarpments that can be traced for some distance beyond T. 23 N., R. 8 E. Still farther south in Tps. 21-22 N., R. 8 E., the top of the upper bed forms a fairly reliable key bed, though there is some overlapping of sandstone ledges. The base of the formation overlies a thick bed of yellowish-gray to drab colored clay which forms a reliable key horizon along most of the escarpment capped by the basal sandstone.

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NELAGONEY FORMATION

Upper Oread Limestone Member

Character: In the northern part of the county, near the Kansas line, the upper or top member of the Oread limestone outcrops as a thin-beded, gray, ledge-forming limestone from 6 to 8 feet thick. Its outcrop on Artillery Mountain in the SW 34 sec. 21, T. 29 N., R. 10 E., is easily found and forms a typical exposure. At this place it lies about 25 feet above the middle bed of this limestone. The interval in T. 29 N., R. 10 E., increases to the south and finally this upper limestone thins rapidly and disappears in the thickening shales and sandstones at the base of the Elgin sandstone. It is not a good marker even in the best part of its outcrop.

Middle Oread Limestone Member

Character: The Middle Oread is the lowest member of the Oread lime of the Kansas section present in Osage County. It is a fine-grained, blue limestone that weathers a muddy yellow color and breaks up into wedge shaped slabs. Other than lots of Pumolina it contains few fossils. It varies in thickness from 1 to 2 feet and locally thins to a few inches.

In the southern part of its outcrop there are several gaps, due to the thinning of the bed and covering by talus material from above. In many places where this limestone thins to a mere stringer, the dark gray shales immediately below are a good guide to its position and in the southern part of its outcrop are often better markers than the thin limestone which may be concealed for considerable distances. Neither the limestone nor adjacent shales were traced south of T. 24 N., R. 9 E. The base of the Elgin sandstone, a few feet above, forms a more persistent and easily followed key bed.

The Wynona Sandstone (Group) Member

Character: This name is given to a series of lenticular sandstones in the upper part of the Nelagoney formation. The group as a whole extends from Arkansas River to the Kansas line, but it cannot be traced continuously except by adjacent key beds. The sandstone beds have few distinguishing characteristics, and individual beds cannot be traced more than a few miles. They thin very rapidly, and as one lens pinches out, another usually comes in a short distance below or above.

The various beds in this group are similar in appearance to the other sandstones in the Nelagoney formation, and except those that are described separately they have no distinguishing characteristics. The individual lenses are thinner, less numerous and finer grained to the north. Most of the intervening shales in this group are red in color. Locally there are some short, thin arenaceous limestone lenses which are of little or no value in correlation or in determination of geologic structure, as they occur at irregular intervals and are usually so poorly exposed that they cannot be traced for any considerable distance. The Bowman (and Jonesburg) sandstone is considered as a part of this group.

Thickness: The thickness of the entire group is variable. In the northern part of the county, from the base of the Bowman sandstone upward to the base of the Middle Oread limestone, the thickness is approximately 120 feet, of which over half is shale. In T. 26 N., R. 10 E., a thickness of 150 feet has been measured, the greater part of which is shale. In the vicinity of Wynona, the Wynona sandstone, including the Fourmile sandstone member, has a thickness of 100 feet, most of which is sandstone. South in T. 22 N., R. 10 E., the sandstone is split up into several lenses separated by shale beds of variable thickness. In this locality, the sandstone, from the top of the Wildhorse limestone to the top of the sandstone lying under the gray to dark blue-gray shales below the Elgin sandstone, has a total thickness of 160 feet or more.

Occurrence: The only members of this group that form valuable key beds are described separately. A few short sandstone lenses in Tps. 27-28 N., R. 10 E., are shown on the map. They are short lenticular beds and occur but a short distance below the persistent Middle Oread limestone. Several similar lenses occur in Tps. 25-26 N., R. 10 E., but are not described and many of them not mapped, the underlying Laladie and overlying Oread limestones form much more desirable key beds. The Fourmile sandstone, described separately, is about the best and most persistent member of this group. South of the town of Wynona the upper part of this group, and south of Hominy all of the group split up into many overlapping lenticular beds, none of which have any distinguishing features. The mapping of the more prominent of these beds on the accompanying map is true only in a general way.

Four-Mile Sandstone Member

Character: The following description is that given by Bowen:

The basal bed of this sandstone is distinguished from other sandstones in this part of the section by being coarse and gritty, resembling the basal part of the Bighearth sandstone, but it differs from the Bighearth in not being conglomerite. It is also immediately underlaid by gray shales whereas the other shales in this part of the section are prevailing red.

Thickness: In Tps. 23-24 N., R. 10 E., the Fourmile sandstone lies from 15 to 30 feet below the other sandstones in the Wynona group. The lower bed consists of a massive sandstone 25 feet thick in its greatest development in sec. 30, T. 24 N., R. 10 E., and thinning to the north and south. The upper beds are very variable.

Remarks: The basal member can be traced from NW, cor. T. 24 N., R. 10 E., to SE 1/4 T. 23 N., R. 9 E., where it is split up into two or more beds by intervening shale wedges. Some short lenticels of the Fourmile sandstone can be traced farther south into Tps. 21-22 N., R. 9 E., but they have no identifying characteristics and are marked on the map only to give their relative sequence in the Wynona sandstone group or series.

Cochasee Sandstone Member

Character: A dark colored, hard, massive sandstone, locally fis-siliferous in the upper part with a rough, wrinkled weathered surface at the top of the bed. The member varies in thickness from 3 to 15 feet or more.

**Correlation:** Equivalent to middle (?) bed of the Fourmile sandstone.

**Bowman Sandstone Member**

**Character:** South of Caney River the lower of two sandstones which make up the Bowman member is the only one exposed. It is here a thin, rather slabby, persistent sandstone which weathers to a dark brown color, sometimes a dark yellow locally. It caps the ridges in the area of its outcrop in T. 28 N., Rs. 10-I1 E., and is easily recognized as the first thin persistent sandstone at the top of the thick shale series that lies above the Cheshewalla sandstone. North of Caney River this lower member is much the same in appearance, but considerably thicker in outcrop. The upper member is the equivalent of the Jonesburg sandstone of Goldman and Robinson. It is from 15 to 30 feet above the lower member in T. 29 N., R. 10 E., but does not have any well defined characteristics to distinguish it from the sandstones above and below it, except in the northern part near the Kansas state line where the top of this bed often shows many deep ripple marks. It varies in color from dark brown to yellow, and is normally from 5 to 10 feet thick, though locally it may be 20 feet or more thick.

This sandstone is the principal and only persistent bed outcropping in the west-central part of T. 28 N., R. 11 E., where it caps most of the ridges. It thickens to the west and dips under the lenticular, unnamed sandstones in the central and eastern part of T. 28 N., R. 10 E.

**Correlation:** These two members of the Bowman sandstone appear to be the equivalent of the basal members of the Chautauqua sandstones. The writer also believes that these two members of the Bowman and the unnamed sandstones in the central part of T. 28 N., R. 10 E., lying as they do above the Labadie limestone and below the Middle Oread limestone are the northern equivalents of the Wynona sandstone group.

**Wildhorse Limestone (Lentil) Member**

**Character:** A yellowish to light gray, very fossiliferous limestone; sandy and rather soft where thin, but a hard, nearly pure limestone in its thickest part. It varies in thickness from a foot or less at the north end of its outcrop to a maximum of 20 feet in the thickest part.

Most of the following data were obtained from R. H. Wood. Its most northerly outcrop is in the shales between the top of the Bigheart sandstone and the base of the Fourmile sandstones in sec. 27, T. 23 N., R. 10 E., where it occurs as a thin yellowish sandy limestone. It thickens rapidly to the south to 20 feet in cliff-like escarpments on each side of Honiny Creek Valley in the northwestern part of T. 22 N., R. 10 E. Farther south in T. 21 N., R. 10 E., it thins, becomes very sandy locally and finally disappears or merges with the overlying sandstones. Near the northern end of its outcrop it lies 30 to 50 feet below the top of the overlying shales. To the south, as it thickens, the overlying shales gradually pinch out and in T. 22 N., R. 10 E., the overlying sandstones lie close to, or directly upon the limestone.

**Labadie Limestone Member**

**Character:** This is the first persistent limestone lentil below the Oread limestone member. It varies both in thickness and in appearance along its outcrop. The best exposures are found in the western part of T. 27 N., R. 11 E., where it appears as a light gray, rather dense, slabby limestone. On fresh fracture it is blue-gray in color. Farther south the upper part is yellowish to dark brown in color and in T. 26 N., R. 10 E., it often has a brownish-red color throughout its entire thickness. It breaks up into rectangular slabs 2 to 4 feet broad and about 4 inches thick. It is very fossiliferous in the northern part of its outcrop and a little less so in the southern part.

**Thickness:** In T. 27 N., R. 11 E., the maximum thickness is about 20 feet but it thins rapidly to the north and northwest and less so to the southwest. In T. 26 N., R. 10 E., it is from 5 to 10 feet thick, farther south in T. 25 N., R. 10 E., it splits into two beds each about 2 feet thick and separated by 6 to 8 feet of shale.

**Correlation:** The two thin limestones, 8 to 10 feet apart and about 15 feet below the base of the Fourmile sandstone in T. 24 N., R. 10 E., are here correlated as 'the' probable equivalents of the Labadie limestone north of Bird Creek, though they are not shown on the map with this report.

The only other correlation the writer has attempted, and that a tentative one, is with the Wildhorse limestone lentil in Tps. 22-23 N., R. 10 E. From present information the Wildhorse would appear to lie a little lower in the shale interval between the base of the Fourmile and the top of the Bigheart sandstone group. However, this shale interval varies considerably and it is possible that the Labadie and Wildhorse limestones lie in nearly the same horizon.

**Cheshewalla Sandstone Member**

**Character:** The Cheshewalla sandstone is very similar in appearance to the sandstones above and below. It is rather fine-grained, cross-bedded sandstone that usually occurs as one massive bed, though locally it has included lentils of gray and red shale. The top of the bed is the best marker, for it often contains many casts of fossils and imprints of *Fusulina*. In T. 29 N., Rs. 11-12 E., and at a few localities in T. 28 N., R. 11 E., an impure fossiliferous limestone of variable thickness lies either directly on, or is separated from this sandstone by a few feet of shale. This impure limestone is correlated as the Iatan (?) limestone of the Kansas section by Goldman who describes it as follows:

The Iatan (?) limestone, which lies from 100 to 180 feet below the top of the Cheshewalla sandstone, is an impure limestone, in some places as much as 7 feet thick and in others represented merely by impression of fossils on the upper surface of the underlying sandstones (Cheshewalla). "This variation in thickness is characteristic of Iatan (?) limestone ... *Fusulina* is the most characteristic and easily recognizable fossil in the limestone ..."


17. Wood, R. H., Personal communication.

The scattered exposures of this limestone which are always directly on top of, or within a few feet of the top of the Cheshewalla sandstone, are of great aid in locating the top of the sandstone in the townships described.

**Thickness:** The Cheshewalla sandstone varies from 20 to 50 feet in thickness. At most places in T. 29 N., R. 12 E., it is 20 feet or less in thickness. In T. 25 N., R. 10 E., it is 50 feet in thickness, but this increase in thickness from north to south is not uniform.

**Remarks:** In the northeastern part of T. 28 N., R. 10 E., and of T. 29 N., R. 10 E., the Cheshewalla sandstone, as shown on the map with this report, is in reality the outcrop of the thin Possum-bearling Tatan (?) limestone which lies just above the Cheshewalla. The sandstone outcrops across the northwestern part of T. 27 N., R. 11 E., and the SE. cor. T. 27 N., R. 10 E. It is well exposed at places in the east-central part of T. 26 N., R. 10 E., but on the map which the writer examined, it was not differentiated from other sandstone outcrops so is not shown in the township on the map with this report. It is well exposed as a thick massive bed in the central part of T. 25 N., R. 10 E., both north and south of Bird Creek, which it crosses just below the town of Nelagoney. The Cheshewalla sandstone usually lies 60 to 70 feet below the Labadie limestone where both members are present.

**Revard Sandstone Member**

**Character:** The Revard sandstone member is well developed in the northeastern part of T. 26 N., R. 10 E., which is considered its type locality. Where exposed in that area there is a nearly continuous thickness of sandstones of approximately 200 feet. This thickness includes part if not all of the Bigheart Group, of which the Revard is considered as an overlapping lens. Of this great thickness the Revard sandstone as here mapped and described, consists of only the upper 20 to 50 feet of sandstones. It is a massive unevenly bedded lenticular series of siliceous sandstones, highly cross-bedded and with a very rough or uneven surface, and carries many included boulders of shale usually red in color. It is one of the longest continuous sandstone horizons in the eastern part of the county below the Elgin sandstone and also one of the most difficult to use in mapping of detailed structures. To the north it thins out and is separated into individual beds by thickening shale intervals. The widely separated sandstones, called the Mission, Possum or Hulah and Gap sandstones, are here considered as equivalent to the Revard and upper part of the rest of the Bigheart sandstone group. To the south in the southeastern part of T. 25 N., R. 10 E., it becomes one thick heavy bed of sandstone with a few lentils of light colored shales, and north of Bir-1 Creek it is provisionally correlated with the top of the massive cross-bedded ledge of Bigheart sandstones.

**Correlation:** The Revard sandstone, and the beds here correlated as being the northeast extension of the Bigheart group, show no lithologic characteristics to differentiate them from the sandstones above or below. Great care is necessary in structural mapping of this northerly area in order to check intervals and to trace out the many different sandstone beds.

**Remarks:** The shale interval between the top of the main Bigheart sandstone and the base of the Revard sandstone decreases from north to south. In the area described above the top or base of the main bed of sandstone and some of the shale lenses are the only horizons that can be safely used for structural mapping.

The Revard is well developed north of the type locality in the northwestern part of T. 26 N., R. 11 E., and shows in the SE. cor. T. 27 N., R. 10 E. It is wide-spread over the southern and eastern parts of T. 27 N., R. 11 E., where the top of it forms a valuable key horizon. To the east in T. 27 N., R. 12 E., it splits into two beds and the upper member outcropping in the northwestern part of the township is considered the equivalent of the Mission sandstone that outcrops in the southwest corner of T. 28 N., R. 12 E., and in part of T. 28 N., R. 11 E. The Possum and Hulah sandstones outcropping in the SE. cor. T. 29 N., R. 11 E., and in the southern part of T. 29 N., R. 12 E., are here correlated with the upper sandstones of the Revard-Bigheart sandstone group. The Gap sandstone, in the eastern part of T. 29 N., R. 12 E., is probably one of the most persistent sandstone lenses in the middle part of this group.

**Bigheart Sandstone (Group) Member**

**Character:** The Bigheart sandstones, beds of the Nelagoney formation, are made up of a series of massive cross-bedded ledge-making lenticular sandstone beds. The basal member is underlain by a bed of gray shale, locally red in the upper part. The top lenses are usually overlain by thin gray shales that often carry thin beds of slaty sandstones. In most places, at least to the south of the type locality which is west of the town of Barnsall (formerly Bigheart), the basal part is coarse grained to conglomeratic. In T. 24 N., Rs. 10-11 E., it forms two prominent benches, and in T. 25 N., R. 11 E., there are in places three benches. Farther south in Tps. 21, 22 and 23 N., R. 10 E., this group splits up into many short overlapping sandstones separated by shale beds of variable thickness. The group varies in thickness from 30 to 50 feet in T. 24 N., R. 10 E., and increases up to 70 feet or more in the southwestern part of T. 25 N., R. 11 E. Part of this total thickness is made up of shale intervals between the various lenses. North of T. 25 N., R. 11 E., the Buck Point sandstone, though described separately, is considered a part of the Bigheart group. Also the thin to massive lenticular sandstones between the Revard sandstone above and the Torpedo sandstone horizon below, which outcrop at many places in Tps. 27-28 N., R. 12 E.

In the area where best developed, Tps. 23-24-25 N., Rs. 10-11 E., it forms several prominent benches that can be used locally for mapping of geologic structure, as in the north-central part of T. 25 N., R. 11 E., south and west across the northwest part of T. 24 N., R. 11 E., the east side of T. 23 N., R. 10 E. In the southeastern part of T. 23 N., R. 10 E., it splits into several rather short massive lenticular beds separ-
ated by shale beds of varying thickness. In places there are six or more of these short lenses, present in one vertical section of the group. None of these short sandstone beds can be traced more than a few miles, many of them only one or two miles. This multiplicity of sandstone beds in the Bigheart group continues across the east half of Tps. 21-22 N., R. 10 E. It is impossible to trace any of these beds more than a few miles along the strike. Only the more important ones are shown on the map and no attempt has been made to name them. They are all grouped as Bigheart sandstones. For mapping of structure the top or bottom of the group is the only safe datum plane to use, even locally.

**Buck Point Sandstone Member**

**Character:** This bed, a part of the Bigheart group is described here because it is an excellent example of the thick, very lenticular sandstones which are so numerous in the eastern half of the county. It is a massive medium-grained, very lenticular, rather hard sandstone. It forms a prominent bench and escarpment in the central part of T. 26 N., R. 11 E. Its only distinguishing characteristic is a rather limy conglomeratic bed near its base, which however, cannot be traced continuously. It lies from 90 to 115 feet below the Revard sandstone to the west and over 100 feet above the Okesa sandstone in the northern part of its area, but approaches to within 60 to 70 feet of the Okesa sandstone south of Sand Creek. This rapid convergence and the lenticular character of the bed make it an unreliable key bed except for very local work.

**Thickness:** Its maximum thickness is about 45 feet at Buck Point in the central part of T. 26 N., R. 11 E. It thins rapidly to the south and grades into sandy shale. North of Buck Point it decreases to less than a third of its maximum thickness in a distance of two miles.

**Remarks:** As a key bed for mapping of structure it is of value only in the central and northern parts of T. 26 N., R. 11 E. In the SE. 1/4, T. 27 N., R. 11 E., a thin fossiliferous bed occurs practically at the top of the rapidly thinning Buck Point sandstone and is a valuable marker in that area. It is not shown on the accompanying map as its outcrop is practically the same as that of the Buck Point sandstone.

**OCHELATA FORMATION**

**Character:** This is one of the most variable of the limestones that outcrop in the county. In most of its northeastern exposures it is 40 feet thick, thinning rapidly to the south where locally it becomes quite sandy. Where thickest, the upper 3 to 5 feet usually consist of thin platy ferruginous limestone, very fossiliferous. The lower part is usually a massive blue to gray limestone with few fossils except locally. To the southwest, along the strike, it becomes more red in color and locally changes into a sandy limestone or a dark red sandstone.

It is the best and most persistent key bed to be found in the townships in which it outcrops, and also the best bed to use as a datum for structural mapping in these townships.

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A very good description of its occurrence in T. 20 N., R. 11 E. is that given by Lloyd and Mather who state:

It is extremely variable in thickness and in composition, but generally appears as a hard ledge forming a low cliff and bench along the hillsides. On wooded slopes, however, it may be entirely hidden beneath talus, soil, and vegetation for considerable distances along its outcrop. Its weathered surface is nearly everywhere a shade of brown or red, although certain beds within it are gray in some localities. The color on fresh fracture is ordinarily purplish gray, although this characteristic is also rather variable.

**Thickness:** In the northeastern part of T. 24 N., R. 12 E., a thickness of 40 feet or more is reported. In T. 22 N., R. 11 E., it is variable but in places 20 to 25 feet thick. To the southwest in T. 20 N., R. 10 E., it has decreased to 15 feet and in places considerably less. It is overlain and underlain by shale. The interval between it and the underlying Dewey limestone increases towards the south, while the interval between it and the next overlying key bed, the Clem Creek sandstone, in the southern part of its outcrop, decreases from north to south.

**Correlation:** Equivalent to Iola limestone of Kansas section.

**Clem Creek Sandstone Member**

**Character:** This sandstone, or really a series of lenticular sandstones and interbedded shales, is described by Emery as follows:

The beds here designated Clem Creek sandstone embrace a series of massive medium-grained sandstones and thin lenticular shales aggregating 60 to 85 feet in thickness and are exposed along Clem Creek in the northeastern part of T. 23 N., R. 11 E. This formation is limited below by the red limestone already mentioned, and its upper limit is the top of a massive bed of sandstone 18 feet thick, which is marked by a line of woods at the base of a grass-covered prairie developed on the overlying shale.

The above description applies particularly to the outcrops of this series of sandstones in T. 23 N., R. 11 E. Farther south the thickness of the massive sandstones decreases to less than half and the top seems to consist of a series of more or less overlapping lenses.

**Thickness:** The thickness given in T. 23 N., R. 11 E. is from 60 to 65 feet. In T. 22 N., R. 11 E. and on south it decreases to a maximum measured thickness of 20 to 25 feet for that part here classed as the Clem Creek sandstone.

**Remarks:** From T. 23 N., R. 11 E., to T. 20 N., R. 10 E., this sandstone forms the first persistent and valuable horizon marker west of the Avant limestone, but in many places one that is difficult to follow. Where there are usually one or more benches that can be easily followed, the variations in the sandstones and the included shale beds, as well as the overlapping of the uppermost lenses require careful and frequent checking to keep the different beds correctly placed in the sec-

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tion. The interval between the Clem Creek sandstone and the top of the Avant limestone decreases from over 250 feet in the northern part of its outcrop to 175 feet in the southern part. This variation of the shale interval increases the difficulties of structural mapping and makes it more desirable to use the Avant limestone as the datum bed wherever it is possible to do so.

Okeesa and Torpedo Sandstone Member

Character: These two members are described separately here as they occur as two separate units in the northern part of their outcrops, where they are the most useful for mapping. Farther south they come together into one group with very poor outcrops. The following description of the Okeesa member is from that of Clark. 21

In the vicinity of Okeesa it is confined to one bed which contains numerous pelecypods and a few brachiopods, but in most places within this area two benches are developed, separated by shale. The lower bench is generally massive and forms a ledge, and its upper surface contains fossils. A thin nodular limestone crops out at many places about 5 feet above the lower bench. The upper bench, which is from 10 to 15 feet above the lower, is thinner and not so well exposed, but wherever seen it contains many pelecypods.

The Torpedo is a massive cliff-making sandstone typically exposed in the prominent escarpments along the east side of T. 25 N., R. 12 E., in Osage County. It is massive, medium grained, ripple marked and breaks down into large angular blocks. Few or no fossils were found in it. The most characteristic features are the massive cliff-forming ledges. In T. 25 N., R. 11 E., the sandstone occurs as three distinct beds but they are not of much use in mapping structure except locally. The shale interval between it and the underlying Torpedo sandstone is from 30 to 35 feet or more in T. 26 N., R. 11 E., while to the south it thins and at the north line of T. 25 N., R. 11 E., the shale practically disappears so that the two sandstones cannot be definitely separated in mapping.

The Torpedo sandstone is well exposed in the eastern part of T. 26 N., R. 11 E., where it occurs as a single massive bed 60 feet or so below the Okeesa sandstones. Tracing it south to T. 25 N., R. 11 E., and southeast into T. 25 N., R. 12 E., it outcrops as two separate benches of which the lower is the more massive and persistent in outcrop. Farther south it merges with the Okeesa sandstone into one group of softer sandstones. The only desirable key bed in this merged group is the Birch Creek limestone lentil described below. To the north a sandstone correlated with the Torpedo occurs in isolated outcrops in Tps. 26-27 N., R. 12 E.

Birch Creek Limestone (Lentill Member)

Character: The writer has seen this bed in only a few places and the following is quoted from the work of Hopkins and Powers. 22

The Birch Creek limestone is a hard light to dark-gray crystalline, somewhat dolomitic limestone, which contains few fossils. Its high iron content causes it to weather on exposed surfaces to a rusty-brown color. This limestone, which ranges in thickness from 4 to 11 feet, is usually sandy, at least in part, and grading laterally into sandstone. Over much of the area traced it is really a limy phase of the sandstone.

According to Hopkins and Powers 23 the Birch Creek occurs as follows:

Above the 55 to 70 feet of shale which overlies the Clem Creek sandstone is another series of sandstones which is substantially the equivalent of the Okeesa and Torpedo sandstones to the north. At the base or at some places 12 to 15 feet above the base of this series of sandstones there is a sandy limestone, named the Birch Creek limestone. This limestone has been traced entirely across T. 24 N., R. 11 E., from east to west and over more than one-half its area.

From the above it seems to be a rather thin persistent limy phase in a thick series of lenticular sandstones, and because of its character and persistence it forms a more desirable key bed in the area covered than the thick massive lenticular sandstones. This reddish limy phase has also been noted in SE 34, T. 24 N., R. 10 E.

Red Limestone (Lentill) Member

This rather local limestone lentil is described by Hopkins and Powers 24 as follows:

From 8 to 20 feet above the top of the Fusulina-bearing limestone in the base of another limestone which because of large content of iron, usually weathers red on exposed surfaces. This limestone usually occurs in two benches, of which the lower is the more persistent and conspicuous. It is at most places a massive red or reddish-brown sandy limestone ranging from 8 to 20 feet in thickness: here and there, however, it is a purer limestone, is loaded with fossils, particularly crinoid stems, and is gray on exposed surfaces.

Fusulina-Bearing Gray Limestone Member

Character: The writer is not familiar with this limestone and the following description is taken from that of Hopkins and Powers, 25 who described its outcrop in T. 24 N., R. 12 E., as follows:

It is a gray to yellow thin-bedded to platy limestone from 2 to 4 feet thick. Its upper surface is covered with large Fusulina, which have much the shape and size of wheat grains, and its lower surface shows many Proodont and fragments of crinoid stems. Over a large area it appears to be characterized by the presence of a species of large Pinna. The interval from this lime stone to the Avant decreases from 115 feet in the southern part of T. 24 N., R. 12 E., to 30 feet near its northeast corner.

It is probable that the Fusulina-bearing sandstone described by Goldman 26 is the equivalent of this Fusulina-bearing gray limestone, described above, as it occurs about 90 feet above the Avant limestone

and is a hard slabby sandstone 3 to 5 feet thick. It is overlain and underlain by shale and usually shows many casts of *Pseudolina*.

**Occurrence**: This limestone as a mappable unit occurs only in the southeast corner and west side of T. 24 N., R. 12 E., and at various places in the north half of T. 23 N., R. 12 E. It outcrops in a few places in the townships to the south and southwest but not enough to be considered as a mappable unit.

**Panther Creek Limestone (Lentil) Member**

**Character**: The Panther Creek limestone lentil is the name given to a hard light colored impure siliceous fossiliferous limestone that outcrops as a useful key bed only in the west half of T. 26 N., R. 12 E. and a few places in the northern part of T. 25 N., R. 12 E. The U.S. Geological Survey also shows it in a few places along the east side of T. 26 N., R. 11 E. It varies from 2 to 12 feet in thickness.

**Correlation**: This lentil has been provisionally correlated with the Stanton limestone of the Kansas section and as a limestone lentil in the Torpedo sandstone group, at about the same horizon as the Birch Creek limestone in T. 24 N., R. 11 E. The writer is inclined to consider it the equivalent of the Avant limestone which is considerably lower in the section than the Birch Creek.

It is about the best bed that can be found for structural mapping in the vicinity of its outcrop, though the writer prefers using the top of the Dewey limestone, for a datum bed, which outcrops just east of the county line, or even the massive cliff-forming members of the Torpedo sandstone capping the hills above the Panther Creek limestone.

**DEWEY LIMESTONE**

**Character**: Coarse grained massive to locally shaly limestone. Fossiliferous, bluish-gray to slightly reddish in color. Its thickness is 10-12 feet in this county.

**Correlation**: Equivalent to the upper part of the Drum group, Kansas section.

**Remarks**: From 10 to 13 feet below the Dewey limestone there is a thin to massively flabby persistent sandstone and 50 to 55 feet below this bed a rather massive bench-forming sandstone lens. Both of these have better and more persistent outcrops for structural mapping than the overlying limestone. These are described by Lloyd and Mather as follows:

Immediately below the Dewey limestone and associated ferruginous sandstone is a group of sandstone beds with a total thickness of 75 feet or more. The higher beds of this group are flabby, the lower part massive. The topmost bench, which is 12 to 15 feet below the top of the Dewey limestone, capped the higher hills in the central part of the township (T. 20 N., R. 11 E.) east of Shell Creek. West of Shell Creek this upper sandstone is fossiliferous but throughout the greater part of the area no fossils are found. Another prominent bench marking the top of a lower sandstone of the group is 50 feet below the top bench. This

sandstone also is typically massive sandstone and in the southern part of the township is separated by shale from the massive sandstone above it.

**NELLIE BLY FORMATION**

**Character**: Alternating shales and hard, usually gray to brownish-yellow, sandstones. This formation is mentioned here principally because of some persistent sandstone lenses some 40 to 60 feet above the Hogshooter limestone. They are best described by Ross who states:

These shales and interstratified lenticular sandstones appear to be foreset beds of a delta deposited by a northward-flowing stream in Pennsylvanian times. Their thickness is about 100 feet near the southwest corner of T. 21 N., R. 11 E., but there is evidence of a marked increase in thickness from north to south. This series of beds forms a considerable part of the exposed rocks in the Bald Hill region of T. 20 N., R. 12 E., where they have a steep northward dip that does not correspond to that of the Hogshooter limestone below.

**Correlation**: Equivalent to the middle formation of the Drum group, Kansas section.

**Thickness**: The formation is approximately 200 feet thick in southeastern Osage County. The sandstone beds vary from a few inches to 10 feet or more in thickness.

**HOHSHEETER LIMESTONE**

**Character**: A thin bedded, argillaceous limestone, blue on fresh fracture and weather to a light blue color. Locally on weathered surface it often shows red spots. Fossils are chiefly corals and crinoid stems.

**Thickness**: Variable, in Osage County from 2 to 15 feet.

**Correlation**: Lower part of Drum group, Kansas section.

**Remarks**: There is a rather persistent sandstone 18 to 20 inches thick lying 40-45 feet below the Hogshooter that can be used for structural mapping in parts of T. 20 N., R. 12 E., but the interval between it and the Hogshooter is not constant and should be frequently checked if the sandstone bed is used. It is both underlain and overlain by shale and the top of the bed is easily followed except in the northern part of the area described, where it is very thin and usually covered by talus material from overlying beds.

**SUBSURFACE FORMATIONS**

**GENERAL STATEMENT**

A fairly complete section of the subsurface formations in Osage County is available to the base of the Mississippian. (See Plate II). In the western half of the county, in the Mississippian section, the data is not all complete because of the scarcity of well logs. Underneath the entire county the normal dip is westward about 30 feet per mile and, as the surface rises in the same direction, the formations appear at increasingly greater depths to the west dipping at an average rate of 45 feet to the mile. In the southern part of the county the average dip is greater than near the Kansas line.

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Most of the subsurface formations are easily correlated where sufficient wells have been drilled, as there are several persistent key horizons. Since the practice of keeping more accurate records and of taking samples of well cuttings at frequent intervals has been adopted by many companies (operators) more and more subsurface data are becoming available, especially of the older formations. The thickness of the principal formations here given will in all probability be revised from time to time as more detailed information becomes available.

Pennsylvanian

The Pennsylvanian system is represented under the entire county by a great thickness of alternating sandstones, shales, and limestones. The series is approximately 1,600 feet thick along the eastern edge of the county and approximately twice that, or 3,200 feet along the western side. The formations thicken to the east as shown in comparing surface measurements and subsurface measurements of individual formations. The entire thickness of the Pennsylvanian formations, if measured along the outcrop, aggregates approximately 4,400 feet while, if measured in drilling wells on the eastern side of the county, it is found to vary from 3,000 to 3,200 feet, showing a thinning of 1,200 feet or more down the dip. In the subsurface formations shales predominate in the section. Many lenticular sandstone and limestone beds can be traced a considerable distance. There are, however, several sandstones and limestones that form valuable horizons for subsurface correlation. Some of the more persistent of these are: the Foraker limestone, outcropping in the western part of the county; the Pawhuska limestone, outcropping in the central part of the county; the Elgin sandstone series, which is probably equivalent to the Hoover sand series of the Tonkawa pool; the Bigheart sandstone group which Clark, in a later part of this report, correlates with the Tonkawa sand series of the Tonkawa pool; the Layton sand, which forms a very persistent sandstone extending entirely under the county and well into Kay County; the “Big Line” group of the driller; the Purg sand, which is the most productive horizon in the northeastern part of the county; the Fort Scott (Oswego) limestone, which is one of the most persistent and widely distributed limestones of the lower Pennsylvanian in northeastern Oklahoma and the Bartlesville-Burbank sandstone series in the basal part of the Cherokee shales. Several of these key horizons have been described in previous publications and others that outcrop in the county or to the east have been described by Gould.30 The description of some of the producing horizons is given in the following pages under the description of type pools.

Mississippian

The Mississippian as described here includes the Chattanooga shale. It is a series representing about 200-300 feet of “Mississippi lime” and from nothing to 40 feet of Chattanooga shale. The Chattanooga shale is here classed as basal Mississippian in age, and so far as known, there are no rocks of Devonian age present. The Chattanooga, where present, consists of a dark to black, fissile, carbonaceous shale sometimes called “pencil shale” by the drillers, containing little or no lime and, in the shale itself, no sand. Locally it shows considerable pyrite. Occasionally there is a bed of sandstone at the base of this shale and in several places in the county well records and samples have shown the Chattanooga to be absent, or at least very thin in the section.

The Mississippian limestone or the “Mississippi lime” of the drillers grades from a grayish brown to black, almost black limestone. In some places, especially in the eastern part of the county the upper 20 to 30 feet is very cherty with a varying thickness of residual chert on top of it. Two and sometimes three different horizons can be recognized in this limestone group. The writer does not have sufficient information at this time to classify and give the distribution of these various horizons. In a general way it may be said that in the western part of Osage County the top of the Mississippian lime is probably younger in age than it is in the eastern part of the county. It is probable that there is a large time gap between the Mississippian and Pennsylvanian, as in some parts of the county there has been considerable erosion.

Ordovician

The only formations of Ordovician age in the county are those belonging to the Simpson group of White31 who has described them in considerable detail. In this bulletin the characteristics and distribution of the various members of the Simpson group in Osage County are described in like detail. Only the Burgen and Tyner members are apparently present under the county, and these only in the southern and southwestern parts, with possibly a little Wilcox sand under the extreme western part of the county. Over the remainder of the county the basal Mississippian lies unconformably on the eroded surface of the Arbuckle limestone.

Cambro-Ordovician

On top of the basement granite there lies an unknown thickness of massive, dolomite, siliceous limestone of Cambro-Ordovician age, known as the “Siliceous limestone” or Arbuckle limestone. This formation has been penetrated in several places in Osage County as will be noted in the list of wells that have encountered granite. Most of these wells went through a considerable thickness of Arbuckle limestone. The character of the Arbuckle limestone is much the same wherever encountered in northeastern Oklahoma. White32 states: “Samples of Arbuckle limestone from widely separated wells resemble each other so much that it is difficult to distinguish between them.” Clark and Cooper33 describe the Arbuckle limestone as found in drill cuttings, as follows:

31. White, Luther H., op. cit.
32. White, Luther H., Idem.
This formation varies from white to brown in color and from dense to coarsely crystalline in texture, as found in drill cuttings and in occasional fragments obtained when a well is shot. No quantitative analyses are available but from rough tests made on samples from various wells the magnesium content is estimated to be somewhere between 20 and 40 per cent and wherever tested is consistent throughout the entire thickness of the formation.

The maximum thickness of this formation is unknown. A few wells have shown it to be absent where granite hills protrude through it into the overlying Mississippian. In other places several hundred feet of Arbuckle limestone have been penetrated before the granite was encountered. In still other places from 600 to approximately 1,400 feet of Arbuckle have been penetrated without passing through the formation.

The presence of a number of granite hills and the greater thickness of the Arbuckle limestone to the south and southwest would indicate a sea advancing to the northeast in Arbuckle times. It is probable that there was either a gradual submergence or a periodical depression which caused some overlapping of the Arbuckle beds, but the evidence is not at all complete.

The upper surface of the Arbuckle is unconformable with all overlying formations. In several places this upper surface has been truncated, and in other places post-Ar buckle folding has taken place and the upper surface has been truncated. What is generally referred to as the Turkey Mountain sand or Siliceous limestone is found in the upper part of this formation. There is not sufficient detailed information available at this time to state whether or not the Turkey Mountain beds are upper Arbuckle or lower Simpson in age. It is the writer’s opinion that they will prove to be the upper, porous part of the Arbuckle limestone.

CAMBRIAN

So far as is now known there are no sediments of Cambrian age underneath the county, although it is possible and perhaps probable that sediments equivalent to the Reagan sandstone of the Arbuckle Mountains or the Lamotte sandstone of the Missouri section may be found upon the granite floor.

PRE-CAMBRIAN

Granite and perhaps other igneous rocks underlie all of the county as a basement complex. The wells that have penetrated the granite in various localities (list on page 241) show that it lies at comparatively shallow depths in many places. These well records show the granite hills stood up in Arbuckle time and in a few places were present in early Mississippian time.

Structure and Geologic History

Knowledge of the geologic history of the subsurface formations is available only from well records and drill cuttings. (Map No. XXIII). As comparatively few wells have penetrated the older sedimentary formations our knowledge of such is rather meager. However, as more deep wells are drilled, and more samples collected and examined, additional data will be obtained which in all probability will change the history of the early formations as now outlined.

The granite basement underlies the entire county, and from the data now available its surface is very uneven. There are isolated peaks or ridges that have penetrated the overlying sediments showing that the granite tucks up into the overlying formations from several hundred to perhaps a thousand feet or more. Additional information becomes available it may be possible to outline these high points in the granite as a series of ridges of buried hills and it is the writer’s belief that such lines will prove to coincide in general with the major lines of folding in these overlying formations.

List of Wells Drilled into Granite in Osage County

Carter Oil Co., No. 1, Johnson NW. Cor. sec. 9, T. 26 N., R. 6 E., granite 2,430-41.
Tidal-Osage, No. 8, A. A. Arnold, NE 1/4 SE 1/4 SW 1/4 sec. 3 T. 20 N., R. 8 E., granite 2,432-32.
Prairie Oil and Gas Co., No. 12, SW 1/4 NE 1/4 SE 1/4 sec. 25, T. 23 N., R. 8 E., granite 2,545-33.
Gled Oil Co., No. 5, cen. SE 1/4 NE 1/4 NE 1/4 sec. 16, T. 24 N., R. 8 E., granite 2,708-32.
Gled Oil Co., No. 6, cen. SE 1/4 NE 1/4 sec. 21, T. 24 N., R. 9 E., granite 2,864-34.

Foster and Davis and Finance, No. 1, SW corner SE 1/4 sec. 19, T. 21 N., R. 9 E., granite 2,300-29900.
Barnsall Oil Co., No. 17, SE 1/4 NW 1/4 sec. 12, T. 24 N., R. 10 E., granite 2,960-32.
Amerada Petr Corp. et. al. No. 1, NW 1/4 NW 1/4 SE 1/4 sec. 17, T. 23 N., R. 11 E., granite 2,559-84.
Granite wells near Osage County

Superior Oil Corp. No. 1, Blakemore, 50 ft. of W. line and 875 ft. N. of S. line, sec. 25, T. 21 N., R. 13 E., granite 1,365-1692.

Continued on page 242)
may have formed islands of considerable size in the early Cherokee sea and, so far as now known, such irregularities were well covered before the end of Cherokee times.

Structural movements found in the Pennsylvanian and early Permian sediments probably took place over a considerable period of time beginning in late Pennsylvanian. They are probably the combined result of settling over pre-Pennsylvanian folds and to stresses set up in this area by more intense movement and stresses that occurred in regions to the east and southeast. It is noticeable that most of the pronounced lines of folding and faulting in the Pennsylvanian sediments follow similar lines of weakness in pre-Pennsylvanian and in all probability pre-Chattanooga formations. Some secondary effects were in all probability due to movements in the Ozark uplift to the east of this general area and the buried granite hills of Kansas, which are known to extend down into Kay County, Garvin County, and perhaps farther south into Oklahoma, and it is quite probable that what are now deeply buried granite masses with an unknown thickness of sediments lying over and lapping against them form the wall or buttress which with the pressure from the south and southeast caused the initial wrinkling of the sediments of this area. Later formations of Pennsylvanian age are explained above; that is, folded and faulted along the same lines of weakness set up at that time.

CIL AND GAS DEVELOPMENT

General Statement

Oil and gas accumulations in Osage County are related to but not necessarily controlled by structural features. In many places sand conditions and distribution are more important than favorable structural conditions. The Burbank pool is an excellent example of a lenticular sand body of fair porosity, in which the best producing areas show little or no relation to either surface or subsurface folding. In the following pages some of the more interesting types of producing areas are described and illustrated with maps and cross-sections. Many other illustrations could be given, especially of those pools producing from sands in the Pennsylvanian formations, but the general conditions are much the same, not only for the Bartlesville sand, which is the principal producing horizon in the eastern half of the county, but for most of the other sands such as the Peru, Cleveland, Skinner, Wheeler, Burgess, etc. (See Map No. XXIV). The

Most of the pools that are producing from formations of Mississippian age show the same general characteristics as those producing from Pennsylvanian sediments, at least as far as the oil production is concerned. In several places, notably in the northeastern part of the county, some very productive gas pools have been found at the top of the

35. See Oklahoma Geol. Survey, Bull. 40-14 for additional information on pools of this county.
“Mississippi lime” where it is structurally high, and in some of these areas the best gas wells, both as to volume and length of life when properly cared for, are those located on the tops of these Mississippian folds.

In the formations of pre-Mississippian age, the producing areas are, as a rule, more closely related to structurally high areas. These structures are higher in the older formations, are usually smaller in area, and are in the shape of small domes and anticlines very sharply folded and in a few places faulted. Some of the principal types of pools in the pre-Mississippian or pre-Chattanooga formations are described by other contributors to this report.

Acquiring of the Osage Reservation by the Osage Indians and Oil Operation Thereon

In 1866 the Osage Tribe of Indians were living on their lands in southern Kansas. By Article 16 of a treaty with Cherokee Tribe of Indians, concluded in July, 1866, it was provided that the United States might locate “Friendly Indians” on that part of the Cherokee County, afterwards known as the “Cherokee Outlet” which was a strip of land about 60 miles in width, lying west of the 96th Meridian and south of the south line of Kansas. After proclamation of the Treaty of September, 1866, negotiations were opened with the Cherokee Tribe for the purchase of the lands lying west of and between the 96th Meridian and the Arkansas River and north of the Creek Nation, comprising 1,670,333.62 acres; of this amount the Kansas Tribe was to have 100,137.32 acres, a tract that was afterwards known as the Kaw Reservation and is now a part of Kay County. The remainder, 1,570,196.30 acres, was known as the Osage Reservation and is now Osage County.

For this tract of 1,670,333.62 acres, the Cherokees received $1,099,137.41 (approximately 66¢ per acre) which was appropriated from the funds derived from the sale of Osage lands in Kansas and a deed was duly executed under date of June 14, 1883, by Dennis W. Bushyhead, principal chief of the Cherokee Nation, in favor of Osage and Kansas Tribes of Indians.

In 1889, T. J. Norman drilled a well near Neodesha, Kansas, which was probably the first commercial oil well drilled in the Mid-Continent field and it was not long after this until attention was directed to the Cherokee and Osage Reservations to the south.

In 1891, Congress passed a law which made it possible to lease Indian lands with the approval of the Secretary of the Interior for a period of 10 years.

Early in 1895 Henry Foster, father of H. V. Foster, now president of the Indian Territory Illuminating Oil Co., entered into negotiations with the Osage National Council, under the provisions of the 1891 statute, covering their entire Reservation (now Osage County) of approximately 1,500,000 acres and the result of these negotiations was

what was later known as “the Foster Lease” dated March 16, 1896, and approved by the Secretary of the Interior.

The Phoenix Oil Co. was organized as the “operating company” and on June 20, 1896, commenced drilling the first well, located about the cen. NE¼ sec. 13, T. 29 N., R. 10 E. This well was about one-fourth mile south of the Kansas line and about 9½ miles west of the northeast corner of the Osage Reservation. It was completed in July and although a show of oil and gas was found, it was abandoned and plugged. A second well was completed in September, located nearly 6 miles west, in the NW¼ sec. 18, T. 29 N., R. 10 E. This well was also a failure.

In the spring of 1897, the Cudahy Oil Co. drilled a well in the NE¼ sec. 12, T. 26 N., R. 12 E., on the Indian Territory side (the section upon which the city of Bartlesville is now located) which was probably the first commercial oil well drilled in the State of Oklahoma and although completed about April, 1897, it was shut in and not put to producing until in 1903, six years later.

In June, 1897, the Phoenix Oil Co. completed their third well, located in SW¼ sec. 34, T. 27 N., R. 12 E., which proved to be a commercial oil well and was the first well drilled on the Osage Reservation.

In January, 1902, the Indian Territory Illuminating Oil Co. took over the “Foster Lease” and early in their administration began to issue subleases for oil only, reserving all of the gas rights and thus was established precedent for the separation of the oil and gas interest which still obtains in the Osage.

In the summer of 1902, the Almeda Oil Co., under a sublease, drilled their No. 1 in the SE¼ sec. 22, T. 26 N., R. 12 E. It was soon put to producing and at present writing (January, 1927) is still producing.

On December 31, 1904, the Indian Territory Illuminating Oil Co. had subleased 687,000 acres and had retained the gas rights in all except about 150,000 acres.

By an act of Congress, March 3, 1905, the lease was renewed for a period of 10 years from March 16, 1906, to the “Indian Territory Illuminating Oil Co. and its sublessees to the extent of 680,000 acres’ still recognizing the division of the oil and gas interests, and was perhaps the precedent for the policy of leasing the oil and gas separately, after the expiration of the “Foster Lease” in 1916.

Prior to 1906 the total amount of oil run from the Osage Reservation was 4,174,164 barrels.

The first lands leased on the Osage Reservation under the “Allotment Act” of June 28, 1906, was on Nov. 11, 1912, when 24,541 acres were leased. This was done by sealed bids at a stipulated royalty, the bidder to state amount of bonus per acre. For these leases they received $39,436.00, an average of $1.60 per acre. It was not until the sale of April 20, 1916, the policy of an auction sale was adopted which has prevailed since that time.

36. Leech, Chas. F., Personal communication.
The largest bonus paid for acreage in the Osage was during the sale, in March, 1924, when the Midland Oil Co. paid $12,437.50 per acre for the NW 1/4 sec. 14, T. 27 N., R. 5 E., in the Burbank pool.

**Petroleum Production in Osage County**

For fiscal years 1901-1926 (Burbank field excluded)

<table>
<thead>
<tr>
<th>FIELD</th>
<th>LOCATION</th>
<th>FIELD</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1915</td>
<td>7,587,788</td>
<td>1916</td>
<td>7,587,788</td>
</tr>
<tr>
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<td>1918</td>
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</tr>
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<td>1919</td>
<td>7,587,788</td>
<td>1920</td>
<td>7,587,788</td>
</tr>
<tr>
<td>1921</td>
<td>7,587,788</td>
<td>1922</td>
<td>7,587,788</td>
</tr>
<tr>
<td>1923</td>
<td>7,587,788</td>
<td>1924</td>
<td>7,587,788</td>
</tr>
<tr>
<td>1925</td>
<td>7,587,788</td>
<td>1926</td>
<td>7,587,788</td>
</tr>
<tr>
<td>Total</td>
<td>7,587,788</td>
<td></td>
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</tr>
</tbody>
</table>

**Burbank Field**

**HISTORY**

The first oil produced in Osage County was on its eastern line near Bartlesville, Oklahoma, and from the Bartlesville sand. This sand was found at a depth of 1,600 feet and is near the base of the Pennsylvanian series. It is the most widespread and prolific of any oil sand in the county. The western limit of this sand, as now known, is a line running in a northeast and southwest direction nearly through the center of the county. Because developments started in the eastern part of the county and worked west, operators after drilling many dry holes west of the center of the county became reluctant to drill even on well known structures in western Osage, in which the Burbank field is located. It was not until the Marland Oil Company drilled in its first well in the Burbank field in May, 1920, in the southeast quarter of sec. 36, T. 27 N., R. 5 E., and the Carter Oil Company drilled in its first well in September, 1920, in sec. 9, T. 26 N., R. 6 E., on two small anticlines, that the possibilities of the Burbank field were recognized by oil men in general.

Since that time, thirteen oil leases have been held by the Osage Agency under the direction of the United States Government. At these sales, quarter-sections were auctioned to the highest bidder. So far the highest price paid has been $1,900,000 for the 160 acres in NW 1/4, sec. 14, T. 27 N., R. 5 E., which was bought by the Midland Oil Company. Including the small part of the field which is in Kay County, 170 quarter-sections are producing. Over 130,000,000 barrels of oil have been extracted from the field. The production at present is 43,000 barrels daily from 2,000 wells. With one well to ten acres, the recovery to date averages 6,500 barrels per acre, while some leases have produced 20,000 barrels per acre.

**Production of the Burbank Field, by fiscal years**

<table>
<thead>
<tr>
<th>Year</th>
<th>Production</th>
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</thead>
<tbody>
<tr>
<td>1920</td>
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</tr>
<tr>
<td>1921</td>
<td>488,040</td>
</tr>
<tr>
<td>1922</td>
<td>24,230,563</td>
</tr>
<tr>
<td>1923</td>
<td>36,206,741</td>
</tr>
<tr>
<td>1924</td>
<td>31,904,479</td>
</tr>
<tr>
<td>1925</td>
<td>15,800,470</td>
</tr>
<tr>
<td>1926</td>
<td>13,352,917</td>
</tr>
<tr>
<td>Total</td>
<td>193,705,918</td>
</tr>
</tbody>
</table>

**STRATIGRAPHY**

The contact of the Permian and Pennsylvanian runs in a northeast and southwest direction, through the eastern side of the Burbank field, so that most of the limestones used in determining the surface structure are of Permian age. The total thickness of the Pennsylvanian series in the Burbank pool is about 2,800 feet. It includes a number of different producing horizons in different parts of the county, some fields producing from several horizons at the same time. The Burbank field, however, is only producing commercially from the Burbank sand, which is located near the base of the Pennsylvanian series, the bottom of this sand being separated from the top of the Mississippian lime by 40 to 70 feet of blue Cherokee shales. Quartzite was encountered at 4,240 feet in a well belonging to the Carter Oil Company, located in the NW cor. NW 1/4 sec. 14, T. 26 N., R. 6 E.

The Burbank sand, which is encountered at 2,800 to 3,200 feet, is from 50 to 80 feet thick. It is a fine grained, siliceous sand, having a calcareous cementing material. Melcher's examination shows the pore space to vary form 12 per cent to 20 per cent by volume. The thickness of the sand varies, and in some places there is a stratum of blue

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shale from a few inches to three feet in thickness at about 50 feet from the base of the sand. Where the sand is thickest, or about 80 feet, that part above this blue shale is about 30 feet thick and carries gas. It is quite probable that the variation in the thickness of the Burbank sand is caused altogether by the variation in the thickness of this upper member and that, where the oil is found at the surface of the sand, this upper member is very thin or in some places entirely absent. While the lower 50 feet of the sand is generally a pure sand without any shale breaks, yet its porosity and content of calcareous material varies so that the sand is probably not productive through its total thickness but the production comes from three or four different zones encountered at different depths. It is quite probable that not more than two-thirds of the total thickness is productive.

Stratigraphically, the Bartlesville and the Burbank sands in Osage County, Oklahoma, and the Rainbow Bend and the Fox Bush sands in Kansas, seem to be at about the same horizon. The Bartlesville sand, however, is a blanket formation covering a large part of northeastern Oklahoma and a small part of southeastern Kansas, while the other three sands mentioned have much smaller areas and may be in the form of large lenses. In the vicinity of the Burbank field, the Burbank sand has been encountered as a water sand considerably outside the field in several localities and within the last year the Kewanee pool, located six miles south of the Burbank pool, has developed production in this sand. Whether or not these two pools ultimately will connect and also whether or not the sand of the Fairfax pool continues south and connects up with the Bartlesville sand, remain as questions for further development to answer.

STRUCTURE

The Burbank field is included in the territory situated on the western flank of the great regional uplift which has for a center the Ozark Plateau. This west flank includes northwestern Arkansas, northeastern Oklahoma, southeastern Kansas, and southwestern Missouri. The strata dip a little north of west at the rate of about 30 feet to the mile, this dip being changed and reversed in different localities depending on local structural conditions. Figure 50 shows structural conditions developed on the top of the Burbank sand. This plate shows an anticline with 50 feet of closure located in sec. 9, T. 26 N., R. 6 E., and another anticline somewhat smaller in size located in NW 7/4, sec. 6, T. 26 N., R. 6 E. There are several other small structures in this field which are almost too small to be called anticlines or domes. The structure of the Burbank field may then be described as an undulating monocline, dipping at the rate of about 33 feet to the mile in a northwest direction with the largest deformations being the above mentioned anticlines which are at the southeastern end of the field (as developed).

As far as as been determined, structural conditions have only a secondary and minor influence on the concentration of oil in this field. The oil sand saturation and the production of wells therefrom seem to be in proportion to the porosity of this sand. The most prolific por-

Figure 50.
that of a very large well to a comparatively small one, depending on
the porosity of the sand encountered in the two wells. The most por-
ous portions of the sand seem to be in irregular patches, mostly discon-
nected and in fairly small units, such units being scattered through the
whole field but being of large size and more frequent in the northwest
part of the field. On the northern, eastern, and southern sides of the
field, the producing sand changes abruptly to an impervious sandy shale.
This change of lithologic character has been the primary reason for oil
concentration, oil and gas having travelled up the slope in an easterly
direction until they could go no farther.
To sum up the whole matter, therefore, it seems that oil and gas have been trapped in the Burbank field because they could not travel any farther east, and that in so accumulating, were concentrated in the most porous portions of the reservoir rock. It was therefore the impervious barrier on the eastern side of the field and the porosity of the reservoir rock in the field that were the controlling factors in the oil concentration, and not the structural conditions.

**Boston Pool**

The discovery well of the Boston pool is located in the SE. cor. sec. 1, T. 21 N., R. 7 E. It was completed on October 27, 1912, in the Bartlesville sand from 2,270 to 2,311 feet and shut in as a gas well. The next well of which there is a record is the Gypsy Oil Co., Boston No. 4, completed in the Bartlesville sand with an initial production of 1,086 barrels. The development of the lease progressed very steadily from that date until 1920.

On April 28, 1920, the deepening of the Gypsy Oil Co., Fred Boston No. 20 was started and was completed as a 3,000 barrel producer in the Arbuckle lime pay on June 19th. There have been 68 wells drilled on the Boston farm, one of which was a dry hole and one was lost because of mechanical difficulties. Of the 66 wells, 52 are producing from the Bartlesville; 13 from the Arbuckle lime; and one well from the Tyner formation. Approximately 11½ million barrels of oil have been produced to date from the Bartlesville sand and the Arbuckle lime, giving a yield of 41 thousand barrels per acre. The structural conditions of the Boston pool are illustrated by the structure maps, Figs. 51, 52 and 53, and the cross-section, Map No. XXV.

**Quapaw**

This pool is in the southwestern part of T. 25 N., R. 11 E., and on the surface is a plunging anticlinal nose with the axis-running in a north-
east-southwest direction. Structure maps on the surface and two on the subsurface are given. It is evident that the subsurface folding is more intense than that at the surface, a feature that is characteristic of practically all structures, even of the more gentle folds and terraces of the Pennsylvanian and Mississippian sediments of Osage County.

Nearly all production of the area comes from the Bartlesville sand horizon and is found on the northern and northwestern flanks of this fold. The producing area and the best wells of this area are more closely related to favorable sand conditions than to structure. The Bartlesville sand is present under the axis of the fold but is not as porous or as thick as on the flanks. In fact some of the wells drilled upon the fold found the sand so firmly cemented that even after a heavy shot they were dry of gas, oil, or water. Some of the other wells located on structurally high points produced considerable gas, and a few of them, small amounts of oil. The largest oil producers were well down on the northwestern flank.

The Pettit pool is located in sections 20, 21, and 29, T. 23 N., R. 8 E. During 1920 two wells were drilled in an attempt to test the Wilcox sand. Pettit No. 1, N.E. cor. SE 1/4 section 20, was completed in June 1920, and produced 5,657,657 cubic feet of gas from the Mississippi lime at a depth of 2,470 feet. Gra-Tah-Me-Tsa-Ha No. 16, NE 1/4 NW 1/4 NW 1/4 section 29, was completed in the Prue sand at 2,205 feet for 16 million cubic feet of gas in December of the same year. The heavy gas pressure in these two wells prevented deeper drilling. The discovery well in the Wilcox sand, Pettit No. 2, located near the center of SE 1/4 section 20 was completed October 15, 1923, with an initial production of about 7,000 barrels.

The Elgin sandstone outcrops over the higher part of the Pettit structure. Some of the structurally lower wells start on the overlying Pawhuska formation. Approximate depths to well known horizons over the higher part of the structure are as follows:

The uppermost producing horizon of the Pettit pool is the shallow sand, found at a depth of about 800 feet. Ten wells in the SE 1/4 section 20, were drilled to this horizon and had initial productions averaging from ten to fifteen barrels. This sand may be correlated with the Bighorn sandstone of the Osage section and with the Tonkawa or Stonaker sand of Kay County. The Bartlesville sand is present locally in the northeastern part of the SE 1/4 section 20. Two wells produced from this sand at a depth of 2,300 feet. In most of the wells, however, no sand is recorded in the lower part of the Cherokee.

PETTIT POOL

Figure 57.

The main producing horizon is sometimes referred to as the Hominy sand. This name may be confusing in this case due to the fact that the important pay zones are below the top of the Siliceous lime. The Simpson is represented in this pool by 5 or 10 feet of Tyner immediately below the Mississippi lime and 40 to 60 feet of Burgen sand between the Tyner and the top of the Siliceous lime. The lower Simpson or Burgen carries some oil and water in varying amounts. The pay horizons in the Siliceous lime vary from the extreme upper part to about 75 feet below the top. There seems to be no relation between pays in different wells.

Considerable difference in the setting of casing was necessary due to the variance in oil and water horizons within the Burgen sand. The 6½ inch casing was set in many wells in the lower part of the Mississippi
lime to shut off gas found through the upper 150 feet of this formation. The 5 3/4 inch casing was then run near the base of the sand. Each well offered a special problem on this last string of casing. Sometimes the water found in the sand could be exhausted but usually it was necessary to shut this off before drilling into the Siliceous lime. In general the water was found in the upper part and oil in the lower part of the sand, but in some cases casing was carried to the top of the Siliceous lime shutting off oil and water above.

The best wells are located near the center of the Pettit lease in the SE 3/4 section 20. Pettit No. 8 had an initial production of 8,000 barrels and No. 7 produced 3,048 barrels. The gravity of the oil is 36°B. The Pettit lease had produced up to June 1, 1926, 2,900,000 barrels.

Pettit No. 2, the discovery well, had produced, at the above date, over 900,000 barrels.

Wildhorse Pool

The pool is located about fifteen miles west of Skiatook, Oklahoma, in secs. 32, 33, and 34, T. 22 N., R. 10 E. It was discovered in 1917, but most of the leases on this structure were sold in 1918, therefore the pool is about ten years old.

The Wildhorse pool is one of the best producers in the Bartlesville sand in Osage County. It also produces from the Cleveland sand, the Big lime, the Peru sand, the Oswego lime, the Skinner sand, the Bur-
gess sand, or top of the Mississippi lime, and the Tyner formation, the latter sometimes being called the Hominy and Burgen sand in this general area.

**TOPOGRAPHY**

The surface elevations of this area range from 750 feet to about 1,000 feet above sea level. The surface geology conforms to some extent to the topography. Wildhorse Creek, after which the pool was named, drains the area and furnishes the relief upon which the surface geology was worked.

**GEOLOGY**

**Surface Geology**

Rocks exposed at the surface belong to the middle Pennsylvanian age, and consist of shales, limestones, and sandstones. The surface geology shown by Fig. 60, was mapped on a sandstone ledge of the Bighorn sandstone series which is very soft and massive, eroding easily making the geology very difficult to work, the true dips being hard to distinguish from erosional dips.
and at 2,600 feet in the same company's well No. 20 in the NE.1/4 of section 32, about one-half mile distant.

It will be noted by referring to cross-section (Fig. 62) that the Bartlesville sand thickens on the flanks of the structure where the best production was found in this sand.

An interesting feature of the subsurface geology of this pool is that the Mississippi lime has been eroded on top of the structures, with the shale interval between the Bartlesville sand and the Mississippi lime increasing off slope. The Chattanooga shale is entirely missing on top of both structures, but comes in on the flanks. It is very thin in the Twin State Oil Company's well No. 1, in the NW.1/4 of section 32. About thirty feet of Chattanooga shale was logged in the Marland Oil Company's well No. 9, in the NE.1/4 SE.1/4 of section 34, on the east slope of the structure. There was only two feet in the Rex-Pyramid well No. 40, in the SW.1/4 NE.1/4 section 34, one-half mile westward. This shows that these structures were present in the Siluro-Devonian time.

To the author's knowledge, the Misener sand does not show up in any of the wells drilled in this pool, the drill going directly from the Chattanooga shale into the Tyner formation, with the Hunton lime, Sylvan shale, and Viola lime absent. The granite found under this pool is believed to be of the same origin as the Nemaha granite ridge of Kansas and Oklahoma, the structures being formed by later folding together with the settling of Pennsylvanian beds over the granite ridge.

The cross-section shows two definite periods of erosion, one occurring at the top of the Ordovician lime and the other at the top of the Mississippi lime.

**Production**

As was stated before, the large majority of the production in this pool was from the Bartlesville sand which is encountered at approximately 1,800 feet, with an average thickness of 100 feet. The initial production of the wells in this sand ranged from 100 to 1,000 barrels per day. The water level in the Bartlesville sand occurred at the -1,000-foot contour line, represented by the dashed contour line in Fig. 61. The production from the Cleveland sand rated second, the initial production from wells in this sand being from forty to eighty barrels per day, with the production holding up remarkably well. This sand also averages about 100 feet in thickness. The Tyner production occurred above the dotted line at the -1,000-foot contour level. These wells came in for an initial production ranging from 1,000 to 10,000 barrels per day, but dropped off very fast. Water encroached into these wells very rapidly, due possibly to the fact that they were not pinched down so that the water would advance gradually instead of coming up from the bottom, decreasing the back-pressure on the water and thereby shortening the life of the wells.

Production from other horizons heretofore mentioned will not be discussed in detail because it amounts to a very small percentage of the entire production.

The average production per acre yield for actual producing acreage was 5,000 barrels. The following table shows data on separate leases, together with the total average, on the Tidal Oil Company leases in this pool. The production from the different sands was not kept separate, therefore the figures given in this table represent the entire production from all of the producing sands.

**Production of Wildhorse Leases of Tidal Oil Company**

*(To January 1, 1927).*

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>Init. Date</th>
<th>Total Gross Prod.</th>
<th>No. of Wells</th>
<th>Actual Prod. Acres</th>
<th>Av. Actual Prod. Per Acre</th>
<th>Av. Prod. Per Acre Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE. 32-22-10</td>
<td>1918</td>
<td>399,988</td>
<td>15</td>
<td>120</td>
<td>3,333</td>
<td>2,500</td>
</tr>
<tr>
<td>SW. 32-22-10</td>
<td>1918</td>
<td>122,878</td>
<td>5</td>
<td>40</td>
<td>3,070</td>
<td>768</td>
</tr>
<tr>
<td>NE. 33-22-10</td>
<td>1918</td>
<td>517,706</td>
<td>24</td>
<td>125</td>
<td>4,102</td>
<td>3,204</td>
</tr>
<tr>
<td>SW. 27-22-10</td>
<td>1919</td>
<td>429,750</td>
<td>21</td>
<td>120</td>
<td>3,581</td>
<td>2,666</td>
</tr>
<tr>
<td>NW. 34-22-10</td>
<td>1910</td>
<td>1,489,074</td>
<td>44</td>
<td>160</td>
<td>9,312</td>
<td>9,321</td>
</tr>
<tr>
<td>SW. 34-22-10</td>
<td>1919</td>
<td>474,457</td>
<td>22</td>
<td>120</td>
<td>3,954</td>
<td>2,966</td>
</tr>
</tbody>
</table>

| Total gross production | 3,429,910 |
| Total number of wells | 154 |
| Total actual producing acres | 685 |
| Average per acre yield for actual producing acres | 5,007 |
| Total acres in each lease | 160 |
| Total acres in all leases | 960 |
| Average per acre yield for total acres | 3,573 |

**Conclusion**

There seems to be a definite relation between topography, surface geology, and subsurface geology in the Wildhorse pool. Surface geology was very difficult to work due to the lack of good exposures, so that an accurate geologic section was almost impossible to obtain. Surface faulting carries down through all of the formations to the top of the Mississippi lime, and it is probable that the Mississippi lime was also faulted. The Mississippi lime has been eroded from the top of the structures to a large extent.

Oil accumulation seems to be from all flanks of the structure, and the water level is the same elevation on all sides. Ultimate production per acre from all sands in this pool will be approximately eight thousand barrels.
Wynona Pool

This pool lies in eastern part of T. 24 N., R. 9 E. The surface is a well defined anticline, the larger axis extending in a northwest-southeast direction showing approximately thirty feet of closure at the surface. The south end is the highest structurally on both the surface and subsurface formations, and in this area most of the wells were originally drilled and operated as gas wells; later they produced some oil but in rather small amounts compared with the oil wells on the flanks of the structure. Here again, the surface on the top of the Oswego lime and Bartlesville sand shows more folding than that found at the surface. The north end of this anticline was not as productive as the south end, or flanks, and in most cases the best producers were found where sand conditions were the most favorable, irrespective of their position on the structure. In fact some very good producers were found in places that were structurally low in this area.

Most of the pools that are producing from formations of Mississippian age show the same general characteristics as those producing from Pennsylvanian sediments, at least as far as the oil production is concerned. In several places, notably in the northeastern part of the county, some very productive gas pools have been found at the top of the Mississippi lime where it is structurally high and in some of these areas the best gas wells, both as to volume and length of life when properly cared for, were those located on top of these Mississippian folds.
Contour maps on top of the Bartlesville Sand and the Osage Lime in the Wynona Pool.

Figure 64.

Figure 65.
GEOLGy OF ROGERS COunTY

By
E. G. Woodruff and C. L. Cooper

INTRODUCTION

An earlier report\(^1\) presents a discussion of the oil and gas industry in the county at the time it was published ten years ago. This report is intended only to review the situation since that time and to present a discussion of the geology and oil and gas resources in the light of the present knowledge.

LOCATION

Rogers County is a rectangular area in northeastern Oklahoma, thirty-six miles north-south, and eighteen miles east-west, with an additional township to the northeast and limited by Verdigris River to the southwest. It embraces approximately 704 square miles in Tps. 19-25 N., Rs. 14-18 E. Claremore, the county seat, is located near the center of the county and Chelsea, the principal center of petroleum activity, is to the northeast. The county is well supplied with railroad facilities by the St. Louis and San Francisco Railroad (Frisco) which crosses it from southwest to northeast, and by the Missouri-Pacific Railway running southeast-northwest. There are a number of hard surfaced highways, hence travel and haulage of supplies are not difficult in this region.

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(This report originally issued as Bulletin 40-U, March, 1928.)
TOPOGRAPHY

In a general way the county is moderately uneven. The details of its surface features are presented on the U. S. Geological Survey topographic maps of the Claremore, Nowata, Vinita, and Pryor quadrangles. There is a hilly area in the northeastern part, traversed by Dog Creek and its branches, and another rough section between Sagleeyah and Talala.

Elsewhere the county is a succession of valley plains and moderately rounded hills which are the result of erosion on westward dipping strata which is made up of alternating beds of hard and soft material. Since the strike of the formations is northeast-southwest, the soft strata have been eroded to moderately broad valleys trending in that direction and hills with long gentle westward dip-slopes and steep eastward-facing escarpments having the same trend as the valleys.

There are two major streams, Verdigris River and its largest tributary, Caney River. The location of these streams is shown on the accompanying map. The Verdigris River enters the county along the north line and flows in a southwest course to the center of T. 20 N., R. 15 E., where it leaves its strike-valley and turns southeast, leaving the county near the northeast corner. Caney River enters the county near the center of T. 23 N., R. 14 E., and flows southeast to join Verdigris River near the center of the south line of T. 22 N., R. 15 E.

The main characteristics of these streams are their broad flood plains at places and the periodic, sudden rises of the streams that overflow these valleys. At times drilling and producing operations in low places must be abandoned because of high water.

GEOLOGY

Stratigraphy

SURFACE FORMATIONS

The formations exposed on the surface of Rogers County are shales, sandstones, and limestones of Pennsylvanian age, ranging from the Cherokee shales exposed in the eastern part of the county to the Coffeyville Formation exposed in the northwestern part. The shales are by far the most abundant with sandstones second in amount. To the casual observer in the field the sandstones and limestones are the most conspicuous because they are hard and weather into prominent ridges and steep eastward-facing scarps. Although the Pennsylvanian formations thicken rapidly both laterally and vertically their thickness in Rogers County does not vary an appreciable amount. A study of the geologic map of Oklahoma together with topographic maps of the county will bring out the relation between surface geology and topography. (See geologic map of Rogers County, Map No. XXVI).

Physiography

Table: Geologic Section of Rogers County

<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Thickness</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coffeyville formation</td>
<td>225-435</td>
<td>Blue to green clay shales with sandstone in upper part, and Chocer board limestone near base.</td>
</tr>
<tr>
<td></td>
<td>Nowata shale</td>
<td>100-130</td>
<td>Shales, sandy in upper part and clayey in lower part.</td>
</tr>
<tr>
<td></td>
<td>Osageh limestone</td>
<td>80</td>
<td>Thick beds of limestone in the upper and lower parts with a bed of shale between.</td>
</tr>
<tr>
<td></td>
<td>(Big Lime)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loretto shale</td>
<td>60</td>
<td>Blue to green clay shales, sandy clays with brown shaly sandstones locally.</td>
</tr>
<tr>
<td></td>
<td>Port Scott limestone</td>
<td>100</td>
<td>Limestone, thick bedded in upper part, with thin beds of limestone and limy shales below.</td>
</tr>
<tr>
<td></td>
<td>(Owego lime or Wheater sand.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cherokee shales</td>
<td>450-500</td>
<td>Vari-colored shales, varying greatly vertically and laterally into sandy shale and sandstone.</td>
</tr>
<tr>
<td></td>
<td>(Including Bartleville sand.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Morrow Group</td>
<td>100</td>
<td>Brown limestone at top, micaeous sandly shale in middle, and brown oolitic channell limestone at base.</td>
</tr>
<tr>
<td></td>
<td>Mayes limestone</td>
<td>115</td>
<td>Light and dark gray, thinly granular, platy, siliceous limestone.</td>
</tr>
<tr>
<td></td>
<td>Boone chert</td>
<td>50</td>
<td>Light gray chert with interstratified limestone.</td>
</tr>
<tr>
<td></td>
<td>St. Joe (?) limestone</td>
<td>10</td>
<td>White coarsely crystalline crystalline limestone.</td>
</tr>
<tr>
<td></td>
<td>Grassy Creek (?) shale</td>
<td>10±</td>
<td>Light greenish gray shaly shale.</td>
</tr>
<tr>
<td></td>
<td>Chattauoga shales</td>
<td>40-50</td>
<td>Black slaty bituminous shale of uniform texture.</td>
</tr>
<tr>
<td></td>
<td>“Turkey mt.” (Sylamore sand.)</td>
<td>Variable</td>
<td>Highly crystalline, dolomite sand, absent over most of area.</td>
</tr>
<tr>
<td></td>
<td>Cotter dolomite</td>
<td>400-500</td>
<td>Medium to fine, crystalline, dolomitic limestone with occasional thin beds of sandstone.</td>
</tr>
<tr>
<td></td>
<td>(Arumite limestones or Siliceous lime)</td>
<td>1,000-1,500</td>
<td>Medium to fine, crystalline, dolomitic limestone with occasional thin beds of sandstone.</td>
</tr>
<tr>
<td></td>
<td>Pre-Cambrian</td>
<td></td>
<td>Spavinaw granite.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dark red, mottled fine-grained granite.</td>
</tr>
</tbody>
</table>

CHEROKEE SHALE

The Cherokee shales outcrop at the surface in approximately all of the eastern half of the county. The strike of the formation is approximately N. 20° E., so that the lowest beds of Cherokee are found in the southeastern corner of the county.

The Cherokee formation is made up of 450 to 500 feet of varicolored shales from light gray and yellowish-brown to black in color, together with a number of lenticular sandstones, especially in the lower part. Shales and sandstones change both laterally and vertically and often grade into each other within comparatively short distances. The
most important of the sandstones is the Bluejacket sandstone (the
Bartlesville sand horizon), which outcrops from the northeastern part
of T. 21 N., R. 17 E., southwest to the southeastern corner of T. 19 N.,
R. 16 E. This horizon produces oil and some gas in most of the fields
of the county.

FORT SCOTT (OSWEGO) LIMESTONE

Immediately above the Cherokee shale is found the Fort Scott lime-
stone, known to the drillers as the Oswego lime and in the Cushing field
as the Wheeler sand. Its average thickness is approximately 100 feet
in this area. It consists of thick bedded limestone in the upper part,
grading into alternating thin beds of limestone and limy shales in the
lower part. Immediately below this limestone but in the Cherokee
shale is found the Fort Scott coal which is mined at a number of places
for local consumption. The outcrop of the Fort Scott forms a very
prominent scarp running northeast-southwest through the center of the
county just west of Claremore.

LABETTE SHALE

Immediately west of the Fort Scott limestone scarp the Labette
shales crop out in the valley of the Verdigris River. These shales
consist of blue to green clay shales and sandy clays with brown shaly sand-
stones of local occurrence. The Labette shale is approximately 60 feet
thick in Rogers County.

OOLOGAH LIMESTONE

The Oologah limestone consists of thick beds of limestone in the
upper and lower parts with a bed of shale in the center, and has an ag-
gregate thickness of about eighty feet. The formation outcrops in a
belt from the north-central part of the county southwest and forms the
limestone country just east of Talala and Oologah. In the northeastern
corner of T. 23 N., R. 15 E., just west of Talala, the formation is di-
vided into the Altamont limestone at the top, the Bandera shale in the
center, and the Pawnee limestone at the base. The Pawnee and Alta-
mont both thicken from north to south while the Bandera shale thins
rapidly in the same direction. The Oologah is known as the “Big Lime”
of the drillers.

NOWATA SHALE

The Nowata shale forms a fairly broad valley in the northwestern
part of the county. It consists of 100 to 130 feet of shales which are
sandy in the upper part and clayey in the lower part. A small seam
of coal is found in the type locality near Nowata just north of Rogers
County.

COFFEVILLE FORMATION

The youngest formation in Rogers County outcrops in the extreme
northwestern corner. The formation is made up of blue to green clay
shales, a number of thin sandstones in the upper part, and limestones
in the lower part. Near the base is a very persistent thin limestone 2½
to 3 feet thick, known as the Checkerboard limestone. It is very fine
grained, fossiliferous, and yellowish-white in color on weathered sur-
faces.

SUBSURFACE FORMATIONS

The subsurface formations encountered in deep wells drilled in
Rogers County, range from the Spavinaw granite of pre-Cambrian age
up to and including the lower formations of Pennsylvania (early Potts-
ville) age. The entire geologic section is not present as may be seen by a
study of the chart on page 271. Uplift and erosion has removed all
Cambrian sediments, if they were ever deposited. Upper Ordovician,
all of Silurian and Devonian formations are also absent.

SPAVINAW GRANITE

The basement rock, or the floor upon which all of the sedimentary
rocks were deposited is the Spavinaw granite of pre-Cambrian age. It
is fine grained, dark red granite of mottled appearance due to large
amounts of deep red feldspar, black hornblende, and white quartz. A
number of wells in this and surrounding counties have encountered the
Spavinaw granite and a number of them have drilled several hundred
feet into it.

ARBuckle LIMESTONE

The Arbuckle limestone underlies all of Rogers County and is a
medium to fine grained, crystalline dolomitic siliceous limestone, with
occasional thin beds of sandstone. Its thickness varies according to the
topography of the underlying granite surface being 400 to 500 feet on
top of the hills and 1,000 to 1,500 feet in the valleys. The upper part of
this formation is a highly crystalline dolomite having a very porous or
spongy texture in places, probably caused, at least in part, by the erosion
of the higher beds. This truncated upper surface of the Arbuckle is
known as the Turkey Mountain sand, while the main part of the Ar-
buckle is referred to by oil men as the Siliceous lime. Ulrich has cor-
related this part of the Arbuckle with the Cotter dolomite of Arkansas.

It is thought that the entire thickness of Arbuckle present in this area
is Ordovician in age as no evidence has been found to show the pres-
ence of Cambrian beds similar to those found in the Arbuckle Moun-
tains. There has not been a single instance recorded of the presence of
a sandstone between the limestone and the sandstone of Cambian age.

CHATTANOOGA SHALE

The Chattanooga is a black bituminous shale of very uniform text-
ure and attains a thickness of 40 to 50 feet in this area. The shale
1 Ulrich, E. O., Fossiliferous boulders in the Ouachita “Caney” shale and the
age of the shale containing them: Oklahoma Geol. Survey Bull. 46, p. 31, 1927.
is remarkably persistent in lithologic character and thickness in Rogers and the surrounding counties. This shale, originally thought to have been Devonian in age, is now definitely known to be Mississippian.

BOONE CHERT

Following the persistent Chattanooga shale a series of interstratified limestones, cherty limes, and cherts, known as the Boone chert was deposited. The formation thins rapidly to the west from the outcrop so that its maximum thickness in eastern Rogers County is 50 feet, disappearing altogether a few miles west of the county. This disappearance is thought to be due to the absence of the Boone sea in this area. The St. Joe (?) limestone is a definite faunal horizon about 10 feet thick found at the base of the Boone. The St. Joe (?) occurs at the same horizon as a subsurface formation of the same thickness and character found in Seminole County. It is there called the Sycamore limestone (Kinderhook) and the two are thought to be equivalent by many Tulsa paleontologists. For this reason, the Kinderhook-Keokuk boundary in the geologic section, page 271, is questioned.

MAYES FORMATION

The Mayes formation is made up of approximately 100 feet of dark gray to black argillaceous limestone, forming a large part of the "Mississippi" lime of this area. The lithologic boundary of the Mayes is rather definitely known, but its age equivalent is somewhat uncertain.

The Pitkin limestone, Fayetteville shale, Batesville sandstone, and Moorefield shale do not occur in the geologic section of Rogers County. The data of those most intimately connected with this problem strongly indicates that there is no Pitkin anywhere in Oklahoma; the beds which were formerly called Pitkin are now placed in the Morrow group (basal Pennsylvanian). This change will probably be questioned by many since it places the upper part of the "Mississippi" lime in the Pennsylvanian system.

Luther H. White states:

I have been of the opinion for more than a year that the upper part of the "Mississippi" lime in Oklahoma is directly equivalent to what is known as the Lyons limestone which occurs and is well known in the Okmulgee-Henryetta territory, and especially in the Lyons-Quinn pool in T. 11 N., R. 11 E. I have been inclined to believe that this lime is equivalent to Pitkin. However, paleontologists agree that this limestone is Pennsylvanian in age and is to be correlated with the Morrow and the Wapanucka. In my opinion it is apparent that in any event there is a tremendous unconformity, particularly with reference to sediments cutting out at this horizon, in the "Mississippi" lime. In the southern part of Oklahoma there are many hundreds of feet of shale between what I refer to as Lyons limestone and what is certainly identified as Mayes limestone below.

4. White, Luther H., Personal communication.

ROGERS COUNTY

I think it pertinent to make this further observation. In all probability it is this horizon which is known as the first break in the "Mississippi" lime in northern Oklahoma which occurs about 50 feet more or less, below the top of the formation. In the southwestern part of Rogers County, as well as in certain localities in Osage County, there is another horizon about 300 feet below the top of the "Mississippi" lime, but still within the formation which also produces oil. I very strongly suspect that this horizon is that of the unconformity at the base of the Mayes limestone.

MORROW FORMATION

The Morrow formation, which is found immediately below the Cherokee shales, consists of 100 feet of shale, limestone, and sandstone. The basal member, the Hale sandstone (not everywhere present) contains a number of fossiliferous limy horizons. The middle portion of the formation is a hard blue limestone grading into shale at the top. The upper member of the formation is mainly shale, blue to black in color.

The series of beds just described, [St. Joe (?), Boone, Mayes, and the lower part of the Morrow] aggregating from 250 to 300 feet of strata, is known as the "Mississippi" lime to drillers. These beds form a conspicuous and easily recognizable horizon in drillers' logs and makes one of the best key horizons for correlation in this county.

Sample Determination on the Well in NW 1/4 NE 1/4 NE 1/4 Sec. 17, T. 21 N., R. 18 E.

Altitude 713 feet

PENNSYLVANIAN SYSTEM

Des Moines Group

Cherokee Formation

<table>
<thead>
<tr>
<th></th>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intereclated, light gray, finely arenaceous, flaky shale and finely micaceous grit shells</td>
<td>85</td>
</tr>
<tr>
<td>2</td>
<td>Intereclated, finely micaceous and finely laminated light and dark gray shale with some minute spherical siliceous concretions</td>
<td>95</td>
</tr>
<tr>
<td>3</td>
<td>Black, finely laminated, thinly micaceous shale. Some dark brown, even crystal-like limestone shells</td>
<td>135</td>
</tr>
<tr>
<td>4</td>
<td>Intereclated, dark gray, platy and thinly laminated micaceous grit shells</td>
<td>140</td>
</tr>
<tr>
<td>5</td>
<td>FAUNA: Trigites secalica, Sphaerodoma sp., Thalassina sp.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>FAUNA: Ostracoda and foraminifera.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>FLORA: Pyritic replacements of plant remains.</td>
<td></td>
</tr>
</tbody>
</table>

### Morrow Group

**Formations Undifferentiated**

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Drib, coarsely crystalline limestone with included granules of glauconite and some large sand grains. Very finely granular buff matrix in the interstices between the coarse calcite crystals</td>
<td>220 225</td>
</tr>
<tr>
<td>(2) Black, platy, finely micaceous shale</td>
<td>225 230</td>
</tr>
<tr>
<td>(3) Same as from 225 to 230 with some intercalated, finely arenaceous, flaky, light and dark gray clay shale</td>
<td>230 252</td>
</tr>
<tr>
<td>(4) Subangular, well assorted, free and included sand grains in a light gray argillaceous matrix</td>
<td>252 255</td>
</tr>
<tr>
<td>(5) Oolitic, finely granular, drab, dolomite limestone Oolites light gray, sub-spherical, 7 mm, in average diameter</td>
<td>260 280</td>
</tr>
<tr>
<td>(6) Highly fossiliferous, finely granular, drab, dolomite limestone, intercalated with light gray, flaky shale</td>
<td>280 291</td>
</tr>
<tr>
<td>(7) Same as from 250 to 291 with abundant ostracoda fauna</td>
<td>291 295</td>
</tr>
<tr>
<td>(8) Light gray, calcareous grit. Finely subangular sand grains of good assortment set in a fine white calcareous matrix</td>
<td>290 330</td>
</tr>
<tr>
<td>(9) Black, finely arenaceous, somewhat platy, argillaceous shale. Quartz and mica particles set in a fine white calcareous matrix</td>
<td>350 240</td>
</tr>
</tbody>
</table>

**RODGERS COUNTY**

### Burlington-Keokuk Group

**Boone Formation**

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Light gray, massive chert with some minute pyritic inclusions. Some white chert with disseminated rhombohedra of dolomite and some white chalcedony</td>
<td>454 460</td>
</tr>
<tr>
<td>(2) Light gray chert and partly silicified, finely crystalline buff limestones. Some small fission lines with chalcedony and agate</td>
<td>460 501</td>
</tr>
</tbody>
</table>

**St. Joe (?) Formation**

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3) White, coarsely crystalline limestone, highly arenoidal</td>
<td>501 509</td>
</tr>
</tbody>
</table>

**Kinderhook Group**

**Grassy Creek (?) Shale**

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Light, greenish-gray flaky shale</td>
<td>509 518</td>
</tr>
</tbody>
</table>

**Chattanooga Formation**

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2) Black lithoconic, slaty shale, containing much free and associated pyrite</td>
<td>518 571</td>
</tr>
</tbody>
</table>

**FLORA:** Sporangites huronense

**FAUNA:** Abundant condonts

### Ordovician System

**Abbeville (?) Formation**

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) White, evenly crystalline, dolomite limestone with many included subangular sand grains of fair assortment. Some chert and some sand grains tightly bonded with a white calcareous cement</td>
<td>571 615</td>
</tr>
</tbody>
</table>

### General Discussion

The geological section as shown by the cuttings of this well is worthy of further note because of its relation to the general stratigraphy and paleoecology. Some further explanation of the correlations set forth is due also.

The well starts in the Cherokee formation just below the outcrop of the Bluejacket sandstone member. The section of intercalated argillites, grits, sandstones, and coal are normal with the general lithology of the lower Cherokee, as observed elsewhere. This portion of the formation is the equivalent of the upper Winnow of Arkansas, and the microfauna is remarkably similar to that observed in the McAlester formation of south-central Oklahoma.

A series of limestones, calcareous grits, and argillites comprise the section assigned to the Morrow from the cuttings ex-
This section is consistent over a large part of north-central and eastern Oklahoma and is correlative, at least in part, with the Wapanucka limestone of south-central Oklahoma. A thickness of 100 feet in this well compares favorably with thickness measured at the outcrop which varies from 110 to 130 feet. A highly arenaceous zone at the base of the group seems fairly persistent and may be the approximate equivalent of the sand section found at the base of the Wapanucka in south-central Oklahoma.

It is probably representative of the Hale sandstone member of Arkansas.

The Pittkin limestone and Fayetteville shale are not found in this well. The Pittkin limestone as exposed in Arkansas has a maximum thickness of 40 feet and is typically blue. It is a fossiliferous limestone. It is separated from the Morrow limestone by the Hale sandstone, and so is quite distinct by virtue of its stratigraphic position. In Oklahoma, however, the formations of the Morrow group are no longer perceptible enough to warrant separate mapping. The faunas of the Pittkin and Morrow groups are very similar, the Pittkin being classified as Chester in age, and the Morrow as lowermost Pennsylvanian. It must be noted, though, that the latter group has a decided Mississippian facies, together with Pennsylvanian. The Pennsylvanian elements of this fauna are termed proximal and the Mississippian, residua by Mather. 8 who has made a careful study of them. Then on the basis of lithology, and faunas also, the Morrow and Pittkin limestones are not rapidly distinguishable, and where the stratigraphic position of each may be clear in Arkansas, it is not in Oklahoma. The fact that the Morrow is resting directly on the Mayes formation in this well, suggests that the Pittkin-Fayetteville formations may be present entirely in this area, and that they have been mistaken for Pittkin in both well records and outcrop is part of the Morrow.

The Mayes formation is typically represented in the cuttings, the lithology showing but little variation over a widespread area in the eastern part of the State. In general, the formation becomes more argillaceous and more arenaceous to the south, but the texture and appearance vary but little. A Moorefield age has been assigned to the Mayes fauna by most of the paleontologists who have studied it.

Because of its stratigraphic position, lithology, and one fragmentary fossil, we are placing the chert and dolomite limestone at depths from 454 to 501 feet in the Boone formation. At the outcrop the Boone has a maximum thickness of 250 feet in Oklahoma, while it is represented by 47 feet in the well under consideration, and is entirely missing in the area a few miles west of this point, as shown by well records and cuttings. This thinning suggests a profound unconformity at the top of the Boone, which is probably erosional and depositional. The erosional phase is suggested by the more marked silicification in the upper part of the formation and the heterogeneous character of the sediments in a thin zone on top of it. The fact that there are no reported outliers of rocks above the Kinderhook group and below the Mayes formation that might be classed as Boone, west of the sub-aerial limits, is highly indicative that this was also approximately the depositional limit. It might be noted that there is a distinct faunal break between the Mayes and Boone formations, the former being assigned to the Marance stage, and the latter to the Burlington-Reelfoot as age equivalents.

The section of intercalated coarse crystalline white limestone is probably the middle section of the St. Joe limestone, which has been considered lower Burlington in age. The St. Joe limestone does not contain a microfauna which may be used for correlation purposes in every locality, but its lithology and highly crinoidal character are remarkably consistent.

The aggregate Morrow, Mayes, Boone, and St. Joe limestone comprise the "Mississippian" time of the driller. In the but it is hoped that the above detailed description and discussion may be of some value in stimulating the identification of these widely differing groups and formations in further drilling development. The scientific and economic importance of this is immediately evident, and therefore, the saving of well cuttings cannot be too strongly urged upon the various operators.

The light gray argillite, overlying the black shale of the Chattanooga formation, and, in some localities, apparently intercalated with it, bears the same microfauna and flora as the latter and it is here suggested that these two are interfingral. The gray argillite is present in well cuttings over a remarkably widespread area, and in Kansas attains a maximum thickness of over 100 feet.

In south-central Oklahoma, it is probably correlative with the series of sediments included in the Syvenore limestone, the microfauna and flora being remarkably similar. It is suggested that the Grapels thick shale may be the Missouri equivalent, though the microfauna and flora have not been determined.

The Chattanooga shale is typically represented, both as to lithology and microfauna and flora.

The heterogeneous mixture of sand, arenaceous dolomite limestone, and chert in the last sample taken, has the aspect of an erosional zone. This is probably the zone immediately overlying the unconformity in this general area. There was no faunal evidence to support this, but the stratigraphic position and lithology are enough to strongly suggest it.

The microfaunas and floras obtained from the cuttings of this well are mounted and filed in the Micro-paleontological Collection of the Sinclair Oil and Gas Company, and are available for inspection upon application.

Geologic History

The geologic section of Rogers County, including both surface and subsurface formations, ranges in age from pre-Cambrian to Pennsylvanian. However, the complete section is by no means present, as there are numerous unconformities representing times of no deposition and erosion.

The oldest sedimentary rock, the Arbuckle limestone, was deposited on a very irregular surface of pre-Cambrian granite. Consequently


7. Esaki, No. 1, sec. 15, T. 21 S., R. 3 W., McPherson County, Kansas; Grassy Creek (?) shale-2,665-2,830 feet.
the thickness of this formation varies greatly from place to place as a result of the structural and topographic highs on the granite surface, which were islands in the early Arbuckle sea. That some of these highs were structural is shown by the fact that subsequent uplift has occurred at these points, resulting in structures in younger formations as high as the Cherokee shale. The uplift and erosion immediately following this deposition tilted the rocks to the southwest and greatly reduced the original thickness of the Arbuckle, which probably reached at least 2,000 feet in places. No mention has been made of the Reagan sandstone since this formation has not been encountered in any of the deep drilling in this area.

Following the erosion of the Arbuckle limestone the Simpson sea transgressively overlapped the truncated beds of the older formation. The nature of this deposition resulted in the omission of the older beds of the Simpson formation in a northeast direction. Subsequent uplift and erosion has pushed the boundaries of the various members of this formation farther to the southwest, so that the two members of the Simpson (Tyner and Burgen) are now found southwest of Rogers County. The paleogeography of this area has been described in detail by White.8

After the erosion of the Simpson formation the Viola, Sylvan, and Hunton formations were deposited, all of which were later removed from the area of Rogers County by a pre-Chatanooga interval of uplift and erosion. The subsequent deposition of the Chickasha shales occurred in a very widespread sea which covered most of the central interior of the United States, followed by the deposition of the gray shale here referred to as the Grassy Creek (?). The "Mississippi" lime [St. Joe (?), Boone, Mayes, and lower Morrow] was then deposited conformably upon the Grassy Creek (?) followed by the deposition of the remainder of the Cherokee shales of Pennsylvanian age. The Morrow beds are separated from the Mayes limestone by an unconformity of considerable extent.

Structure

Like all of this general region the formations of Rogers County dip generally westward. The formation which is on the surface at the east line of the county is approximately 850 feet deep on the west line, giving an average dip to the west across the county of about 37 feet per mile. A conception of the general geology of the whole region is essential to understand the structure of the area here discussed. This part of the earth's surface was approximately horizontal when the strata of this region were deposited. (See cross-section, Map No. XXVII).

The uplift of the central Ozark region carried upward with it the strata on all sides, but the amount of uplift decreased as distance from the mountains was attained. As a result of these big earth movements the strata slope from the mountains and since the mountains are southeast of this region the slope is westward and at the rate noted above.

Smaller upward foldings or structures resulted from these general movements of the strata. These small structures are the ones of prime importance to the petroleum industry because they are where the oil and gas accumulate. Descriptions of some such structures in Rogers County are given in the following paragraphs.

SENeca FaULT

One of the most extensive faults in Oklahoma enters the State near the northeast corner in T. 27 N., R. 25 E., and trends southwest to T. 18 N., R. 17 E., where it breaks into a series of faults. It therefore is in the southeast corner of T. 19 N., R. 17 E., Rogers County. It has no direct bearing on the petroleum resource but is a geological feature of considerable interest.

WISEnHUT STRUCTURE

(Named from Wisenhut School)

The most pronounced anticline in the county trends southwest from the eastern part of sec. 4, T. 22 N., R. 15 E., to the southeastern part of sec. 8, T. 21 N., R. 15 E. It raises to a considerable crest in sec. 21, T. 22 N., R. 15 E., but is apparently lower where it is crossed by Caney River and then raises to a very pronounced anticline in the northern part of T. 21 N., R. 15 E. This structure has produced a considerable quantity of gas which was used at the smelters at Collinsville and some oil but in general it has been a disappointment. Generally a structure of the shape and extent of this one is abundantly productive.

FOYIL STRUCTURE

There has been considerable production in sec. 6, T. 22 N., R. 17 E., just south of the village of Foyil. This structure is known to be small but the exact form and extent has not been determined by the writers and no maps are available.

There is a small structure in sec. 16, T. 22 N., R. 17 E., which has not been tested and another in sec. 36, T. 22 N., R. 17 E., only partially developed.

OIL AND GAS DEVELOPMENT

History of First Drilling in Oklahoma9

In 1882 the Cherokee Council passed a law providing for leasing of lands for the mining of all minerals except gold and silver. A blanket oil and gas lease was made by the Cherokee Nation in 1886 to Ed-

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ward Byrd. The lease comprised 94,000 acres, and was signed and approved by Chief Bushyhead and Robert Ross, treasurer, but it was not approved by the Secretary of the Interior Department at Washington, so development did not officially start until the summer of 1889.

The first well was drilled at this time on what was known as the Laura Taylor land, sec. 5, T. 23 N., R. 17 E., on the south prong of Spencer Creek to the west of Chelsea. This well was drilled by a contractor by the name of Sam Frances. He used a horse-power outfit and could not go very deep. This well was completed in August, 1889, at a depth of 36 feet, and made one-half barrel of fine green oil. A power house was put up over the well and an upright boiler and engine used to do the pumping. This was done for several months, there being a 50 barrel tank used to receive the oil. This well was drilled to test the oil spring known to almost every old Cherokee citizen. This spring was used for many years by the Indians before anyone thought about oil being worth anything, or was any good for any purpose than for greasing an old wagon or for softening leather.

The second well was put down 150 feet due west of No. 1, and was drilled to a depth of 86 feet. This well made 3 barrels a day on the pump. No. 3 was started 200 feet west of No. 2. This well was drilled by 120 feet, where the tools were lost, causing the abandonment of the well. The rig was moved one mile north on Spencer Creek and in November, 1889, another well was started. This well was drilled to 96 feet and 5 barrels of oil were found.

At this time the United States Oil Company was formed for deep drilling. A contract was let to drill 2,000 feet on the Martin Bill lands, down Spencer Creek some two and one-half miles. A standard rig was built and the well drilled to 1,200 feet where the hole was lost due to crooked hole, cavities and salt water. The rig was skidded eight or ten feet and another hole drilled to 1,230 feet where similar trouble again developed in the “Big Lime” and the hole was again lost.

The United States Oil Company then made a deal with a man named Lynn to take over and develop the property for an interest. Another standard rig was built 900 feet east of the old well. A bad fishing job developed and the well was never completed due to the death of Lynn. The well was plugged in the spring of 1893 with three strings of tools in the hole.

The company then secured J. B. Phillips of Pennsylvania, who took charge and cleaned up the old property before starting new wells. The first new well, completed in 1896, was shot with 500 pounds of gunpowder.

A few years later Phillips formed the Cherokee Oil and Gas Company which brought in the first Star drilling machine (about 1903). The first well drilled by this machine was on the Jane Byrd land and came in for 10 barrels. The machine was kept running steadily and a well a week was completed. These wells made from 10 to 40 barrels a day and many are still producing, averaging one-fourth barrel per day.

Just before statehood the Secretary of Interior granted a lease to the Cherokee Oil and Gas Company covering 32 sections of land on the basis of a lease on a full section of land for each well drilled under the old blanket lease. The boundary lines of the 94,000 acres comprising the old lease are as follows:

Beginning at the Frisco depot, running northeast one mile to water tank, or Pryor Creek bridge, thence northwest to Coody’s Bluff, then following the Verdigris River to what is known as the old Claremore Mounds, thence due east to Sequoyah, then northeast up the Frisco Railway to the place of beginning.” (See figure 67).

### Producing Sands

Most of the oil and gas accumulation in Rogers County is controlled by sand conditions as well as by structure. This is due to the lenticular character of the sand bodies forming the reservoir rocks. The largest producing area of the county is in the vicinity of Chelsea. This is the southeastern extension of the great Nowata field, which is limited to the northwest by small fields to the south of Wann in Washington County, and on the southeast by the fields of Chelsea, two points 35 miles apart. This area is not an anticline though there is local evidence of structure, so it is thought to be an old stream bed in which the sands now bearing oil were deposited. Occasionally “new leads” from the main trend are found, which were evidently branches of the main stream. This condition closely parallels the accumulation of oil in the “shoe string” sands of southeastern Kansas. The surface structure at Sageeyah is a monocline where production is found, hence it is inferred that lenticular sands hold the petroleum there.

Some of the sands above the Bartlesville which are productive in the fields west of Tulsa occur in Rogers County but either outcrop or are so shallow that they are not oil bearing. Therefore, only the Bartlesville and lower sands need be considered. The Bartlesville underlies all of the county except the southeast corner, where it outcrops in Tps. 19-21 N., R. 17 E. It is productive in the Sageeyah, Foyil, and Chelsea-Alluwe fields where it averages 20 feet thick. It has also been found productive to a considerable extent in a few small scattered groups of wells.

The “Mississippi” line has produced a considerable amount of gas in several of the fields of the county. The Boone averages about 40 feet thick, and is found from 450 to 1,350 feet below the surface.
Many of the wells which have been drilled below the “Mississippi” lime have reported the “Wilcox” sand. The true Wilcox sand does not underlie this county. It was probably present at one time in the area of Rogers County but was eroded away before the Mississippian formations were deposited. There are sands in the basal Morrow beds and just above the “Siliceous” lime or in the top of it which have been designated the “Turkey Mountain” or Sylamore sand.

Most of the oil is high grade, ranging from 34° to 43° B., with an average of 38° B. Most of the gas is too dry or in too small quantities to give commercial quantities of gasoline at the casinghead. The Gladys Belle pool, near Inola, has yielded an appreciable amount of natural gasoline, but is nearly exhausted now.

**Producing Areas**

**CATOOSA**

The Catoosa field, located in secs. 7, 8, 17, 18, 28, 29, 32, and 33, T. 20 N., R. 15 E., is principally a gas field having wells with an initial production of 2 to 10 million cubic feet. The gas comes from two horizons, the Booch sand, which is the equivalent of the Tucker, found at a depth of 850 feet and the “Mississippi” lime at 900 feet. The field was opened in 1913, by a well drilled by Kansas Natural Gas Company.

**CHELSEA**

The Chelsea field, the oldest producing field in Oklahoma, is located in the northern part of the county in T. 24 N., R. 16-17 E. The whole area, containing several thousand wells, is now completely developed. The age of the wells now producing is from 3 to 30 years old. The principal producing horizon, the Bartlesville sand, is found at a depth of 460 feet, though some oil is found in the Burgess sand at 600 feet. Most of the wells now have a production of ½ to 20 barrels per day. Many of the properties in this district are using various methods to increase recovery, the air pressure method being one of the most used. The oil produced ranges from 34° to 38° E.

**CLAREMORE**

There are a number of small, scattered areas of production in the vicinity of Claremore in T. 21 N., R. 15, 16, and 17 E. The most important of these areas is located six miles east of the town in sec. 9, T. 21 N., R. 17 E. The first oil well, located SE 1/4 SE 1/4 section 9, was completed in May, 1925, with a production of 70 barrels. Additional wells have had an initial production of as high as 160 barrels, though there is no regularity of their initial output. Dry holes are found as close as 300 feet from producers. This area has been producing gas since 1913, from a sand which is probably correlative with
the Tucker sand, at about 700 feet. This pool now has 20 producing wells with a settled production of 2 to 3 barrels of 43° B. oil each, and 8 gas wells making 1½ to 3 million cubic feet of gas. Six additional wells were either dry holes or abandoned because of small production. The production is mainly from the Burgess sand which has an average thickness of 22 feet. There is now about 20 million cubic feet of gas and a settled production of 100 barrels of oil from 4 leases in this area.

GLADYS BELLE POOL

The Gladys Belle Oil Co. developed one of the most profitable shallow oil pools in the whole region in secs. 3, 4, and 9, T. 19 N., R. 16 E. Wells with an initial production as high as 500-2,000 barrels were brought in from a depth of 600 feet. This field has produced steadily since it was brought in in 1914 and is still yielding oil. The field has yielded a large quantity of gas and a compression plant of 250 gallons capacity was erected for the purpose of recovering the natural gasoline. The pool now has about 13 producing wells which together make 18 to 20 barrels of oil per day. Gas under pressure is used to increase the recovery.

INOLA POOL

The Inola pool is a small area producing oil and gas south and west of the town of Inola. In the main Inola pool (T. 19 N., R. 17 E.) there are 70 producing wells and approximately 20 dry or abandoned wells. The pool averages 32 barrels of oil a day from the 70 wells. Many of the wells had an average initial production of 250 to 300 barrels, one making as high as 2,000 barrels. The producing horizon (the Burgess sand) is about 20 feet in thickness and is found at a depth of 500 feet. The recovery is increased by using air pressure at 160 pounds per sq. in. This air is introduced through 13 scattered wells on the lease, much of it being lost through faulty sand conditions and channeling.

OOGOH POOL

The Oologah pool located in secs. 3, 4, 5, and 8, T. 22 N., R. 15 E., produces gas from the Oswego and the "Mississippi" limes at 700 and 1,355 feet respectively. These horizons are 20 and 45 feet in thickness, and the wells have an initial production of one to 3 million cubic feet. The pool was opened about 1906.

SAGEYEH POOL

The Sageyeh pool located in secs. 24, 25, and 36, T. 22 N., R. 15 E., has a number of small wells with a settled production of 2-3 barrels per well. The oil is 38° B. and is produced from the Bartlesville sand at about 650 feet. There are also some small gas wells in the Burgess sand at 970 feet. This pool was opened in 1918.

ROGERS COUNTY

CATALE POOL

A small pool in secs. 15, 16, 21, and 22, T. 24 N., R. 18 E., produces a little oil and gas from the Burgess sand found at a depth of 400 feet. The oil wells had an initial production of 3 to 10 barrels and the gas wells from 1 to 2 million cubic feet. The pool was opened in 1910.

TUTTLE-KEPPLE POOL

In secs. 24, 25, T. 22 N., R. 16 E., known as the Tuttle-Kepple pool, there are 18 wells averaging 2-3 barrels of 43-44° B. oil on settled production from first break in limestone at 715 feet. Some of these wells have an initial production of as much as 20 barrels, but settle to two to three barrels, where the production remains stationary for a long time. There are now about 40 wells with settled production in this area.

MISCELLANEOUS OCCURRENCES

Some 2 million foot gas wells found in Bartlesville sand in secs. 27 and 28, T. 22 N., R. 16 E.

Gas field (secs. 21, 22, N.W. 27 and 28, and SE. 26, T. 21 N., R. 15 E.) Wells in Bartlesville, Tucker, and Burgess found at 600, 800, and 980 feet respectively. Gas is taken by Oklahoma Natural Gas Co.

A well in sec. 3, T. 21 N., R. 16 E., northeast of Claremore produces 1½ million cubic feet of gas, used by Unity Gas Co. N.E. 4th SE. ¼ NE. ¼ sec. 4, T. 21 N., R. 16 E., one million cubic feet of gas. Gas used by Unity Gas Co. This area now has a 25 barrel well in the Burgess sand.

Secs. 11, 12, 13, and 15, T. 22 N., R. 14 E., 50 wells in Bartlesville at 800 feet making 38° B. oil.

Ten wells averaging 2-3 barrels production of 38° B. oil from Bartlesville sand are located in secs. 6, T. 22 N., R. 17 E., one mile south of Foyil. This production comes from Burgess sand at 600 feet.

To the south of Inola there is a structure in sec. 33, T. 19 N., R. 17 E., partially tested. This structure parallels the large Seneca fault.

POSSIBILITIES OF NEW POOLS

There are very few untested structures in Rogers County but no doubt there are many places which have not been tested where lenticular sands that contain oil may be found. In fact sand lenses are so prevalent that any well not too near a dry hole may have considerable possibility of small production. There are some wells, though mostly small, in every township in the county. Large wells cannot be expected due to sand conditions and because the depth is not sufficient for large ones.
Increased Recovery Methods

Vacuum and pressure have been used in Rogers County to secure increased oil recovery. The vacuum seems to have secured an increase in production for a short time followed by a gradual decline which soon dropped below the amount of production which was obtained before the vacuum was started.

The shallow depth at which the sands are found offers very favorable conditions for the application of pressure where the sands are sufficiently porous to respond to this method of increased production. In general, the Bartlesville and Tucker sands are porous enough to respond to this method of production, and, in general, the Burgess is too "tight" for good results. However, there is no broad rule which is dependable for universal application, as the porosity of the sand on each lease must be considered separately.

Air, gas, and a mixture of air and gas have been used in the pressure method. Which to use, the volume necessary, and the amount of pressure required varies between wide limits. Almost every "air" well is a problem in itself, and there is, as yet, no criteria for determining just how the well is to be operated.

Figure 68 is a curve showing the results of recovery on a property in the Chelsea field on which both the vacuum and pressure methods have been used. At the beginning of 1917 when the vacuum was applied the production was 19,000 barrels per year. The increase due to the vacuum was over 1,200 barrels at the end of the year, when the lease started to decline. The low point of production was reached at the end of 1924 at 7,000 barrels. Pressure was then applied, increasing the production to such an extent that at the end of two years, the lease was producing more oil than the peak production reached by vacuum at the end of 1917. The expense curve is plotted with the production curve and shows the remarkably low increase in operating costs incident to maintaining the pressure on the lease. The lease represented a total of 57 wells.

GEOL OGY OF SEMINOLE COUNTY

By

A. L. Levinson*

INTRODUCTION

During recent years Seminole County has attracted a great deal of attention as an oil-producing region and at present it is one of the leading producing areas of the United States. The oil production during the past week in July, 1927, reached 562,000 barrels per day, of which 527,400 barrels were produced from 637 wells situated in the west half of the county. This would have been greater but for cooperative measures which restricted it to a maximum of 450,000 barrels per day in this area. This amount was sufficient, especially owing to its high gravity, to be an important factor in influencing the oil market of the country. There are at present eleven producing areas within the county, of which seven may be classed as major fields. In addition, six wildcat wells have been drilled, in each of which oil has been discovered. The production in these varies from 50 to 150 barrels per hour, but they are now shut in waiting for more favorable market conditions. Several of these wells will probably open up fields of major importance in the future, so that the story of the oil industry in Seminole County is by no means complete at this time.

Figure 69. Map showing location of Seminole County.

This paper is not a complete report but merely summarizes the information that has been gained in the exploration of the present producing areas. In the development of the geology of Seminole County, the most advanced methods and technique in sampling, micropaleontology, microolithology, geophysical exploration, water analysis, surface structural detail, and subsurface mapping have been employed. The ma-

*With the permission of the Independent Oil and Gas Company. (This report originally issued as Bulletin 40-B, March, 1928).
jor companies have established geological departments consisting of specialists in each of the different branches and are having more scientific work done than ever before in the history of oil geology in Oklahoma.

In the preparation of this report it has been the writer's intention to gather together as many facts as possible in the allotted time and to leave to some future writer much of the theory and the discussion of the purely geological problems. Fully 90 per cent of the material presented in this report has been obtained from other geologists, but the writer assumes the responsibility for the statements made herein. It has been his privilege to merely sift the different ideas and material and to attempt to put them in usable form. The exception to this is the discussion of the structural history and origin of folding which is the writer's interpretation of the information available at this time.

The geologic literature which applies to Seminole County is not extensive but the papers that have been published are very excellent. In the order of their publication, they are:

Geology of the Stonewall Quadrangle, Oklahoma, by Geo. D. Morgan, Bureau of Geology, Bulletin No. 8, 1924. This is the standard reference for all geologists working Seminole County. Since the Stonewall quadrangle extends into southern Seminole County, it has been particularly valuable in both surface and subsurface work. It contains a detailed description of all of the formations found in Seminole County and the geologic history, folding, and faulting of the northern part of the Arbuckle Mountains.

Petroleum Engineering in the Cromwell Oil Field, by O. E. Wiser and John R. Bunn, United States Bureau of Mines, 1924. This report was prepared during the later part of the development of the Cromwell field and discusses the history, stratigraphy, subsurface structure, and production and operating methods of that field.

The Seminole Uplift, Oklahoma, by Sidney Powers, Bulletin of the American Association of Petroleum Geologists, Vol. 11, pp. 1097-1128, 1927. The geology, structure of the rocks, the origin of the folds, the accumulation of the oil and the history and statistics of the fields of the Greater Seminole area are described one year after its discovery. A great deal of information is contained in this paper, including two maps of the structural conditions of the Seminole City field.

The writer has drawn freely from the literature mentioned, and has embodied in this report many of the statements and ideas of the several authors. He gratefully acknowledges the assistance of many geologists and others working out the problems of Seminole County and is indebted to Geo. S. Buchanan, C. W. Byron, L. C. Case, Ira H. Cram, Robert H. Dott, Oscar Hatcher, J. H. Nelmark, O. E. Nordan, J. T. Richards, Charles Ryniker, Edward E. Shew, Jess Vernon, and Luther White, for valuable suggestions, information and criticism: to the Gypsy Oil Company for statistical data, and to The Independent Oil and Gas Company for permission to publish this report.

SEMINOLE COUNTY

GENERAL FEATURES

Seminole County covers an area of about 630 square miles and is located a short distance southeast of the geographical center of the state.

Most of Seminole County covers what was formerly the land of the Seminole Nation, an Indian Tribe, from which the county also derives its name. Wewoka, the county seat, was the capital of the Seminole Nation. These Indians, an offshoot of the Creek tribe, were originally from Florida. By 1842, and after considerable fighting and a number of treaties with the Government, they were transferred to Oklahoma and became one of the Five Civilized Tribes. In March, 1906, their tribal government ceased and by reason of Acts of Congress passed in 1904, 1906 and 1908 their lands, which had previously been allotted in severalty, were in part open to purchase and settlement. The allotted lands which remained restricted, together with the lands later purchased or acquired by Seminole Indians, at present do not constitute over a fifth of the land of Seminole County.

Seminole County is bounded and drained by the north Fork of Canadian River and on the south by the Canadian River. Wewoka Creek, Little River, and Salt Creek, all flowing in a southeasterly direction, drain the central part of the county. The surface elevation ranges between 800 and 1,050 feet above sea level. The topography, which represents a mature stage of erosion, consists of low rounded hills, low east-facing escarpments, gentle west slopes and alluvial bottom land along the streams.

The soil is sandy, owing to the large number of sandstone layers in the bed rock, and much of it is unfit for cultivation. The principal crops are cotton and corn, generally grown in the small valleys and along the flood plains of the streams. Black jack, post oak, and some hickory cover the more sandy and higher areas and wild pecan, sycamore, elm, and cottonwoods grow along the streams and valleys.

The southern half of the county is served by three railroads, the M. K. & T., the Rock Island, and the Frisco, all of which are branch lines. The active oil development has brought a great deal of new wealth into the county and has probably doubled its population. Numerous new boom towns have sprung up in the oil fields and the original towns of Wewoka and Seminole have had a large increase in population and business activity.

GENERAL GEOLOGY

Surface Formations

Shale, sandstone, conglomerate and limestone of upper Pennsylvanian age compose the rocks outcropping through most of Seminole County. The exceptions are the belts of river sand and alluvium along the larger drainage channels and the areas of Guertie sand found in the
south side of the county, both of Quaternary age. Shales constitute 76 per cent, sandstone and conglomerate 23 per cent and limestone one per cent of the outcropping rocks. However, owing to the more resistant qualities of the sandstones, conglomerates and limestone, the shales cover a lesser area than their thickness would indicate.

The source of the sediments comprising the rocks found at the surface is not yet known. The conglomeratic material was derived from the Arbuckle Mountains to the south which were rising and undergoing rapid erosion at this time. During Vanoss time the pre-Cambrian granites of the Arbuckle Mountains were probably exposed to erosion as evidenced by the arkosic material characteristic of the Vanoss formation. The Arbuckle Mountains did not supply the material for all of the sediments, however, since the conglomerates grade laterally into rocks of an entirely different character in other parts of the Mid-Continent region. The writer's idea is that the erosion of the Arbuckle Mountains to the south merely contaminated a sea already having a more or less stable source of sediments and well established over the Mid-Continent region.

In Figure 70 is shown the character of the outcropping formations, as described by Morgan along the south side of the county and the character of the same formations as found by O. E. Nordman in a section across the county through T. 9 N., 20 miles north of Morgan's section.

The reader is referred to the "Geologic Map of Oklahoma" published by the United States Geological Survey in cooperation with the Oklahoma State Geological Survey for the location of the formation boundaries, areas covered by the different outcropping formations, and for the location of the surface faults.

A detailed description of the outcropping formations follows:

VAN OSS FORMATION

The Vanoss formation occupies an area covering approximately the west half of Seminole County. It ranges in thickness from 250 to 520 feet and consists of shales, arkosic sands, conglomerates, and a few thin limestones. Of the limestones, the Pawhuska (?) limestone at the base of the formation is of most importance. It is a thin, gray, fossiliferous limestone of variable thickness outcropping in the Seminole City, Bowlegs, and Little River fields. In these fields it is used as the datum to which the surface structure is referred. The following description of the Vanoss formation as given by Morgan in his description of it in the Stonewall quadrangle applies equally well to Seminole County:


Figure 70. Geologic section showing the nature of formations outcropping in southern and central Seminole County.
OIL AND GAS IN OKLAHOMA

SEMINOLE COUNTY

Name

The name of this formation is after the town of Vanoss which is situated on the outcrop in the north central part of T. 3 N., R. 4 E.

Thickness and Character

The Vanoss formation consists of alternating sandstones, conglomerates, shales and a few thin limestones. All the strata are arkosic, some of the sandstones so much so that at first glance a few of them might be mistaken for true granites.

The base of the Vanoss rests on the Ada formation, the contact between the two being the plane dividing the arkosic and non-arkosic materials. Due to the lenticular nature of strata along the contact and to the fact that the Vanoss is progressively overlapping southward no one stratum can be selected to mark the adjacent limits of the formation. The base of the arkosic zone, however, is relatively contemporaneous.

Age and Correlation

* * * * The Vanoss formation is probably equivalent to the upper Permian of Texas, and to the late Wabaunsee of Kansas and Missouri.

ADA FORMATION

The Ada formation occupies an area up to 2 miles in width in R. 6 E., in the southern part of the county. It becomes thinner and is either absent or cannot be differentiated north of T. 7 N. It consists of sand and shale and reaches a maximum thickness of 60 feet. The following description of it in the Stonewall quadrangle as given by Morgan applies equally well to the remainder of Seminole County:

Name

The formation is here named after the town of Ada within and to the west of which lies the type area.

Thickness and Character

The average thickness of the Ada formation is about 100 feet. Limestone conglomerates and coarse sandstones are very prominent along the greater portion of the outcrop. Clastic material becomes less toward the north, however, and in the vicinity of Vanoss is very scarce. With the decrease in the amount of clastic material northward the formation becomes thinner and at the northern edge of the sheet has a total thickness of only 60 feet.

Although fossils are very scarce in the Ada formation a few species were found which indicate that the sediments are of marine origin.

VAMOOSA FORMATION

The Vamossa formation occupies a belt two to eight miles wide through Rs. 6 and 7 E. It consists mainly of conglomerates, sandstones, and variable amounts of shale and furnishes the most pronounced topo-


graphic expression of any of the formations. The conglomerates consist of rounded to sub-angular quartz pebbles, weathered chert pebbles, and sand grains, cemented by siliceous material. The size of the pebbles is generally less than one inch in diameter but locally pebbles up to six inches in diameter occur. Cross-bedding, lensing, and rapid lateral variations are common throughout the formation. It thins toward the south from 525 feet in T. 9 N., to 325 feet in the south part of T. 6 N. An interesting fact is the occurrence of the largest boulders in the conglomerate in T. 9 N., R. 7 E., where the formation is thickest.

Morgan originally describes it in the southern part of the county, the following extracts being from his report:

Name

A suitable geographic name was not available for this formation. The term finally selected is after the village of Vamosa which is located in the northern part of the Stonewall quadrangle, about one-half mile west of the outcrop. The formation is typically developed on the main road between Sasakwa and Komaw.

Thickness and Character

Where all of the formation is exposed the entire section has an average thickness of 280 feet. At the base is about 20 feet of dark shale that might easily be mapped as a marine formation. No collections were made from this member, but it is very probably fossiliferous. The main mass of the formation is above this shale and has a maximum thickness of about 230 feet. It consists in large part of the chert conglomerates, of massive, coarse, red and brown sandstones, and red shales. The clastic material is finer near the top and the red coloration is there also less pronounced.

The chert conglomerates of the Vamosa formation closely resemble those of the Wewoka, Holdenville, Seminole, and Francis formations, but may be distinguished from somewhat similar beds in the Pontotoc terrane because of arkosic material contained in the latter. The Vamosa formation contains a greater thickness of chert conglomerates than does any other formation of the area.

Overlap of the Vamosa formation, by the succeeding Ada formation, is progressive southward. For this reason only the lower shale and about 30 feet of the clastic portion of the formation are exposed near Byng.

No fossils were found nor is it highly probable that any are present in the clastic beds of the Vamosa.

Age and Correlation

Because of the absence of collections from the Vamosa formation and the paucity of fossils in the succeeding Ada formation and the still higher Pontotoc terrane, the problem of
correlating the Vamoosa and later strata is very difficult. As stated elsewhere, the method used in determining the correlations here suggested are largely based on the percentage and average range of common species.

The evidence derived from a strict application of this method to the Vamoosa and Ada formations, as well as to the strata of the Pontotoc terrane, is conflicting and contradictory. The general weight of evidence, however, seems to favor a correlation of the Vamoosa with the lower Permian of Texas, and with a portion of the Wabaunsee of Kansas and Missouri. Evidence supporting this correlation is contributed by two collections of plant fossils from the Pontotoc terrane. The plants indicate that the Pennsylvanian-Permian contact lies near the top of the Vamoosa formation of the Pontotoc terrane.

**BELLE CITY LIMESTONE**

Morgan’s describes the Belle City limestone as follows:

**Name**

Belle City limestone is the manuscript name given by Boone Jones to a formation that is well developed in the Stonewall quadrangle. The name is after Belle City, a village in Seminole County.

**Thickness and Character**

The formation has an average thickness of 30 feet. It is composed of two limestones of varying thickness with an intervening shale. The upper limestone is generally thicker and much more massive than the lower. Its range in thickness is from one foot, as just south of Byng, to as much as 15 feet near Canadian River. The bed is white or light gray in color and is often characterized by well developed striae. Pronounced weathering along joint cracks is common and in the eastern part of sec. 24, T. 6 N., R. 6 E., results in the formation of small sinkholes at the intersection of a few of the prominent joints.

The lower limestone bed is buff colored. Its range in thickness is from one foot, as in the vicinity of Byng, to as much as five feet near Canadian River and northward. At variance with the massive character of the upper member of the formation the bedding of this stratum is relatively thin.

The interval between the upper and lower limestones is composed of shale that ranges in color through shades of green, blue, and black. Its average thickness is 12 feet.

**Fossils**

All three members of the formation are fossiliferous, but the largest fauna is from the massive limestone at the top.

**Age and Correlation**

The Belle City Limestone is to be correlated with at least a part of the Moran of Texas, and is equivalent to a part of the Wabaunsee of Kansas and Missouri.

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**SEMINOLE COUNTY**

**FRANCIS FORMATION**

The following extracts from Morgan’s report on the Stonewall quadrangle show its characteristics and apply equally well to the formations found farther north in Seminole County:

**Thickness and Character**

In the type area and northward the Francis formation has a thickness of 500 feet. In the vicinity of Ada and southward only the lower part of the formation is exposed, the upper part being overlapped by the Ada formation.

At the base, but within the Francis formation, is the DeNay limestone member, the lower part of which marks the top of the Seminole formation. Above this limestone is an interval of about 30 feet that is represented by dark blue and black shales. These grade upward into sandstones which on the creek bluff northwest of Saskaqua have a thickness of nearly 30 feet. This is the sandstone that outcrops in the railroad cut below the viaduct in the northeastern part of Francis and is also correlated with the sandstone ledge in the road cut just north of the brick plant and railroad crossing near the southeast corner of Ada. Above the sandstone member is a series of thick, dark and sometimes calcareous shales. The average thickness of this part of the formation is 230 feet. In the northern part of the type area it is slightly more than this, but in the southern part it seems to be slightly less. West of Saskaqua the surface of this deposit extends to the residence of the former Governor Brown of the Seminole Nation. Most of the town of Francis is located on these shales and they are typically developed around the water tower there. Shales of this member are utilized by the brick plant at Ada. As is clearly shown in the pit at the latter place, the lower part of the shale is much darker and more calcareous than the upper part. One of the most characteristic features of the shale series is the abundant limestone concretions which it contains. These vary in size from less than an inch in diameter up to as much as a foot. When freshly broken the central mass consists of a dense, dark blue limestone, on weathering, however, the color becomes yellow or yellowish brown. The concretions are often very fossiliferous. Other concretions collected from the shales were of the core-in-cone type.

Above the shale series is a thickness of almost 100 feet within which coarse brown sandstones and chert conglomerates predominate. Only occasional fossils were found within this member. Although much higher in the geologic column some of these conglomerates greatly resemble the conglomerates at the base of the Seminole in the type area of that formation. For that matter, however, they also closely resemble the conglomerates of the Wewoka, Holdenville, and Vamoosa formations, and were it not for the presence of arkose in the Pontotoc strata, hand specimens of Francis conglomerate could probably not be distinguished from similar specimens of the chert conglomerates in that terrane. All the very similar chert conglomerates in the Pennsylvanian section must have had a similar source. The writer is in agreement with Taff’s suggestion that this source was the Ouachita area.

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The upper part of the Francis formation is a shale that is about 100 feet thick. This part carries a few thin sandstones and one rather persistent conglomeratic limestone. The limestone is often very fossiliferous and is typically exposed in the road about 180 yards west of the school house in the southeast corner of sec. 19, T. 6 N., R. 7 E. In the vicinity of Ada this shale and a part of the underlying sandstone member is overlapped by the Ada formation. Southwest of Ada successively lower beds are overlapped until in the vicinity of Fitzhugh the entire formation is concealed by the Ada formation.

**Fossils**

The Francis formation carries its most prolific fauna in the thick shale series which is quarried at the Ada brick plant. At the latter point 50 well preserved species were collected.

**Age and Correlation**

The Francis formation is thought to be equivalent to the Pueblo and lower Moran of Texas, and to the Shawnee and lower Wabanaee of Kansas and Missouri.

**SEMINOLE FORMATION**

The Seminole formation outcrops in a narrow belt in the southeastern part of the county. It consists of 150-250 feet of shale with prominent sandstone layers at the top, middle, and base of the formation. It is correlated by Morgan with the Harpersville and Thrifty formations of Texas and with most of the Douglas of Kansas and Missouri.

**Subsurface Formations**

**PENNSYLVANIAN ROCKS**

Rocks of Pennsylvanian age extend below the surface to depths varying from 3,400 to 4,000 feet and consist of alternating shales, sands, conglomerates, and thin limestones. The following table shows the amounts of each encountered in wells of three areas within the county:

**Character of Pennsylvanian Sediments**

<table>
<thead>
<tr>
<th>AREA</th>
<th>SHALE Feet</th>
<th>SHALE Per cent</th>
<th>SAND Feet</th>
<th>SAND Per cent</th>
<th>LIMESTONE Feet</th>
<th>LIMESTONE Per cent</th>
<th>Total Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cromwell field</td>
<td>2825</td>
<td>82</td>
<td>470</td>
<td>13</td>
<td>155</td>
<td>4</td>
<td>3450</td>
</tr>
<tr>
<td>Wewoka field</td>
<td>2905</td>
<td>87</td>
<td>380</td>
<td>11</td>
<td>40</td>
<td>1</td>
<td>3225</td>
</tr>
<tr>
<td>Earlsboro field</td>
<td>2980</td>
<td>77</td>
<td>750</td>
<td>19</td>
<td>140</td>
<td>3</td>
<td>3840</td>
</tr>
</tbody>
</table>

In the eastern part of the county, where a number of wells were drilled by the cable tool method, the different formations can be traced from well to well and finally to the outcrop at the surface, but in the western half of the county, where rotary drilling prevailed, the individual beds can be followed in well logs with difficulty if at all. Of these, the Calvin series, which includes beds up to the basal sand of the We woka formation, is the most important structurally. It forms a persistent series of sands interstratified with shales 200-250 feet thick and is used as a datum in mapping the subsurface Pennsylvanian structure. The basal sand of this series quite often contains gas and oil and occasionally in commercial quantities. The Calvin series is correlated with the Oswego lime horizon of northern Oklahoma. The Calvin sands are progressively deeper from east to west and conform with the regional dip of the surface rocks. Thus in the Cromwell field they are found at 1,400-1,500 feet, in the Seminole field at 2,300-2,500 feet, and in the Earlsboro field at 2,900-3,200 feet below the surface.

In the eastern part of the county the lower part of the Pennsylvanian (the Pottsville) is of commercial importance and consists of the following subdivisions:

**Lower Pennsylvanian sands in eastern Seminole County**

<table>
<thead>
<tr>
<th>Sand</th>
<th>Thickness</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booch sand</td>
<td>0-60</td>
<td>Sand</td>
</tr>
<tr>
<td>Gilleraese horizon</td>
<td>0-300</td>
<td>Sand, shale, and limestone</td>
</tr>
<tr>
<td>Cromwell sand</td>
<td>0-100</td>
<td>Sand</td>
</tr>
</tbody>
</table>

Oil is produced from the Booch sand in the Bethel field and minor quantities have been produced from it in other areas, but it is in general water bearing. It is correlated with the productive Booch or Taneha sand of the Okmulgee District and with the Hartshorne sandstone which outcrops in eastern Oklahoma.

The Gilleraese horizon is a variable series of sand, sandy limestone, and limestone separated from both the Booch sand above and the Cromwell sand below by a shale interval. It is productive locally, the accumulation being related more to its porosity than to folding. In this respect it is similar to the Dutcher series farther northeast with which it is correlated. The writer believes it can be correlated with the Atoka formation which outcrops in the Atoka region and is therefore of Pottsville age. It thins to the west by progressive overlap, the higher members extending farthest west.

The Cromwell sand is productive in the Cromwell field, and in the Wewoka field where it is known as the Smith and Sykes sands. It is the basal sand of the Pennsylvanian, varies from 0 to 100 feet in thickness, and extends as far west as the east side of R. 6 E. A thin limestone, which thickens to 125 feet farther east, there known as the Lyons limestone, is found capping it in several places. The Lyons limestone is correlated with the Morrow and Wapanucka limestones.

of the outcrop, which in turn are correlated by Plummer and Moore with the Marble Falls limestone of north-central Texas. Thus the Cromwell sand of Seminole County is approximately of the same age as the Bend producing horizon of Texas.

The structure of the upper part of the Pennsylvanian rocks is the same as that of the surface beds. The westward regional dip varies from 50 to 90 feet per mile and would normally carry the basal part of the Pennsylvanian to a depth of 4,700 feet on the west side of the county. However, the lower formations of the Pennsylvanian are progressively cut out by overlap at nearly the same rate as the surface regional dip carries them downward, the result being that the base of the Pennsylvanian is much nearer the same level in all parts of the county than would be expected. The basal Pennsylvanian formation, however, is not the same throughout the county. Thus on the east side it is the Cromwell sand, farther west the Booch sand, and on the west side of the county either the McAlester shale or the Boggy formation. The intervening 1,000 or 1,200 feet being progressively cut out toward the west through non-deposition. This westward thinning and other details of Pennsylvanian stratigraphy are shown in the cross-sections of Map No. XXVIII. The convergence is the cause of the westward shifting and the apparent sharpening of the structures on depth.

In the western part of the county, particularly in the Earlsboro area, the base of the Pennsylvanian is commonly identified by a sandy shale zone up to 40 feet thick, containing subangular to rounded sand grains, weathered chert, traces of glauconite, lignite fragments, and other conglomeratic material. A number of round, frosted sand grains resembling those of the Simpson sandstones are found. In this part of the county progressively younger beds of the Pennsylvanian system rest on the upper or shale member of the Caney formation with structural and erosional unconformity. Where the lower part of the Pennsylvanian is mostly shale and rests on the Caney shale member of the Mississippian, samples of the cutlines offer the only evidence of the contact. In places very little contact material is found in the samples and the general lithologic change between the Pennsylvanian and Mississippian is used to approximately define the contact. The Pennsylvanian shales are variegated, granular, "greasy", fossiliferous, non-calcareous, and slightly sandy in contrast to the underlying, uniform, fine grained, dull, non-fossiliferous, slightly calcareous Caney shales containing disseminated pyrite in the upper part and mica in the lower part, and no sand.

MISSISSIPPIAN ROCKS
CANEY FORMATION

In Seminole County the Caney formation includes the beds lying between the base of the Pennsylvanian and the top of the Chattanooga

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shale. The lower 90 to 110 feet is locally termed the "Mayes" limestone and the shales above it are called the Caney shale.

Caney Shale Member. As observed in well cuttings the upper shale member is a bluish-gray, uniformly fine grained, fissile shale. It drills easily but caves badly. It is slightly calcareous and contains small amounts of finely disseminated pyrite. Toward the base it becomes more granular in texture and apparently grades into the lower calcareous member, locally known as the "Mayes" limestone.

"Mayes" Limestone Member. The "Mayes" limestone is a black to brown, finely crystalline, highly calcareous shale or argillaceous limestone. It does not cave and drills easily. At the base occurs a variable, thin, gray limestone bed, and this is underlain by a very persistent layer containing considerable glauconite and some sand grains.

A few microfossils are found in the Caney formation. The following fossils have been observed:

- Hindeodella sp.
- Caneyella wapanuckensis
- Orthoceras sp.
- Kirkbya sp.

The thickness of the Caney formation varies from 120 to 700 feet depending on the depth of the post-Mississippian erosion. Of this thickness, the lower or "Mayes" limestone member is uniformly 90 to 110 feet thick. The upper shales vary from 20 to 600 feet in thickness, the thin areas being high structurally whereas the thick areas are low structurally.

The Caney formation is overlain unconformably by rocks of Pennsylvanian age. This unconformity is both structural and erosional, the erosion in places having removed up to 600 feet of Caney shale prior to the deposition of the Pennsylvanian sediments. The Pennsylvanian formations which overlie the Caney formation range in age from the Cromwell sand up to the McAlester or Boggy formations. Apparently faulting and folding occurred during post-Mississippian or early Pennsylvanian time, followed by base-leveling and the progressive westward overlap of the Pennsylvanian formations. Thus the structurally higher parts of the Mississippian were eroded to a greater depth than those areas which were structurally low and protected. The presence of the persistent glauconite layer and the local sandy phases at the base of the "Mayes" limestone member, would indicate that a stratigraphic break separates it from the underlying Chattanooga shale. Otherwise the basal contact appears to be conformable.

The Caney formation of Seminole County is correlated with the lower or Mississippian Caney shale of the Arbuckle Mountain region to the south, which in turn has been correlated by Girton as being litho-

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10. Plummer, Frederick B., and Moore, Raymond C., Stratigraphy of the Pennsylvanian formations of north-central Texas: Univ. of Texas, Bull. 2132, pp. 53-64, 1921.

logically and faunally similar to the Moorefield shale of northern Arkansas. For this reason it would be of pre-Chester age. The "Mayes" limestone member of the Caney formation can be traced northward in well cuttings and correlated with the black Mississippi limestone of the Ponca City district. The variable white limestone layer occurring at the base of the "Mayes" limestone member is undoubtedly represented in the Arbuckle Mountain section by the Sycamore limestone.

CHATTANOOGA SHALE

The Chattanooga shale as observed in well cuttings is a black non-calcareous, uniformly fine grained shale. It contains an abundance of coarsely crystalline pyrite in irregular nodules. Local occurrences of black chert have been noted. It drills like the overlying "Mayes" limestone member of the Caney formation and is not as a rule distinguished from it by the drillers in the field.

The following microfossils are known to occur in the formation:

Mississippian Conodonts
Large numbers of Sporangites kuronense

The thickness of the formation ranges from 30 to 40 feet in the north part of the county to 100 feet at Earlsboro, 165 feet in the Little River field, and over 200 feet at the south side of the county. The Chattanooga shale is overlain by the "Mayes" limestone member of the Caney formation which contains glauconite and locally sandy layers at its base which would indicate a stratigraphic break. The base of the Chattanooga shale rests with erosional and angular unconformity upon beds ranging in age from middle Sylvan to upper Hunton.

The Chattanooga shale is equivalent to the Chattanooga shale of northern and eastern Oklahoma, and also to the Woodford chert of the Arbuckle Mountain region to the south.

In the field, the names Chattanooga shale and Woodford shale are both used. The term Chattanooga shale is preferable since as a subsurface formation it is better established in Oklahoma and is so well known and wide-spread in east-central United States. The age of the Chattanooga shale was originally determined as upper Devonian and is still considered as such by the United States Geological Survey. An increasing number of geologists, however, believe that from both paleontological evidence and stratigraphic relations it bears a closer relation to the Mississippian and should be considered as the basal member of that system. The major unconformity at its base and the Mississippian fossils found in the formation in Seminole County are the basis for placing it in the Mississippian system in this report.

A few feet of sand resembling the Simpson sand is found locally at the base of the Chattanooga shale. This sand farther north in Oklahoma is called the Misener sand. In some areas, particularly in the

Bowlegs and Little River fields, it contains a considerable amount of limestone conglomerate and this has been mistaken for the Hunton limestone. The Misener sand has produced some oil in Seminole County. White's description of it in northern Oklahoma applies to the few occurrences in Seminole County. He states:

A surprisingly small amount of erosion debris was left upon this old eroded surface. However, there were a few sand dunes composed of sand derived from the Simpson formation. In addition to a few well developed dunes a thin veil of wind-blown sand was scattered over broad areas. This sand was preserved by the deposition of the Chattanooga shale above it. Where it is exposed in eastern Oklahoma and Arkansas it is known as the Sycamore sandstone. By the drillers in the oil country, it is called the "Misener" sand. Because of its source of origin, therefore, samples of it from wells resemble samples from the "Wilcox" or "Burgan". It is extremely lenticular in extent. Wells drilled to this sand are often dry, even though higher structurally than offset wells producing from it, because of its absence. Where the "Misener" is sufficiently wide-spread for structure to affect the accumulation of oil, it produces on domes or anticlines. In most cases, however, it produces as a true lens without reference to structure.

DEVONIAN-SILURIAN ROCKS

HUNTON FORMATION

The Hunton formation, or Hunton limestone as it is commonly called, where a full section is developed in Seminole County ranges from a light gray to white, fine-grained, cherty limestone at the top (the Bois d'Arc member) to a darker gray, crystalline limestone at the base (the Chimneyhill member). Locally each of the three members into which the Chimneyhill or lower Hunton is divided, the pink crinoidal member, the glauconitic member, and the oolitic member, have been identified in well cuttings. The average Hunton limestone is difficult to distinguish from the Viola limestone by its physical appearance in well samples. Its position in the geologic section below the black Chattanooga shale and above the green to gray Sylvan shale and its abundance of microfossils, in general, offer the best evidence for its identification.

It contains a wide variety of microfossils, particularly ostracods and crinoids of which but few are as yet known to be diagnostic of individual beds. It is of interest to note that the systemic boundary between the Silurian and Devonian occurs within the Hunton limestone.

Depending on the post-Hunton erosion and the extent of the unconformities within the Hunton formation, the thickness varies from 0 to 195 feet. Where the Hunton is thin the lower or Chimneyhill member is the division encountered and this indicates that the princi-
pal reason for the change in thickness is the erosion of the upper members. Throughout a large, irregular area across central Seminole County the Hunton is entirely absent or very thin as shown in Fig. 71. Apparently a broad, irregular arch extending through this area existed at the end of Hunton time, the crest having been eroded during the peneplanation which preceded the deposition of the Chattanooga shale.

The upper contact of the Hunton formation is an erosional and gently angular type of unconformity, the Chattanooga shale resting on the different members of the Hunton formation or upon the underlying Sylvan shale, depending on the depth of the erosion. The Hunton limestone rests conformably on the Sylvan shale.

The Hunton formation outcrops on the north side of the Arbuckle Mountains 20 miles south of Seminole County. Reeds has subdivided it into four separate formations as shown in the generalized geologic section of Seminole County. He places the upper two formations (Bois d’Arc limestone and Haragan shale) in the Devonian and the lower two formations (Henryhouse shale and Chimneyhill limestone) in the Silurian system. The unconformities within the Hunton formation as described by Reeds have not been observed in the samples from the Hunton limestone in Seminole County.

Oil in commercial quantities has been found in the Hunton limestone of Seminole County in the Wewoka, Seearight, Seminole, and Bowlegs fields. The oil occurs in solution cavities, small vugs, fissures, and other secondary features in the limestone. It is generally found near the top, indicating that the porosity is an effect of the pre-Chattanooga weathering and erosion.

**ORDOVICIAN ROCKS**

**SYLVAN SHALE**

The Sylvan shale as observed in well cuttings is a gray to light gray uniformly fine textured shale. The upper five or ten feet is characteristically light green in color but due to pre-Chattanooga erosion is missing in many areas. The Sylvan shale drills easily and fast but caves badly when wet. It is slightly effervescent in dilute hydrochloric acid. It contains finely disseminated pyrite. The basal 5 to 10 feet is darker, more calcareous, locally sandy, and in one well was found to contain considerable arkosic material. The Sylvan shale has a "soapy" or "slippery" feel when wet.

In the basal five or ten feet are found some graptolites of Medina age; otherwise the Sylvan shale is unfossiliferous.

The thickness of the Sylvan shale ranges from 30 to 100 feet. The Sylvan is in general thickest where overlain by the Hunton limestone

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15. Buchanan, Geo. S., personal communication.
and thin where pre-Chattanooga erosion has removed the Hunton limestone and the upper part of the Sylvan shale. Since nearly all of the wells are remeasured at the base of the Sylvan shale or the top of the Viola limestone, the variable thickness reported in some cases is not real but is due to the correction of the drilling measurement.

The Sylvan shale is normally overlain conformably by the Hunton formation but throughout the central part of the county where pre-Chattanooga erosion has removed the Hunton limestone, the Chattanooga shale rests with erosional and slightly angular unconformity on different horizons of the Sylvan shale depending on the depth of erosion (See figure 71). The Sylvan shale rests conformably on the Viola limestone unless the lithologic change at the base of the Sylvan shale and at the top of the Viola limestone can be construed as indicating a break in sedimentation.

The Sylvan shale has been considered to be upper Ordovician in age and is still so considered by the United States Geological Survey. Ulrich believes it to be of Silurian age and his most recent paper on the problem presents a very convincing argument in favor of such a change. It is placed in the Ordovician in this report only because the writer has no information of his own to offer on the subject and this is the generally accepted correlation. Eventually the Sylvan shale and the underlying upper Viola limestone will undoubtedly be generally regarded as Silurian in age.

**VIOLA LIMESTONE**

The Viola limestone is generally used as the datum for Ordovician structure. It is a light gray to gray, coarsely crystalline limestone 30 to 40 feet thick. The upper five to ten feet is milky white, flaky and soft. The remainder of the formation is denser, drills hard, and furnishes an excellent casing seat. The Viola limestone contains no dolomite and effervesces strongly in dilute hydrochloric acid.

The Viola limestone contains very few microfossils in contrast to the highly fossiliferous Hunton limestone. Some crinoid stems and some simple ostracods have been found in it.

The Sylvan shale rests conformably on the Viola limestone unless the lithologic change at the base of the Sylvan and the white, flaky upper part of the Viola limestone can be taken to indicate a stratigraphic break. Locally the Viola limestone is apparently conformable on the underlying Simpson formation but over broad areas it overlaps the entire middle and lower Viola and the upper Simpson section.


**SEMINOLE COUNTY**

Fannie C. Edison states that the Viola limestone of the Mid-Continent "consists of two members, an upper, coarsely crystalline, Rich mond bed, and a lower dense, buff, lithographic bed, probably upper Black River in age." This dense lithographic limestone underlies the Viola limestone in Seminole County and is here considered as the upper member of the Simpson formation. The exact stratigraphic position of this limestone has not been worked out and either interpretation may be correct. In Seminole County the dense limestone member seems to be more closely associated with the Simpson formation than with the Viola limestone and the "top of the Simpson" as commonly reported in the field is the top of the dense brown limestone.

The Viola limestone is considered to be of Ordovician age by the United States Geological Survey.

White states that the Viola limestone observed throughout east central Oklahoma is the Richmond phase of the Viola limestone of the Arbuckle Mountains and correlates with the Fernvale limestone of Arkansas. Ulrich places the Richmond and consequently this upper phase of the Viola limestone in the Silurian system. It is assigned to the Ordovician system in this report since the writer has no special knowledge of the problem and as it is the commonly accepted correlation. Like the Sylvan shale, the upper or Richmond phase of the Viola limestone eventually will probably be assigned to the Silurian as suggested by Ulrich.

**SIMPSON FORMATION**

In Seminole County the Simpson formation consists of several members in descending order as follows:

Simpson formation:

- Dense limestone member
- "Simpson" formation of the First dolomite member
- Seminole sand member
- "Wilcox" or "First Wilcox" sand of oil fields
- Second dolomite member
- Wilcox sand member
- "Second Wilcox" sand of oil fields

**Dense Limestone Member.** This is a dense, brown to gray, lithographic limestone, locally containing thin dolomitic layers. Microfossils are abundant, particularly ostracods, but very few of them have been described. It underlies the white to gray, coarsely crystalline Viola limestone and is readily distinguished from it by the drillers. It is reported in the well logs as the "top of the Simpson." It varies in thickness from 5 to 30 feet, the average thickness being about 15 feet.

**First Dolomite Member.** This is a gray to brownish-gray, coarsely crystalline dolomite. It is of lighter color and coarser texture than
the dense limestone member which together with its greater magnesian content offers a means of distinguishing it. The lower 5 to 10 feet in the producing fields is more coarsely crystalline, very hard, and contains increasing amounts of Simpson sand grains with depth. It varies in thickness from 15 to 50 feet, the average thickness being 25 feet.

**Seminole Sand Member.** This is the most important producing horizon of Seminole County. It consists of a bed of uniformly fine grained, slightly dolomitic sandstone up to 80 feet thick. The sand grains are subangular to rounded, many of the round grains being larger and frosted or etched. The Seminole sand drills alternately hard and soft, the greater production generally coming from the softer horizons. The hard layers are probably due to local cementation or dolomitization and the softer parts are less consolidated.

The Seminole sand member is commonly known in the Seminole County fields as the “Wilcox” or “First Wilcox” sand. It has been recognized, however, by nearly all of the geologists working in the field as a younger and different sand than the true or original Wilcox sand of Oklahoma. The writer is indebted to Luther White for his suggestion of the need of a separate name for this sand, and for the name Seminole sand member. The Seminole sand member is a definite stratigraphic unit in the upper part of the Simpson formation; it has been definitely recognized as a distinct horizon throughout most of Seminole County and in the surrounding counties, particularly those to the north and northeast of Seminole County; it is uniformly bounded above and below by dolomite layers; lithologically it differs from the original or true Wilcox sand by containing considerable amounts of dolomite; and stratigraphically it is younger than the original Wilcox sand and separated from it by a layer of dolomite or sandy dolomite. Since it has reached its maximum geological and commercial development in Seminole County, the name Seminole sand member is introduced as an appropriate name for this sand.

The Wilcox sand was discovered and originally developed for oil in the Okmulgee district of Oklahoma, where it was found underly the Viola limestone. Later developments showed that in a number of areas it was separated from the overlying Viola limestone by a variable series of dolomites, dolomitic limestones, interbedded green shale and dolomite, and standstone. This series has been termed the “post-Wilcox” Simpson by Luther H. White.

He states:

> The group of rocks referred to as the post-Wilcox Simpson is a series of brown or gray sandy dolomitic limestones interstratified with some green shale and thin sandstone members.
> Wells in the vicinity of Holdenville, Okemah, Stroud, and Cushing.

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22. White, Luther H., personal communication.

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ing and all intervening territory encounter a series of this character having a minimum thickness of 3 feet of sand at its upper contact. This group occurs between the Viola limestone above and the “Wilcox” sand below. It is referred to as the Simpson because the sand grains are rounded and etched, the shales present are green and the dolomite is more characteristic of the Simpson than the Viola limestone. It is desirable to differentiate it from the “Wilcox” sand, since it produces oil and gas in small quantities, the oil generally being much lower in gravity than that found in the “Wilcox” sand. It is also possible that water may be encountered in this horizon before reaching the “Wilcox” sand.

From a study of the well records in the vicinity of Ada and northward it appears that the rocks referred to here as post-Wilcox belong to the upper Simpson and would comprise all the beds from the top of the Simpson formation down to the top of the bed of glass sand at Roff. The term post-Wilcox is not used as a name but merely as a descriptive term to indicate a certain portion of the Simpson formation, namely that part above the “Wilcox” sand.

The first four members of the Simpson formation, of which the Seminole sand is one, therefore comprise the post-Wilcox Simpson of Luther White in Seminole County.

The Seminole sand member is probably a lense, grading into dolomite toward the southern part of Seminole County and thinning out toward the north and northeast parts of the State either by erosion and overlap of the overlying Viola limestone, non-deposition, or gradation into dolomite. It is distinguished in well cuttings from the Wilcox sand by its dolomite content and the uniformity and slightly smaller size of its sand grains. The Wilcox sand contains a few feet of characteristically coarse sand grains at the top and is interstratified with thin layers of green shale rather than dolomite.

**Second Dolomite Member.** Below the Seminole sand member is found a dolomite, sandy dolomite, or interstratified shale and dolomite from 10 to 100 feet in thickness. It is persistent throughout Seminole County, the thicker beds being found where the Seminole sand is thin or absent as in the southern part of the county. There it is not distinguished from the first dolomite member.

**Wilcox Sand Member.** The main sand body of the upper Simpson formation is found below the second dolomite member or from 150 to 200 feet below the top of the Viola limestone. Wells in the Seminole and Wewoka fields have penetrated it a depth of 217 and 675 feet respectively and have not encountered the base. In both fields it was found to be interstratified with thin layers of green shale. The upper few feet in all wells which are known to have reached it characteristically consist of coarse grained sand. Dolomitic layers have been found but they are not common as in the Seminole sand member and in general
the quartz is clearer in the Wilcox sand grains than in those of the Seminole sand. The Wilcox sand member ("Second Wilcox" of the oil fields) produces some oil in the Seminole County fields at locations structurally high. Most of the wells, however, which have been drilled into it have found only water.

The above divisions of the Simpson formation are in general true for the producing fields of the county. Toward the southern part of the county, however, particularly through Tps. 5, 6, and 7 N., the interval between the base of the Viola limestone and the top of the first saturated sand increases to 200 feet or more. The reason for this increase is not known. A possibility is that the Seminole sand member ("First Wilcox") plays out toward the south by grading into dolomite. A sandy lime, one or two feet thick carrying water or small amounts of oil quite often occurs 100 to 150 feet below the Viola limestone and 50 to 100 feet above the top of the saturated sand in the southern parts of the county. This may mark the southern edge of the prolific producing Seminole sand member of the oil fields farther north. The first and second dolomite members would in this case occupy the position of the Seminole sand member and the saturated sand occurring 200 feet below the Viola would correlate with the Wilcox ("Second Wilcox") sand member of the oil fields. The water of this lower or true Wilcox sand becomes dilute and contains increasing amounts of hydrogen sulfide gas as the Arbuckle Mountains are approached, indicating a connection with the outcropping sands of the Simpson in that area.

Farther south in the Arbuckle Mountains, the upper or Richmond phase of the Viola limestone is separated from the Simpson formation by 500 to 600 feet of middle Viola limestone. This middle Viola limestone is not present in Seminole County, probably due to erosion and overlap by the succeeding Richmond member. This unconformity is evidence by local sandy lenses between the Viola limestone and the dense member of the Simpson formation which contain small amounts of oil.

Figure 72 ideally indicates the relations of the various members of the Simpson formation as found in Seminole County, and the nomenclature herein proposed. The right side of the diagram represents the conditions as found in the northern part of the county and in the producing fields and the left side the relations of the southern half of the county.

**STRUCTURAL GEOLOGY**

**Surface Structure**

The structure or attitude of the Pennsylvanian rocks exposed at the surface is one of a gentle west-dipping monocline, progressively younger and higher beds occupying the surface from east to west. This monocline is a part of a similar but larger structural feature covering, with but few interruptions, the area from Texas to Iowa and generally known as the Plains Monocline. The west dip varies from 50 to 90 feet per mile, a fair average being 70 feet per mile. Thus a formation which outcrops in the Cromwell field is found at a depth of 1,400 feet in the Earlsboro field 20 miles further west.

This west-dipping monocline is uniform only when viewed as a whole for on close examination it is found to contain numerous irregularities covering areas ranging from several square miles to a few acres. These irregularities consist of flattening of the normal dip or terraces; folds where the strata instead of dipping to the west, dip to the north or northwest and to the southwest along a common axis, thus arching the intervening area; and in places where the breaking strength of the rocks was exceeded, they were broken and faulted. These minor irregularities on the surface are found by means of close observation and accurate detailed methods of surveying and have been mapped throughout the county by most of the major companies. Each of the oil fields found thus far have been located under or adjacent to one or more of these irregularities and while all of them do not produce, yet the only indication at the surface of buried folds is to be found in these areas of abnormally structure. Their location, character, and relations are therefore of direct commercial importance. The surface structure of the Seminole City field is shown in Fig. 73.

The writer knows of no folds in the county which, when referred to sea-level datum, can be classified as domes or closed folds. When referred to the average west dip or natural datum, these terraces and folds become closed folds or true domes.

The faults in Seminole County are of the normal or gravity type. They strike N. 35°-40° W. and have vertical displacements up to 140 feet, but most of them range between 20 and 50 feet and generally are not over 2½ miles in length. They probably do not extend to great
## Generalized Geologic Section, Seminole County, Oklahoma

Note: The formations below the Francis formation known only from well logs.

<table>
<thead>
<tr>
<th>System</th>
<th>Formation</th>
<th>Thickness</th>
<th>Character of Sediments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Recent</td>
<td>0-40</td>
<td>Alluvium, sand, clay and conglomerate</td>
</tr>
<tr>
<td></td>
<td>Pleistocene</td>
<td>0-50</td>
<td>Unconformity, gravel and sand</td>
</tr>
<tr>
<td></td>
<td>Pampa formation</td>
<td>260-500</td>
<td>Shale, arkose sand, and conglomerate</td>
</tr>
<tr>
<td></td>
<td>Ada formation</td>
<td>0-50</td>
<td>Sand and shale. Thins out northward</td>
</tr>
<tr>
<td></td>
<td>Vamoska formation</td>
<td>270-500</td>
<td>Conglomerates, sands, and shale. Thins southward</td>
</tr>
<tr>
<td></td>
<td>Belle City limestone</td>
<td>0-30</td>
<td>Gray, fossiliferous limestone. Thins northward</td>
</tr>
<tr>
<td></td>
<td>Francis formation</td>
<td>370-500</td>
<td>Shale with interbedded sandstone layers</td>
</tr>
<tr>
<td></td>
<td>Seminole formation</td>
<td>800-1000</td>
<td>Shale with interbedded sandstone layers</td>
</tr>
<tr>
<td></td>
<td>Holdenville shale</td>
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<td></td>
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<tr>
<td></td>
<td>Wewoka formation</td>
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<td></td>
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<tr>
<td></td>
<td>Wewoka shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calvin sandstone</td>
<td>250-300</td>
<td>“Calvin sand series” of well logs. A persistent series of sands extending from the base of the Calvin sandstone to the top of the basal sand of the Wewoka formation.</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>Senora formation (7)</td>
<td>600-1400</td>
<td>Shale with several variable sandstones including the Earthborn sand. The Senora, Stuart, Thurman, and Saunawa formations probably represent only in southeastern part of county at all.</td>
</tr>
<tr>
<td></td>
<td>Stuart shale (7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thurman sandstone (7)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Saunawa sandstone (7)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>McAlester shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mississippi</td>
<td>Harthorne sandstone</td>
<td>0-40</td>
<td>Bedded sand of oil fields. Unconformity, structural and erosional features.</td>
</tr>
<tr>
<td></td>
<td>Atoka formation</td>
<td>0-500</td>
<td>Gypsum horizons of oil fields. Shale, limestone, and sandstone. Thins westward.</td>
</tr>
<tr>
<td></td>
<td>“Cap rock” of Cromwell Field.</td>
<td>0-10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wapanucka limestone member</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cromwell sand member</td>
<td>0-100</td>
<td>Produces oil in Cromwell and Wewoka oil fields.</td>
</tr>
<tr>
<td></td>
<td>“Mayne” limestone member</td>
<td>90-110</td>
<td>Unconformity (?). Blush, gray, fine-grained sand overlying unconf ormably by formations up to Boggy shale</td>
</tr>
<tr>
<td></td>
<td>Mienor sand at base</td>
<td>20-600</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chattanooga shale</td>
<td>20-220</td>
<td>Uniform, black shale, thickens southward.</td>
</tr>
<tr>
<td></td>
<td>Haragan shale</td>
<td>0-195</td>
<td>Unconformity, structural and erosional features.</td>
</tr>
<tr>
<td></td>
<td>Bois d’Arc limestone</td>
<td>35-100</td>
<td>Gray-green shale</td>
</tr>
<tr>
<td></td>
<td>Haragan shale</td>
<td>20-40</td>
<td>White to gray limestone. Unconformity</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Seminole County**

The discussion of the structure of Seminole County may be conveniently divided into two parts according to age, as that of the Pennsylvanian and that of the pre-Pennsylvanian formations.

### Pennsylvanian Structure

Since most of the wells are drilled through the Pennsylvanian formations by the rotary method, it has been possible to obtain such information as to the structural details of the upper part of the geologic section that can be correlated in adjoining counties where more is known of the upper Pennsylvanian structure. The structure of the upper 2,000 feet or more of the Pennsylvanian section is similar to that of the surface, consisting of terraces and noses. Thus the Calvin sand structure, as far as can be determined, shows little if any closure over the producing folds. The lower part of the Pennsylvanian, owing to its decreasing thickness toward the west or convergence of the strata in this direction, will contour as dome folds. This is true of the Cromwell sand of the eastern part of the county and of the basal Pennsylvanian zone of unconformity of the western part.

In general the individual members of the pre-Pennsylvanian formations are nearly parallel and the structure of the upper part of the Mississippian is the same as that of the Simpson sandstones. The thickening of the Chattanooga shale toward the south and southwest and the variable thickness of the Hunton lime gives slight structural divergence over wide areas. However, a discussion of the structure of the Viola limestone will essentially cover the structure of all the overlying rocks up to the top of the Mississippian.

Regionally, Seminole County is located on the saddle between the Arbuckle uplift to the south and the Ozark uplift to the northeast. This can be seen in Figure 73, which shows the generalized structure of the Viola limestone and Simpson formation in eastern Oklahoma. The writer's opinion is that the Arbuckle folding and faulting, a later movement than the Ozark uplift, does not have as great an influence on the Seminole region as the Bend Arch of Texas which can be directly correlated with the Ozark Arch of northeastern Oklahoma. In other words Seminole County is fundamentally on the saddle between the Bend Arch of Texas and the Ozark Arch of Oklahoma and Missouri.

The west side of this saddle is indicated by a relatively steep west dip. This is possibly a post-Mississippian fault similar to those described in the section on structural history.

Seminole County has a total structural relief of 2,035 feet, the lowest point on the Viola being 3,750 feet below sea level and the highest point 1,715 feet below sea level. The highest structure is in the south side of the county where the Viola and Simpson formations are rising and continue to rise until they outcrop 15 miles south of the county line in Pontotoc County. In the oil fields the Viola lime of the highest wells is 2,950 feet below sea level, and it is of interest to note that structurally one of the lowest known points in the county is in the heart of the Bowlegs field.

The true details of the Viola structure are difficult to map. The nature of some of these problems is brought out more fully in later paragraphs. In general it may be said that the principal difficulties are whether to contour the area as smooth dip or whether the evidence warrants faulting as a contributing factor to the irregularities. The writer believes that early Pennsylvanian and post-Mississippian faulting is one of the major structural factors throughout the county and that until we obtain a better idea as to the direction of these faults it is impractical to publish a contour map of the Viola lime which one might hope would even in a small measure prove of permanent value.

With the present control, then, all of the present oil fields and two of the wildcat wells, (Gypsy in sec. 5, T. 8 N., R. 6 E., and Barnsdall in sec. 23, T. 7 N., R. 6 E.) are structurally high and with the exception of the south side, which is rising regionally to the south, the remainder of the county is relatively low.

On Map No. XXVIII is shown cross-sections through the central part of the county from southwest to northeast. The same logs are used in both sections. In the section to the left the logs are arranged.
using sea level datum to show the present structure and in the other the logs are referred to the top of the Calvin series as a datum and show the structure of the older rocks during Calvin time.

A statement of interest to geologists working in the Seminole County region was made by Barton in discussing the geophysical methods now in use in the United States. He states: 26

The torsion balance is being tried out extensively in the Mid-Continent and West Texas areas, but as yet little drilling has been done on structures discovered by it. In the Seminole district the Bowlegs oil field was predicted in advance from torsion balance work and the eastward and northward extension of Earlsboro.

**Structural History and Origin of Folds**

The rocks of Seminole County so far as known are all of sedimentary origin and, with the exception of weathered horizons, fault planes and associated zones, are unaltered. It is therefore inferred that neither igneous nor volcanic activity has occurred nor has folding and deformation been sufficient to metamorphose or change the character of the sediments since their consolidation. We observe, however, that their original attitude has been changed and through the inferences drawn from the surface and subsurface records of Seminole County, together with those of the surrounding structural province of which Seminole County is a part, at least some idea is gained as to the succession of events during geologic history which left the rocks in their present structural position.

A correct interpretation of the structural history of a region is of commercial importance to the geologist in that, if rightly understood in one locality, it often furnishes a key as to what may be expected in another area where development is beginning. On account of the economic importance of the oil fields of Seminole County and because of the many new and different erratic structural conditions found in them, the origin of the producing structures has been given a great deal of thought by a large number of geologists. Opinion regarding the origin of these structures varies from setting over buried hills to settling over buried sink holes and from pure folding to pure faulting. The writer is of the opinion that the present structure of the producing fields can best be explained by a combination of both faulting and folding.

The following are some of the essential facts which must be considered in any theory of the origin and history of the folds of Seminole County: (1) As a background there are a number of fields in Oklahoma which have a similar and very definite geologic history. The Thomas 27 and Tonkawa 28 fields have been described. The Blackwell,

Cushing, Braman, and other fields in Oklahoma together with the granite ridge of Kansas undoubtedly have a like structural history. This history consists essentially of pre-Chattanooga arching and erosion, early Pennsylvanian or post-Mississippian faulting and associated folding followed by erosion, and post-Pennsylvanian faulting.

(2) Structural erratics are common in the Searight, Seminole, Bowlegs, and Little River fields and occur in the Earlsboro field. They are here defined as small areas consisting of a few acres in which the producing horizons vary as much as 600 feet structurally in adjacent wells. The average difference in structural elevation in the erratic areas ranges between 100 and 300 feet. These structural erratics are the reason for the wide difference of opinion among geologists regarding the origin of the Seminole County structures and are a new phase of Oklahoma structural geology.

(3) As far as the writer knows these erratic areas are in almost every case downward relative to the average surrounding wells as a study of the profiles of the Seminole and Bowlegs fields, Figures 76 and 80, discloses.

(4) The elimination of these low, erratic datums in any given field leaves a structure consisting of one or more relatively simple dome folds.

(5) The several members of the pre-Pennsylvanian section, as shown by the thousands of samples that have been collected from them, are remarkably uniform in thickness within the different fields. This uniformity is for a decrease in thickness which suggests faulting, rather than an increase in thickness suggestive of steeply dipping beds. This uniform thickness is constant within and without the erratic areas and erratic well is discovered as soon as the first identifiable upper Mississippian beds are reached.

(6) Faults, as an explanation of these erratics, are difficult to map because of the small areas affected. To postulate faulting as being the cause of the erratics, one must in many cases assume three faults which completely surround an area, enclosing one or two wells as a triangular downthrown block. At the present time there are many areas in which the erratics can be lined up to conform to any regular system. One such alignment is possible through section 14 of the Bowlegs field where several erratic wells, all dry holes, line up in a direction slightly east of north. In this area there is direct evidence of faulting in two of the wells. The structure map of the Seminole field, Figure 75, suggests alignments of erratics but in each case other alignments are possible, which may be as correct as the one shown. This structure map is shown merely to indicate a possible method of associating erratics in the different parts of the field.

(7) Of all the wells drilled in the Greater Seminole area only 10 or 15 can be definitely said to have crossed faults. This is remarkable
since such a large number of faults are required to account for the erratics. Faults have been crossed, however, and in those areas the resultant structure is identical with that of the erratic areas where no direct evidence of faulting has been found. The evidence in the wells which show faulting is the shortening of the section within the Mississippian equal in amount to the difference in structural elevation. (See Little River field, page 342.)

(8) In the areas of regular dip the water level of any field is relatively uniform. It usually occurs 3,300 feet below sea level in the Seminole sand member. Within and adjacent to the erratic areas, however, this water-oil level is also erratic and commercial wells producing oil with no water have been found as much as 300 feet below the average water level of the field.

(9) The geologic section involved in the erratic areas varies from 700 to 900 feet in thickness. To postulate the origin of the erratics by folding would require the parallel downward folding of this entire section a vertical distance of 600 feet and up again, in a horizontal distance of 1,320 feet, an improbable condition.

(10) The writer knows of no geologic literature which describes closed synclines or basins similar to those required to account for the erratics found in Seminole County. If close folding were the cause of the erratics, the folds would elevate the strata relative to the surrounding area rather than depress them. There are, however, a number of descriptions of block faulting in the literature which would appear to satisfy the conditions found in the erratic areas of Seminole County. A few of these areas are the Cave-in-Rock Quadrangle in western Kentucky, the Silver City district of New Mexico, and some of the Rocky Mountain structures.

(11) Contractors and drillers in the fields report numerous "crooked holes." Some of these are so crooked that a new hole has to be drilled, while others merely make drilling more difficult. It is certain, however, that many of the holes are not straight and the general opinion is that the path of the crooked hole is that of a long spiral. A survey of a drill hole has been made in California and the results show that the errors in both horizontal and vertical measurement may be considerable. Errors due to deflected holes are undoubtedly present in the oil fields of western Seminole County, and are a factor that may, after more information is available, be of considerable importance, particularly in structural differences up to 100 feet.

The writer believes that the present structure of Seminole County was developed in the following manner:


At the close of Devonian time several low broad arches were formed in the eastern half of what is now the United States. One of these is the renewal of the folding of the Ozark region of Missouri and northeastern Oklahoma, and another but smaller arch through central Seminole and adjacent parts of Pottawatomie and Hughes counties, Oklahoma. In Seminole County this arch had a structural relief of at least 195 feet or equal to the thinnest section of Hunton lime that has been found. (See Fig. 71, page 220.)

During or immediately following this uplift, base leveling occurred and the formations were eroded from structurally high areas and were left in full thickness in areas of low structure. Thus in Figure 71 the area in which the Hunton is gone and the Mississippian rests directly on Sylvan shale, in general, outlines the crest of the arch. During this same period of erosion the Arkhilee limestone was exposed in the Ozark arch as shown by Luther White.

If any oil were present in the Simpson formation sands at that time there would have been a tendency for it to migrate into this area of higher structure.

Following this penepelation, the Chattanooga shales was laid down over the flat surface throughout Seminole County, as well as a large part of the eastern United States. The deposition of a series of Mississippian age followed in regular succession culminating in the beds of upper Mississippian age. Gentle downwarps of southeastern Oklahoma and relative upward of the remainder of the State at the end of the Chester time exposed all but the southeast quarter of the State to erosion. This warping or tilting was at first very gentle allowing the deposition of the Morrow-Wapanucka limestone (lower Pottsville age) in the southeastern part of the State, the western limits of which were probably in Seminole County.

The arching increased following the deposition of the Morrow-Wapanucka limestone and exposed a greater Mississippian section to erosion in central and western Oklahoma and allowed the deposition of great quantities of shale, limestone, and sand (Atoka formation) in the southeastern part of the State. The deposits of Pottsville or Atoka age progressively overlapped one another toward the west from the bottom to the top of the formation. In other words, in proceeding from east to west, progressively younger Pottsville (Gilcrease formation of the oil fields) beds are in contact with the underlying Morrow-Wapanucka limestone and the older Mississippian formations. Thus in the southeast part of the State the oldest Pottsville rests on the youngest Mississippian, in the Seminole fields the upper Pottsville rests on pre-Chester Mississippian, while farther northwest in Kansas erosion had removed the entire Mississippian section and post-Pottsville Pennsylvanian formations rest unconformably on beds of Ordovician age.

33. White, Luther, Idem., pp. 21-22.
unconformity is probably represented in the Earlsboro field by the "unconformity zone" at the base of the Pennsylvanian, in this case either McAlester or Boggy formation. This subsidence and deposition of the thick Pottsville toward the southeast and erosion of the older formations toward the northwest can be traced with but little variation from Texas to Pennsylvania. Thus, up to this time the structural and geological history of Seminole County is but a part of a system of much wider extent.

During Pottsville time the downwarp toward the southeast had developed a structural relief in eastern Oklahoma of over 10,000 feet. Probably as a readjustment of this tilting, the rocks were faulted in a great many places. Nearly all of these faults were of the normal or gravity type and in general they were in trends N. 5°-25° E. Associated with these faults were cross faults, in general parallel to the present fault pattern of the Arbuckle Mountains, and in Seminole County a large number of fault blocks probably varying from 10 acres up to a township or larger in size, were dropped down. Arching and some steep dips were associated with the faulting, but these are of lesser importance structurally.

Following this period of faulting and associated folding, erosion continued, leaving the younger formations which were protected, in the down blocks. In Seminole County the thickest section of Caney shale member which has been found is 600 feet. In the areas of folding and faulting it is reduced by erosion to a thickness as low as 20 feet. Thus several hundred feet of material was removed before the Pennsylvanian sea covered the western part of the county, and this eroded material was undoubtedly carried southeastward into the seas of late Pottsville and early Allegheny time.

This period of faulting and associated folding is well known in the Tonkawa* and Thomas* fields of northern Oklahoma, and is probably one of the controlling factors in the Cushing, Blackwell, Wewoka and some other fields of Oklahoma, and of the granite ridge of Kansas. The faulting in the western Seminole County fields differs from the faulting in the other fields mentioned only in the limited size of many of the areas affected. In discussing the Seminole City field, K. C. Heald** best expressed the situation by calling it a "fault mosaic."

Any oil in the Simpson formation which had been localized within the pre-Chattanooga arch would have been further localized at this time along and around the areas which were faulted and deformed. The fact that oil is found in the erratic areas at very irregular depths, would indicate that there had been a considerable accumulation of oil in the Wilcox sand up to that time and that it was faulted down and sealed by the fault planes and by the associated steep dips.

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SEMINOLE COUNTY

The Pennsylvanian seas continued to advance over the area and over 3,800 feet of sands, shales, and limestones were deposited. Deposition of the Permian shales, sands, and red beds continued without break after which the entire Mid-Continent region was gently folded into west to northwest striking anticlines and synclines, most of which were relatively small. The surface folds of Seminole County were probably formed at this time. Later or possibly as a related movement the entire Mid-Continent region was tilted up toward the east and southeast resulting in the present Plains Monocline or regional west to northwest dip. This tilting caused horizontal differential movement along the underlying Mississippian fault zones and is expressed in the surface formations as the present belts of en echelon faulting.

Fully 75 per cent of the folding of Seminole County, both surface and subsurface, occurred during this post-Pennsylvanian deformation. The subsurface reflection of it is found in the relatively regular dome folds which result if the structural erratics in the oil fields are disregarded, as previously described. The closure on depth is a function of the convergence of the Pennsylvanian formations.*

A further and probably major localization of the oil occurred, the oil migrating into these post-Pennsylvanian folds. It is probable that there was also some shifting of the earlier localization along the faulted areas due to the differential movements recurring at this time and to the deflection of the migrating oil by the fault zones.

OIL DEVELOPMENT

Development of the oil fields of Seminole County began with the discovery of the Wewoka field by R. H. Smith in the spring of 1923. Gas had previously been found in the Cromwell structure but the active development of that field did not start until after oil was discovered in the fall of 1923. During the drilling of the Cromwell sand in these two fields, the wildcatters were busy but had rather disappointing results. Several small areas of production from lower Pennsylvanian sands were discovered but none of these were of commercial importance. The Simpson formation had been found to be non-productive beneath the top of the Cromwell structure as well as in several large structures east of the county and not much hope was expressed for its commercial possibilities. This continued until late in the fall of 1925 when the Magnolia Oil Company completed a 4,000 barrel well in the Seminole sand member of the Simpson formation in what was then believed to be the south flank of the Wewoka structure. This well was followed rapidly by the discovery of oil in the Seminole sand member in the Seminole City, Seabright, Earlsboro, Bowlegs, and Little River fields during 1926 and 1927. These are all in the west half of the county and comprise what is known as the Greater Seminole area.
Along with the development of the fields, much lease and royalty buying and trading was going on, royalty selling for as high as $11,000.00 per acre and leases as high as $16,000.00 per acre in areas that were believed to be proven. Most of the producing leases are owned by the major oil companies of Oklahoma and nearly every company is interested, thus insuring as orderly development as is possible. The market price of the Wilcox sand oil was $2.63 per barrel during the summer of 1926, but through several cuts was reduced to $1.34 per barrel by the early spring of 1927. Most of the oil was produced when selling at the lower price.

A more detailed description of the history, production, surface and subsurface geology of the major producing fields follows.

Wewoka Field

The first commercial oil production of Seminole County was in the Wewoka field located two miles southeast of the town of Wewoka. On March 17, 1923, R. H. Smith and others found a sand at a depth of 3,150 to 3,157 feet in their No. 1 Betsy Foster located in the NW 1/4 SW 1/4 NE 1/2 sec. 33, T. 8 N., R. 8 E., which produced at the rate of 3,500 barrels per day. This sand, named the Smith sand, occurs in the upper part of the Cromwell horizon. The development of this sand continued until sections 32 and 33 were completely tested. A lower sand in this horizon, found in Magnolia’s No. 1 Jones in the NE 1/4 SE 1/4 NW 3/4 sec. 32, produced at the rate of 290 barrels per day, and was completed October 20, 1923. It was later learned that this represented a separate and important producing horizon when Louis Sykes completed his No. 1 Boggs in the NE 1/4 SE 1/4 NE 1/4 sec. 31 on June 26, 1924, for 1,100 barrels at a depth of 3,160 to 3,183 feet. This lower sand, called the Sykes sand, is separated from the Smith sand by 50 feet or less of shale and is productive in secs. 31 and 32, T. 8 N., R. 8 E., and in the northern part of sec. 6, T. 7 N., R. 8 E. The Dixie Oil Company’s No. 5-A John Long in the NW 1/4 SW 1/4 SE 1/4 NE 1/4 sec. 32, T. 8 N., R. 8 E., first found the Hunton limestone and was completed as a 50 barrel well from a sandy phase of the limestone at a depth of 3,873 to 3,891 feet. After the development of the Smith and Sykes sands when the structure appeared to be closed in all directions and the limits of the field defined, the Magnolia Petroleum Corporation drilled its No. 1 Skinner in the NW 1/4 se. sec. 5, T. 7 N., R. 8 E., on the south flank of what was then the Smith sand structure. In this well the Seminole sand was found at a depth of 4,074 to 4,091 feet and it was completed December 18, 1925, as a 4,000 barrel well. At that time it was far in advance of Wilcox sand production in Oklahoma.

Production from the Hunton limestone was obtained in secs. 31 and 32, T. 8 N., R. 8 E., and Seminole sand (“Wilcox”) production found in these two sections and in secs. 5 and 6, T. 7 N., R. 8 E., where the top of the Simpson structure is located. The peak of the Smith and Sykes sand production was reached during the week ending June 12, 1925, when 134 wells averaged 19,860 barrels per day. The peak production from the Seminole sand was 29,023 barrels per day during the week ending August 20, 1926. During the week ending November 22, 1927, the entire field averaged 10,326 barrels per day from 215 wells. The limits of the field are completely defined and it covers an area of 1,700 acres. In the spring of 1927, Shea and Mossberg estimated the recovery up to that time to be as follows:

- Smith sand: 3,500,000 barrels
- Sykes sand: 4,500,000 barrels
- Seminole sand and Hunton limestone: 7,000,000 barrels

The surface formations of the Wewoka field consist of the shales and sandstones of the Francis and Seminole formations. The surface structure of the Smith sand area in secs. 32 and 33, T. 8 N., R. 8 E., is a normal west dipping regional monocline and shows no irregularity. In secs. 31, T. 8 N., R. 8 E., and in secs. 5 and 6, T. 7 N., R. 8 E., the regular dip is broken by several surface faults which probably belong to the same en echelon belt which passes through the Cromwell field farther north. Associated with these faults are some abnormal dips.

The Pennsylvanian rocks extend below the surface to a depth of 3,200 to 3,300 feet and contain the highly productive Smith and Sykes sands at the base. The top of the Calvin series is found at a depth of 1,000 to 1,100 feet. Locally, production has been obtained from the Bouch sand and Gilcrease sands but this has not been of much importance. The structure of the Smith sand is an irregular dome roughly outlined by the present limits of production, which are superimposed a number of minor domes covering 40 to 80 acres. This fold is cut off on the west by a gravity fault downdropped approximately 300 feet on the west and striking roughly north and south. As near as can be determined from the rotary logs, this fault ends in or near the top of the Gilcrease horizon, which would place its age as upper Pottsville.

Below the Pennsylvanian the following formations are found:

- Pre-Pennsylvanian formations:
  - Mississippian:
    - Casey formation:
      - Caney shale member: 740
    - "Mays" limestone member
  - Chattanooga shale: 40-110
  - Devonian-Silurian:
    - Hunton limestone: 0-195
  - Ordovician:
    - Viola limestone: 30-40
  - Simpson formation:
    - Dense limestone member: 15-30
    - First dolomite member: 15-35
    - Second dolomite member: 50-70
    - Third dolomite member: 20

The structure of the Ordovician rocks as described by Shea and Mossberg is a dome of 200 feet closure, the highest part of which is in secs. 5 and 6, T. 7 N., R. 8 E. This fold is cut off on the west side by the same fault which cuts off the Smith sand structure as described above. Over the highest parts of the Ordovician structure the Hunton limestone is thin or missing. It thickens rapidly, however, toward the north and in secs. 31 and 32, T. 8 N., R. 8 E., reached a thickness of 165 feet. This is the top of the Hunton high, the southward shifting of the Wilcox structure being in part caused by the southward thinning of the Hunton limestone.

The following is an average of the logs of the Wewoka field with correlations by the writer:

**Average section Wewoka field, sec. 5, T. 7 N., R. 8 E.**

*Average Elevation: 875' Above Sea Level*

<table>
<thead>
<tr>
<th>Top Formations</th>
<th>Bottom Formations</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 Shale</td>
<td>2450 Sand-water</td>
</tr>
<tr>
<td>170 Sand</td>
<td>2835 Sand—oily</td>
</tr>
<tr>
<td>335 Sand</td>
<td>2970 Sandy lime</td>
</tr>
<tr>
<td>400 Sandy lime</td>
<td>2970 Sandy lime</td>
</tr>
<tr>
<td>510 Sand—water</td>
<td>3005 Shale</td>
</tr>
<tr>
<td>700 Sand—water</td>
<td>3140 Sand—oily</td>
</tr>
<tr>
<td>850 Lime</td>
<td>3190 Sand—gas</td>
</tr>
<tr>
<td>975 Sand—water</td>
<td>3325 Lime shells</td>
</tr>
<tr>
<td>1095 Sand—water</td>
<td>3325 Lime shells</td>
</tr>
</tbody>
</table>

**Cromwell Field**

Gas was first found in the Cromwell field in the Cosden Oil & Gas Company's No. 1 Jim Wallace located in the SE 1/4 SE 1/4 NW 1/4 sec. 15, T. 10 N., R. 8 E., which was completed November 11, 1922, as a 30,000,000 cubic feet gas well in the Cromwell sand. It was at 3,456 to 3,466 feet. The field was named after the Cromwell Oil & Gas Company, which on October 2, 1923, completed the first oil well in the field.

This was their No. 1 Bruner located in the NW 1/4 NE 1/4 SW 1/4, sec. 15, in which the Cromwell sand was found at a depth of 3,467 to 3,475 feet and had an initial production of 312 barrels per day. The active development of the field followed the completion of this well and the peak production was reached during the week ending August 20, 1924, when 75 wells averaged 62,391 barrels per day. During the week ending November 22, 1927, the production was 10,823 barrels per day from 393 wells. The initial production of most of the wells ranges between 500 and 2,500 barrels per day although wells with a production as high as 3,600 barrels per day were reported.

The field covers an area of 4,700 acres, of which 140 acres are in Okfuskee County, and its limits are fully defined. The gravity of the oil varies between 38.0 and 40.0 degrees Baume. The elevation of the surface is between 850 and 1,000 feet above sea level and the average depth to the Cromwell sand between 3,300 and 3,400 feet.

The rocks that outcrop in this area are the shales, sands, and conglomerates of the Vamosa and Francis formations. The Belle City limestone practically plays out, only a few scattered remnants being found. The surface structure consists of several smaller folds on a large northwest pitching terrace which is bounded on the east by a belt of en echelon faulting.

The Pennsylvanian rocks extend to the base of the Cromwell sand or to a depth of 3,400 to 3,500 feet. Locally the Calvin sand series, the top of which occurs at a depth of 1,400 to 1,600 feet, the Booch sand and the Gilcrease sand of Pennsylvanian age produce relatively small amounts of oil. The Cromwell sand which covers a large area in this part of Oklahoma is believed to be the basal sand of the Pottsville series. It is overlain by the Lyons limestone which is merely a thin cap rock in the Cromwell field but farther east increases in thickness to 125 feet.

The structure of the Cromwell sand consists of three west to southwest pitching folds, the largest of which runs through the center of sections 9 and 10. The east side is cut off by an abrupt dip or fault. It is probably due to early Pennsylvanian deformation underlying the belt of surface en echelon faults. The structure has a relief of over 200 feet, of which the highest parts have produced only gas. The largest oil production was found in the local saddles and along the flanks of the local highs.

The Seminole sand member has been found at several places in the field but has only been found to be productive in sec. 33, T. 11 N., R. 8 E., where wells averaging 200 to 400 barrels have been completed. It occurs at 4,100 to 4,200 feet below the surface or 650 to 750 feet below the base of the Cromwell sand and the details of its structure are yet unknown. The structure of the Ordovician will probably parallel that of the Cromwell sand in a general way. The following pre-Pennsylvanian formations are found in the deep holes within the field:

Pre-Pennsylvanian formations.

Mississippian:
- Caney formation ........................................ 400-450
- Chattanooga shale ..................................... 30-40

Devonian-Silurian:
- Huron lime ................................................. 75-145

Ordovician:
- Sylvan shale ............................................. 75-90
- Viola limestone .......................................... 30-40

Simpson formation:
- Dense limestone member ............................. 5-15
- First Dolomite member .............................. 15-35
- Seminole sand (oil bearing) ........................

An average log of the Cromwell sand wells drilled in the southern part of the field with correlations by the writer follows:

Cromwell, Oklahoma, field, sections 21 and 22, T. 10 N., R. 8 E.
Average Elevation: 900 Feet Above Sea Level

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
<th>Formation</th>
<th>Top</th>
<th>Bottom</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>40</td>
<td>Shale</td>
<td>1540</td>
<td>1575</td>
<td>Sand—water</td>
</tr>
<tr>
<td>40</td>
<td>80</td>
<td>Sand—water</td>
<td>1575</td>
<td>1605</td>
<td>Sand—water</td>
</tr>
<tr>
<td>60</td>
<td>240</td>
<td>Shale</td>
<td>1605</td>
<td>1650</td>
<td>Sand—water</td>
</tr>
<tr>
<td>240</td>
<td>300</td>
<td>Sand—water</td>
<td>1650</td>
<td>1750</td>
<td>Shale</td>
</tr>
<tr>
<td>300</td>
<td>385</td>
<td>Shale</td>
<td>1750</td>
<td>1780</td>
<td>Sandy lime—water</td>
</tr>
<tr>
<td>385</td>
<td>695</td>
<td>Lime</td>
<td>1780</td>
<td>1950</td>
<td>Shale</td>
</tr>
<tr>
<td>695</td>
<td>685</td>
<td>Shale</td>
<td>1950</td>
<td>1990</td>
<td>Lime</td>
</tr>
<tr>
<td>685</td>
<td>855</td>
<td>Shale</td>
<td>1990</td>
<td>2035</td>
<td>Shale</td>
</tr>
<tr>
<td>855</td>
<td>865</td>
<td>Lime</td>
<td>2035</td>
<td>2045</td>
<td>Sandy lime</td>
</tr>
<tr>
<td>865</td>
<td>925</td>
<td>Shale</td>
<td>2045</td>
<td>2785</td>
<td>Shale</td>
</tr>
<tr>
<td>925</td>
<td>965</td>
<td>Sandy lime</td>
<td>2785</td>
<td>2800</td>
<td>Sandy shale—water</td>
</tr>
<tr>
<td>965</td>
<td>1075</td>
<td>Shale</td>
<td>2800</td>
<td>3075</td>
<td>Shale</td>
</tr>
<tr>
<td>1075</td>
<td>1130</td>
<td>Sand—water</td>
<td>3075</td>
<td>3200</td>
<td>Shale</td>
</tr>
<tr>
<td>1130</td>
<td>1280</td>
<td>Shale</td>
<td>3200</td>
<td>3290</td>
<td>Lime shells (Gryphea)</td>
</tr>
<tr>
<td>1280</td>
<td>1290</td>
<td>Sandy lime</td>
<td>3290</td>
<td>3390</td>
<td>Shale</td>
</tr>
<tr>
<td>1290</td>
<td>1470</td>
<td>Shale</td>
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<td>3430</td>
<td>Shale</td>
</tr>
<tr>
<td>1470</td>
<td>1505</td>
<td>Sand—water</td>
<td>3430</td>
<td>3475</td>
<td>Sand—oil</td>
</tr>
<tr>
<td>(Top Calvin Series)</td>
<td></td>
<td></td>
<td>3475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1505</td>
<td>1540</td>
<td>Shale</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The interval between the top of the Booch sand and the top of the Cromwell sand decreases toward the north and is 200-250° at the north end of the field.

Bethel Field

The Bethel pool in the northwest part of T. 9 N., R. 8 E., is a small but interesting field. The discovery well was the Independent Oil & Gas Company's No. 1 Cobb and Hill located in the NE 1/4 SE 1/4 NE 1/4 sec. 7, which was completed for 200 barrels per day in the Booch sand found at a depth of 3,275 to 3,302 feet, on December 9, 1924. The Cromwell sand found at a depth of 3,600 to 3,700 feet and the Simpson formation at a depth of 4,350 to 4,550 feet, have both proven unproductive in this area. The field is of interest because of the production being confined to the Booch sand, which is in general water-bearing; also to the slow decline of the wells. The highest production of the field was reached during the week ending April 12, 1927, when it averaged 2,786 barrels per day. During the week ending November 22, 1927, the field had declined to 1,065 barrels per day from 50 wells. The initial production of most of the wells ranges between 20 and 100 barrels per day although wells with a production as high as 200 barrels have been reported. The gravity of the oil varies between 38° and 40° Baume.

The field covers an area of 500 acres but its limits are not fully defined. The elevation of the surface varies from 950 to 1,000 feet above sea level and the average depth to the Booch sand is between 3,200 and 3,300 feet. The Booch sand is between 25 and 50 feet thick and most of the wells drill through it and into the underlying shale.

The surface formations consist of the shales, sands, and conglomerates above and below the Belle City limestone. The outcrops of the Belle City limestone are poor in this area, consisting of small patches of impure, fossiliferous limestone. The surface structure consists of minor folding and faulting which is difficult to determine accurately on account of the soft, friable nature of the outcropping sandstones.

The top of the Calvin sand series occurs at a depth of 1,600 to 1,650 feet. The Booch sand, which is the producing horizon of this field, is believed to be the equivalent of the Harthorne sandstone (top of the Pottsville) of the eastern part of the State. It certainly can be correlated with the highly productive Booch or Tanaha sand of the Okmulgee district farther northeast.

The subsurface structure of the Booch sand is a north-south closed fold producing through a structural range of 40 feet.

The following is an average of the logs of the Bethel field with correlations by the writer. Most of these wells were drilled by the cable tool method so that more of the details of the Pennsylvanian stratigraphy are known here than farther west in the area where wells were drilled with rotary tools:

Average section Bethel pool, sec. 7, T. 9 N., R. 8 E.
Average Elevation: 900 Feet Above Sea Level

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
<th>Formation</th>
<th>Top</th>
<th>Bottom</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>55</td>
<td>Sand—water</td>
<td>425</td>
<td>435</td>
<td>Shale</td>
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<tr>
<td>85</td>
<td>55</td>
<td>Shale</td>
<td>425</td>
<td>450</td>
<td>Sand—water</td>
</tr>
<tr>
<td>85</td>
<td>85</td>
<td>Sand—water</td>
<td>450</td>
<td>460</td>
<td>Sand &amp; shale</td>
</tr>
<tr>
<td>150</td>
<td>305</td>
<td>Shale</td>
<td>460</td>
<td>480</td>
<td>Sand—water</td>
</tr>
<tr>
<td>305</td>
<td>315</td>
<td>Lime</td>
<td>480</td>
<td>568</td>
<td>Shale</td>
</tr>
<tr>
<td>315</td>
<td>420</td>
<td>Shale</td>
<td>588</td>
<td>695</td>
<td>Sand—water</td>
</tr>
<tr>
<td>420</td>
<td>425</td>
<td>Lime</td>
<td>695</td>
<td>795</td>
<td>Shale</td>
</tr>
</tbody>
</table>

(Continued on page 328)
barrels of oil. One-third of the wells are showing water. In Figure 74 are shown the production curves of the Seminole City field.

The initial production of most of the wells ranged between 1,000 and 3,500 barrels per day, although wells as high as 9,000 barrels per day were reported. The high production generally followed shooting

Seminole City Field

The discovery well of the Seminole City field was the Indian Territory Illuminating Oil Company’s No. 1 Jones located in the NW $\frac{1}{4}$ NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 24, T. 9 N., R. 6 E. This well was completed on March 7, 1926, as an 1,100 barrel well in the Hunton limestone found at a depth of 3,975 to 4,012 feet. It was later deepened to the Wilcox sand where water was encountered. A quarter of a mile east of this well on July 6, 1926, the Amerada Petroleum Corporation drilled in a 60 barrel well in the Seminole sand found at a depth of 4,258 to 4,277 feet. The well which started the active drilling of western Seminole County, however, was the Independent-Garland’s No. 1 Fexico located in the NW $\frac{1}{4}$ NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 26. In this well only 4 feet of Hunton lime was found and, after deepening to the Seminole sand (First “Wilcox”) found at a depth of 4,065 to 4,073 feet, was completed on July 16, 1926 as a 6,120 barrel well. The field then developed rapidly, reaching its peak during the week ending February 28, 1927, when 211 wells averaged 253,192 barrels of oil per day. On November 1, 1927, its production had declined to 64,351 barrels of oil per day from 320 wells and up to this date it had produced a total of 31,250,633
or the application of air lift. The gravity of the oil varies between 40° and 42° Baume.

The limits of the field are now fairly well defined and it covers an area of 3,600 acres. The elevation of the surface varies from 840 feet to 940 feet above sea level and the average depth to the Seminole sand from 4,000 to 4,300 feet.

The surface formations of the Seminole City field include the shales, sands, and conglomerates of the Vanoss and Vamoosa formations. The Pawhuska limestone, occurring at the base of the Vanoss formation, is well developed in the field and is the datum to which the surface structure is referred. Figure 75 is a map showing the surface structure of the Seminole City field.

Rocks of Pennsylvanian age extend to a depth of 3,400 to 3,600 feet and consist of alternating shale and sand layers. The top of the Calvin sand series occurs at a depth of 2,100 to 2,300 feet. The details of the Pennsylvanian stratigraphy are not definitely known due to the rotary method of drilling to depths below the base of the Pennsylvanian formations. The Seminole City area probably marks the western limits of the Cromwell sand due to erosion and overlap by younger formations. No commercial production has been obtained from the Pennsylvanian sands.

Below the Pennsylvanian rocks and separated from them by an erosional and structural unconformity, the following geologic section is encountered:

**Pre-Pennsylvanian formations.**

<table>
<thead>
<tr>
<th>Mississippian:</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caney formation:</td>
<td></td>
</tr>
<tr>
<td>Casey shale member (Av. 275 ft.)</td>
<td>150-400 (f)</td>
</tr>
<tr>
<td>&quot;Mayes&quot; limestone member</td>
<td>90-110</td>
</tr>
<tr>
<td>Chattanooga shale</td>
<td>90-110</td>
</tr>
<tr>
<td>Devonian-Silurian:</td>
<td></td>
</tr>
<tr>
<td>Hunton limestone, Oil bearing</td>
<td>0-75</td>
</tr>
<tr>
<td>Ordovician:</td>
<td></td>
</tr>
<tr>
<td>Sylvan shale</td>
<td>80-100</td>
</tr>
<tr>
<td>Viola limestone</td>
<td>30-40</td>
</tr>
<tr>
<td>Simpson formation:</td>
<td></td>
</tr>
<tr>
<td>Denne limestone member</td>
<td>10-20</td>
</tr>
<tr>
<td>First Dolomite member</td>
<td>30-50</td>
</tr>
<tr>
<td>Seminole &quot;Wilcox&quot; sand member</td>
<td>40-80</td>
</tr>
<tr>
<td>Oil bearing</td>
<td>40-80</td>
</tr>
<tr>
<td>Second Dolomite member</td>
<td>15-30</td>
</tr>
<tr>
<td>&quot;Wilcox&quot; sand, some oil</td>
<td>217+</td>
</tr>
</tbody>
</table>

The structure of the Ordovician rocks in general consists of three domes, located in sections 23 and 24; 34, 35; and 36, and a smaller dome in section 25. Each of these underlie surface folds. These Ordovician folds are broken by a number of erratics where offset wells show a structural difference in elevation up to 500 feet. The structural relief of the

Figure 75. Map showing the surface structure of the Seminole City field. Contours referred to Pawhuska (f) limestone and contour interval is 10 feet. Compiled from various sources including map by Indian Territory Illuminating Oil Company published by The Oil and Gas Journal, April 8, 1927.
folds is roughly 250 feet but the erratics bring the total relief of the field up to 600 feet or more.

In Figure 76 are shown the structure and a series of profiles of the top of the Viola limestone. The contour interval is 100 feet and the heavy—3,200-foot contour line roughly outlines the general structure and marks the normal position of the oil-water contact in the field. An examination of the structure and profiles shows that the primary structure consists of regular dome folds and that the erratics are minor features superimposed upon them.

Figure 76. Structure and profiles on the Viola limestone in the Seminole City field. Contour interval is 100 feet. The heavy—3,200-foot contour line roughly outlines the structure and marks the normal position of the water-oil contact.

The following is the log of the discovery well of the Seminole field with correlations by the writer. It is the only complete cable tool test drilled in the field:

(Continued on page 334)
Searight Field

The Searight field is named after F. J. Searight who drilled the discovery well. This well, No. 1 Youngblood, located in the SE3/4 NE 1/4 SE 1/4, sec. 33, T. 10 N., R. 6 E., after drilling for nearly two years, was completed on April 21, 1926, for 312 barrels in the Hunton limestone found at a depth of 4,090 to 4,157 feet. On October 11, 1925, the Searight Oil Company's No. 3 Youngblood, located in the NW 1/4 NE 1/4 SE 1/4, sec. 33, found the Seminole sand at a depth of 4,315 to 4,317 feet and started flowing 4,572 barrels of oil per day. The field was developed in both the Hunton limestone and the Seminole sand (First “Wilcox”), reaching its maximum daily production during the week ending June 21, 1927, when 42 wells averaged 39,857 barrels of oil per day. The field, whose limits are defined except on the west, covers an area of 700 acres and on November 1, 1927, it had produced a total of 11,282,174 barrels of oil. On this date its production was 25,663 barrels from 62 wells, with 20 to 25 per cent of the wells showing water. In Figure 77 are shown the production curves of the Searight field. This field differs from the other fields in the western half of the county in the slower decline of its production.

The initial production of most of the wells ranges between 500 and 2,000 barrels per day although several wells as high as 4,500 to 5,000 barrels per day were reported. The gravity of the oil varies between 39° and 42° Baume.

The elevation of the surface varies between 960 and 1,065 feet above sea level and the average depth to the Seminole sand member from 4,300 to 4,400 feet.

The surface rocks of the Searight field consist of the shales and sands of the Vanoss formation of upper Pennsylvanian age. The surface structure is a west pitching “nose” type of fold with short en echelon faults cutting it off on the east side.

The Pennsylvanian rocks extend to a depth of 3,700 to 3,850 feet and consist of alternating shales and sands. The top of the Calvin sand series occurs at a depth of 2,500 to 2,600 feet. The details of the stratigraphy are unknown as all the drilling except the discovery well was by the rotary method. Below the rocks of Pennsylvanian age and sep-
arated from them by an erosional and structural unconformity, the fol-
lowing geologic section is encountered:

**Pre-Pennsylvanian formations.**

<table>
<thead>
<tr>
<th>Formations</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mississippian</td>
<td></td>
</tr>
<tr>
<td>Caney formation</td>
<td></td>
</tr>
<tr>
<td>Caney shale member</td>
<td>200-300 (†)</td>
</tr>
<tr>
<td>“Mayes” limestone member</td>
<td>90-100</td>
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<tr>
<td>Chattanooga shale</td>
<td>40-60</td>
</tr>
<tr>
<td>Devonian-Silurian</td>
<td></td>
</tr>
<tr>
<td>Hunton Lime, oil bearing</td>
<td>85-160</td>
</tr>
<tr>
<td>Ordovician</td>
<td></td>
</tr>
<tr>
<td>Sylvan shale</td>
<td>70-100</td>
</tr>
<tr>
<td>Viola limestone</td>
<td>34-40</td>
</tr>
<tr>
<td>Simpson formation</td>
<td></td>
</tr>
<tr>
<td>Dense limestone member</td>
<td>5-15</td>
</tr>
<tr>
<td>First Dolomite member</td>
<td>30-50</td>
</tr>
<tr>
<td>Seminole sand member, Oil bearing</td>
<td></td>
</tr>
</tbody>
</table>

The structure of the Ordovician rocks is an irregular dome with 80 to 100 feet of closure which is broken by several structural erratics giving it a total structural relief of 385 feet.

**Earlsboro Field**

The first oil production in the Earlsboro field was found in Morgan & Flynn’s No. 1 Ingram located in the NW 1/4, NW 1/4, SE 1/4, sec. 10, T. 9 N., R. 5 E., which on March 1, 1926, was completed as a 200 barrel well from what is now called the Earlsboro sand found at a depth of 3,560 to 3,580 feet. On December 3, 1926, the Gypsy Oil Company et al completed their No. 1 State located in the NE cor. sec. 16 as an 8,050 barrel well in the Seminole sand found at a depth of 4,275 to 4,291 feet. This started the active development of the field which reached a maximum average daily production of 205,286 barrels from 135 wells during the week ending August 9, 1927. On November 1, 1927, this field had declined to 148,361 barrels per day from 248 wells and up to this date it had produced a total of 28,230,350 barrels of oil.

About one-fifth of the wells are showing water. The curves showing the average daily production, number of wells drilled, and average production per well are shown in Figure 78.

The initial production of most of the wells ranged between 1,000 and 4,000 barrels per day although wells as high as 14,000 barrels per day were reported. The high production was generally the result of shooting and the application of air lift. The gravity of the oil varies between 40° and 42° Baume.

The major part of the field, which covers an area of 2,830 acres, is in Seminole County although the town of Earlsboro from which it derives its name and the Seminole sand discovery well of the Gypsy Oil Company are both located in Potawatomie County. The elevation of
the surface varies from 935 to 1,050 feet above sea level and the average depth to the Seminole sand member between 4,200 and 4,300 feet.

The rocks outcropping in the Earlsboro field are the shales and sands of the Vanoss formation of upper Pennsylvanian age. The Permian-Pennsylvanian contact is believed to be in the low hills a mile west of the town of Earlsboro. The surface structure differs from that of the other fields of Seminole County by the absence of surface faults, or if present, they are of minor importance. The surface structure consists of several terraces and minor flattennings passing into a broad arch on the west end of the field. From east to west there is a total reduction of 90 to 100 feet in the normal west dip.

The Pennsylvanian formations extend to a depth of 3,800 to 3,900 feet and contain the Earlsboro sand about 250 feet above the base. Several wells have been drilled in the Earlsboro sand with production up to 700 barrels per day of 38 gravity oil but the average initial production is between 100 and 300 barrels per day. The sand is a lens-shaped body and production from it is erratic. The top of the Calvin series occurs at 2,850 to 3,000 feet.

Below the Pennsylvanian and separated from it by a structural and erosional unconformity is the following geologic section:

Pre-Pennsylvanian formations.

Mississippian:

**Caney formation**: 20-200 feet

- **"Mayes" limestone member**: 90-100
- **Chattanooga shale**: 100-125

Devonian-Silurian:

- **Heaton lime**: 0-30

Ordovician:

- **Sylvan shale**: 90-110
- **Viola limestone**: 20-40
- **Simpson formation**: 10-20 feet
- **Dense limestone member**: 10-20
- **First dolomite member**: 40-50
- **Seminole sand member, oil bearing**: 50-100
- **Second dolomite member**: 5-30
- **Wilcox sand, some production**: 50+

The structure of the Ordovician rocks is a dome fold extending east and west through sections 9, 10, 11 and into 12, and having a closure of about 150 feet. This fold is broken by several structural erratics which bring the total structural relief of the field up to 360 feet. It is the most regular of any of the large producing folds of the western part of the county. Wells several miles north and south of the field find the Simpson formation 700-1,000 feet lower than those situated on the top of the Earlsboro fold.

The following is the log of the Wilcox sand discovery well, drilled with cable tools:

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
<th>Formation</th>
<th>Top</th>
<th>Bottom</th>
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</tr>
</thead>
<tbody>
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<td>Red shale</td>
<td>1000</td>
<td>1670</td>
<td>Sandy lime</td>
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<tr>
<td>90</td>
<td>118</td>
<td>Sand-water</td>
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<td>1700</td>
<td>Shale</td>
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<tr>
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<td>120</td>
<td>Red rock</td>
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<tr>
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<td>1505</td>
<td>Sand</td>
<td>3305</td>
<td>3400</td>
<td>Shale</td>
</tr>
</tbody>
</table>

(Seminoe County, page 339)
The discovery wells in the Bowlegs field were drilled by the Indian Territory Illuminating Oil Company. On June 18, 1926, its No. 1 Go- forth, located in the SW 1/4 SW 1/4 NE 1/4 sec. 15, T. 8 N., R. 6 E., was completed as a million cubic foot gas well in the basal sand of the Calvin series found at a depth of 2,426 to 2,443 feet. The active development of the field was started by the same company's No. 1 Davis, located in the SW. cor. sec. 13, in which on January 4, 1927, the Seminole sand was found at a depth of 4,194 to 4,203 feet and completed as a 5,500 barrel well. The peak production was reached during the week ending August 2, 1927, when 173 wells averaged 190,408 barrels per day. On November 1, 1927, the production had declined to 115,313 barrels per day from 265 wells and up to this date the field had produced a total of 30,230,067 barrels of oil. About one-fifth of the wells are showing water. In Figure 79 are shown the production curves of the Bowlegs field.

The initial production of most of the wells ranges between 1,000 and 4,000 barrels per day. The gravity of the oil varies between 40° and 42° Baume. The limits of the field have been nearly defined and it covers an area of 2,800 acres. The elevation of the surface varies between 870 and 950 feet above sea level and the average depth to the Seminole sand between 4,000 and 4,300 feet.

The surface rocks exposed in the field consist of conglomerates, sands, and shales of the upper part of the Vamoosa conglomerate and the lower portion of the Vanoss formation, both of upper Pennsylvanian age. A thin, variable, fossiliferous sandy limestone, the Pawhuska (?) limestone outcrops in the field and is the datum to which the surface structure is referred. The surface structure is similar to that of the Seminole City field to the north in that it consists of several small terraces and folds complicated by the same belt of en echelon faults.

In the Bowlegs field the sands and shales of Pennsylvanian age extend to a depth of 3,300 to 3,500 feet. The top of the Calvin sand series is found at a depth of 2,050 to 2,200 feet. As the Pennsylvanian and upper part of the Mississippian are drilled by the rotary method, the base of the Pennsylvanian and the details of the Pennsylvanian
stratigraphy are difficult to determine. Below the Pennsylvanian series and separated from them by an erosional and structural unconformity, are the following formations:

**Pre-Pennsylvanian formations.**

<table>
<thead>
<tr>
<th>Formation</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caney formation</td>
<td></td>
</tr>
<tr>
<td>Caney shale member</td>
<td>150-450 (1)</td>
</tr>
<tr>
<td>&quot;Mayea&quot; limestone member</td>
<td>90-100</td>
</tr>
<tr>
<td>Chattanooga shale (Av. 125 ft.)</td>
<td>120-150</td>
</tr>
<tr>
<td>W.W. With Misener sand at base</td>
<td>0-15</td>
</tr>
<tr>
<td>Devonian-Silurian</td>
<td></td>
</tr>
<tr>
<td>Hunton limestone, oil bearing</td>
<td>0-5</td>
</tr>
<tr>
<td>Ordovician</td>
<td></td>
</tr>
<tr>
<td>Sylvan shale</td>
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</tr>
<tr>
<td>Viola limestone</td>
<td>30-35</td>
</tr>
<tr>
<td>Simpson formation:</td>
<td></td>
</tr>
<tr>
<td>Dense limestone member</td>
<td>10-50</td>
</tr>
<tr>
<td>First dolomite member</td>
<td>30-50</td>
</tr>
<tr>
<td>Seminole sand member (oil bearing)</td>
<td>40-100</td>
</tr>
<tr>
<td>Second dolomite member</td>
<td>10-40</td>
</tr>
<tr>
<td>Wilcox sand, locally productive</td>
<td></td>
</tr>
</tbody>
</table>

The subsurface structure is in general that of a broad dome roughly outlined by the present limits of production and has a closure of 300 feet. As in the Seminole field it is broken by a number of structural erratics in which offset wells show a structural difference in elevation of 100 to 300 feet, the maximum difference being 600 feet. The largest of these erratics is found in sections 11 and 14 where a number of dry holes have been found abnormally low. Two of these show definite evidence of faulting. These erratics increase the total structural relief of the field to over 800 feet, the lowest structure being within the producing area of the field.

In Figure 80 are shown profiles of the top of the Viola limestone in the Bowlegs field. They show that the erratics are in every case downward relative to the average surrounding structure and, if the erratics are disregarded, the resultant structure is a relatively uniform dome fold.

**Little River Field**

The discovery well of the Little River field was drilled by the Indian Territory Illuminating Oil Company. The company's No. 1 House located in the NW. cor. sec. 1, T. 7 N., R. 6 E., was completed for 13,541 barrels per day on July 1, 1927, in the Seminole sand found at a depth of 4,017 to 4,028 feet. The field is still in the process of active development and its limits are not defined. On November 1, 1927, its production was 45,361 barrels from 59 wells and up to this date the field had produced a total of 2,644,830 barrels of oil. One-eighth of the wells were showing water. The curves showing the production of the field, the number of wells drilled and the average daily production per well are found in Figure 81. The initial production of the wells ranges between 200 and 2,000 barrels per day, although the discovery well produced over 13,000 barrels per day. Due to the co-operative agreement and the erratic structure, the field has not developed as rapidly or over as great an area as was originally anticipated.

The elevation of the surface varies between 820 and 940 feet above sea level and the average depth to the Seminole sand is between 4,150 and 4,500 feet. Little River flows through the field and the bottom lands along it have been flooded a number of times since the field was discovered, thereby making operations more difficult.

The surface formations consist of the shales, sands, conglomerates and limestones of the lower Vanoss and upper Vamoosa formations. The Pawhuska (?) limestone outcrops in the field and is the datum to which the structure surface is referred. The surface structure consists...
of a broad northwest pitching fold broken by a belt of en echelon faulting on the west side as in the Seminole City and Bowlegs fields. The surface faults are all of the normal or gravity type with the downthrow side toward the southwest.

The Pennsylvanian rocks extend to a depth of 3,200 to 3,300 feet below the surface. The top of the Calvin series occurs at a depth of 1,900 to 2,000 feet. A well in the SE, cor. sec. 4, west of the field, is producing an amount of oil from a sand in the lower part of the Pennsylvanian, possibly the equivalent of the Earlboro sand. Below the Pennsylvanian and separated from it by an erosional and structural unconformity, the following formations are encountered:

**Pre-Pennsylvanian formations.**

<table>
<thead>
<tr>
<th>Mississippian:</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caney formation:</td>
<td></td>
</tr>
<tr>
<td>Caney shale member</td>
<td>90-100</td>
</tr>
<tr>
<td>&quot;Mauve&quot; limestone member</td>
<td>165-175</td>
</tr>
<tr>
<td>Chattanooga shale</td>
<td>0-15</td>
</tr>
<tr>
<td>Devonian-Silurian:</td>
<td></td>
</tr>
<tr>
<td>Hunton lime</td>
<td>0</td>
</tr>
<tr>
<td>Ordovician:</td>
<td></td>
</tr>
<tr>
<td>Sylvan shale</td>
<td>40-60</td>
</tr>
<tr>
<td>Viola limestone</td>
<td>30-40</td>
</tr>
<tr>
<td>Simpson formation:</td>
<td></td>
</tr>
<tr>
<td>Dense limestone member</td>
<td>10-20</td>
</tr>
<tr>
<td>First dolomite member</td>
<td>10-50</td>
</tr>
<tr>
<td>Seminole sand member (Oil producing)</td>
<td></td>
</tr>
</tbody>
</table>

The subsurface structure of the Ordovician rocks is not yet defined. Present indications are that in this field occur more erratics than in any other field of Seminole County. The known structural relief is 400 feet with the lowest well within the producing area. The best evidence of pre-Pennsylvanian faulting as the cause of the structural erratics exists in the Little River field. In several wells, the formations are found to be abnormally thin and these are offset by wells showing normal thicknesses. If this shortening of section occurred at the base of the Chattanooga shale it might be interpreted as folding and erosion below the basal Mississippian unconformity. Thus far, however, it has been found to occur within the Chattanooga shale and is interpreted by the writer as being due to post-Mississippian or early Pennsylvanian faulting, the missing beds being cut out by the faults. A good example of this is found in the Prairie Oil & Gas Company's No. 2 House located in the SW 1/4 NW 1/4 SE 1/4 sec. 2. In this well the top of the Chattanooga shale was found at 4,015 feet below the surface or structurally low; the Sylvan shale was encountered at 4,030 feet and the top of the Viola limestone 4,050 feet, or structurally the second highest well in the field. Since only 15 feet of Chattanooga shale and 20 feet of Sylvan shale were found as compared to a normal thickness of 165 feet of Chattanooga shale and 50 feet of Sylvan shale, the total shorte-
ing is 180 feet, or the amount of abnormal structural difference between it and the offset wells.

ANALYSIS OF CRUDE OIL

A. J. Kraemer* of the Bureau of Mines summarizes the results of a number of analyses of Seminole crude oils as follows:

Discussion of Results

Although there are a number of producing sands in the Seminole District, it does not seem possible to ascribe definite and distinctive characteristics to the production from any of the sands.

The Wilcox is the most productive sand in all of the pools in the district. On the basis of the samples that the Bureau of Mines has analysed, (not all of which are included in the report) the gravity of crude oil from the Wilcox sand in this district ranges from 37.6° to 43.3° A. P. I., with the average about 40° A. P. I. The sulphur content ranges from 0.55% to 0.45%, with the average about 0.33%. The “gasoline and naphtha” content ranges from 34.1% to 41.3%, with the average about 38.4%. The production from the Hunton lime ranges in gravity between 37.8° and 40.4° A. P. I. with the average about 38.3° A. P. I.

The sulphur content ranges from 0.22% to 0.39%, with the average about 0.36%. The “gasoline and naphtha” content of the crude from the Hunton lime ranges from 34.7% to 37.3%, with the average about 36.9%.

OIL FIELD WATERS

The writer is indebted to L. C. Case of the Gypsy Oil Company for the following data concerning the chemical nature of the waters found in the Hunton lime and the Simpson formation sands of the oil fields.

The Hunton lime and Seminole sand waters in the western part of the county are quite similar, the chief difference being in the sulphate content which is generally higher in the Hunton lime water. The Earlsboro field, in which the Hunton is generally missing, shows the most characteristic and uniform water analyses of any of the fields. Any one of the seven analyses averaged under C is very nearly the mean. The Hunton water of the Seagight field, averaged under B, carries a characteristic high sulphate content but is otherwise very similar to the Seminole sand water. In the Seminole City, Bowlegs, and Little River fields the Seminole sand water shows as great differences as those found between the Hunton Lime and Seminole sand waters.

No difference has been found in the waters of the Seminole sand and Wilcox sand members which have been analyzed from several wells, in each case the water from the Seminole sand being cased off before drilling into the Wilcox sand.


SEMINOLE COUNTY

Throughout the north half of the county, the water is a typical oil field brine having a concentration of 150,000 to 170,000 parts per million. A decided dilution of the Simpson formation water occurs south of T. 7 N. This is in the area where wells are commonly reported to be flowing “sulphur water” but the analyses show none or only a trace of sulphate. The odor is due to hydrogen sulphide gas.

The average of the Cromwell sand water analyses shown under A indicates it to be similar to the Seminole sand water of the Earlsboro field. Pennsylvanian waters higher in the geologic section toward the surface show a progressive decrease in the amounts of sodium, calcium, magnesium, and chloride and an increase in the amount of sulphate. The total concentration also decreases in the shallower sands.

Table Showing Averages of Analyses of Waters from Producing Horizons of Seminole County.

<table>
<thead>
<tr>
<th>PARTS PER MILLION</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica, SiO₂</td>
<td>154</td>
<td>2568</td>
<td>58002</td>
<td>49939</td>
</tr>
<tr>
<td>Iron, Fe₂O₃ &amp; Al₂O₃</td>
<td>2568</td>
<td>58002</td>
<td>49939</td>
<td>52007</td>
</tr>
<tr>
<td>Sodium, Na</td>
<td>1000</td>
<td>1540</td>
<td>1540</td>
<td>1540</td>
</tr>
<tr>
<td>Calcium, Ca</td>
<td>9856</td>
<td>7341</td>
<td>7341</td>
<td>7341</td>
</tr>
<tr>
<td>Magnesium, Mg</td>
<td>248</td>
<td>1022</td>
<td>1022</td>
<td>1022</td>
</tr>
<tr>
<td>Sulphate, SO₄</td>
<td>98841</td>
<td>93706</td>
<td>93706</td>
<td>93706</td>
</tr>
<tr>
<td>Chloride, Cl</td>
<td>0</td>
<td>48</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Bicarbonate, HCO₃</td>
<td>0</td>
<td>0</td>
<td>54</td>
<td>54</td>
</tr>
</tbody>
</table>

TOTAL                       | 171954| 153596| 161946| 146319|

PERCENTAGE VALUE (Palmer)

<table>
<thead>
<tr>
<th>PARTS PER MILLION</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica, SiO₂</td>
<td>1.60</td>
<td>1.60</td>
<td>1.60</td>
<td>1.60</td>
</tr>
<tr>
<td>Iron, Fe₂O₃ &amp; Al₂O₃</td>
<td>1.60</td>
<td>1.60</td>
<td>1.60</td>
<td>1.60</td>
</tr>
<tr>
<td>Sodium, Na</td>
<td>37.31</td>
<td>40.75</td>
<td>39.85</td>
<td>40.84</td>
</tr>
<tr>
<td>Calcium, Ca</td>
<td>8.74</td>
<td>6.96</td>
<td>7.53</td>
<td>7.39</td>
</tr>
<tr>
<td>Magnesium, Mg</td>
<td>2.35</td>
<td>2.34</td>
<td>2.34</td>
<td>2.34</td>
</tr>
<tr>
<td>Sulphate, SO₄</td>
<td>0.69</td>
<td>0.40</td>
<td>0.68</td>
<td>1.06</td>
</tr>
<tr>
<td>Chloride, Cl</td>
<td>49.89</td>
<td>49.61</td>
<td>49.93</td>
<td>49.80</td>
</tr>
<tr>
<td>Bicarbonate, HCO₃</td>
<td>0.00</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

TOTAL                       | 99.98 | 99.98 | 100.00| 100.00|


C. Earlsboro Field, Seminole sand water. Average of 7 analyses. Analyses by L. C. Case, Gypsy Oil Company.

D. Seminole City Field, Seminole sand water. Average of 3 analyses. Analyses by L. C. Case, Gypsy Oil Company.
The daily production figures of the fields in the Greater Seminole area are assembled and shown by curves in Figure 82. The cost of drilling the deep holes of the western part of the county averages from $55,000.00 to $70,000.00, if a producer, and from $45,-
000.00 to $50,000.00 if a dry hole. For a producing well an additional expense of $18,000.00 to $25,000.00 is necessary to equip it with an oil and gas separator, flow lines, flow tanks, an air plant, and other equipment.

The following figures show the average cost of five wells in different parts of the area, together with the average cost of a dry well and the average cost of a producing well. They represent a fair average, but a larger expense is the rule due to the many fishing jobs, collapsed pipe, lost hole, and other difficulties encountered in all the fields.

Average Cost of Five Deep Wells in Seminole District—1927

- Rig—125 foot Turnbuckle type $6,500.00
- Slush pit 350.00
- Teaming 1,000.00
- Drilling contract, 4200 ft. @ $7.50 per ft. 31,500.00
- Fuel, Oil, Water 7,500.00
- Tank—250 bbl. wood 235.00
- Cement and cementing 825.00
- Pipe: 50-100’ 15 1/2” 70 lbs. 420.00
- 3000’ 8 1/2” 32 lbs. 8035.00
- 1420’ 8” 32 lbs. 6230.00 14,685.00
- Miscellaneous expense, small pipe, fittings, etc. 1,750.00

Total cost of well to top of Wilcox sand $60,345.00

The average recoverable material of a dry well would be:

8 1/2” casing 5500.00
6 3/4” 5000.00
Rig 8000.00
Tank 200.00
Miscellaneous pipe, fittings, etc. 750.00

Recoverable material 15,450.00

Average cost of dry hole $44,895.00

The following additional expense would ordinarily be incurred with a producing well:

- Separator $1165.00
- Flow line, control head, connections, labor, teaming 500.00
- 6-500 bbl. steel vapor pressure tanks 6000.00
- Air plant complete per well 1500.00

Additional material 22,665.00

Average total cost completed well $83,010.00

The following miscellaneous information is of interest in showing the extent of some of the operations connected with the development of the fields of the western half of the county:

Steel Storage, Greater Seminole District; November 1, 1927.

<table>
<thead>
<tr>
<th>Present Capacity</th>
<th>Number</th>
<th>Bull ing</th>
</tr>
</thead>
<tbody>
<tr>
<td>16,000 bbl. tanks</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>55,000 bbl. tanks</td>
<td>265</td>
<td>13</td>
</tr>
<tr>
<td>20,000 bbl. tanks</td>
<td>136</td>
<td>51</td>
</tr>
</tbody>
</table>

Steel tankage divided as follows:

Status of Wells, Greater Seminole District; October 31, 1927.

<table>
<thead>
<tr>
<th>Gathering</th>
<th>On Air or Gas Lift</th>
<th>Flowing</th>
<th>Swabbing</th>
<th>Pumping</th>
<th>Off Production</th>
<th>Shutoff</th>
<th>Lifting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminole</td>
<td>127</td>
<td>8</td>
<td>28</td>
<td>131</td>
<td>31</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td>Bowlegs</td>
<td>192</td>
<td>4</td>
<td>21</td>
<td>13</td>
<td>24</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Earlboro</td>
<td>84</td>
<td>53</td>
<td>29</td>
<td>28</td>
<td>24</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>Scarritt</td>
<td>22</td>
<td>22</td>
<td>3</td>
<td>12</td>
<td>2</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Little River</td>
<td>13</td>
<td>7</td>
<td>9</td>
<td>-</td>
<td>5</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Company</th>
<th>No. of Plants</th>
<th>Present Output - 1</th>
<th>Gas. Per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amerada Petroleum Corporation</td>
<td>3</td>
<td>95,250</td>
<td></td>
</tr>
<tr>
<td>Barnsdall Oil Company</td>
<td>1</td>
<td>27,300</td>
<td></td>
</tr>
<tr>
<td>Carter Oil Company</td>
<td>3</td>
<td>149,000</td>
<td></td>
</tr>
<tr>
<td>Creasbee Oil Company</td>
<td>1</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>Empire Gas &amp; Fuel Company</td>
<td>5</td>
<td>40,000</td>
<td></td>
</tr>
<tr>
<td>Gypsy Oil Company</td>
<td>1</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>Independent Oil and Gas Company</td>
<td>1</td>
<td>12,000</td>
<td></td>
</tr>
<tr>
<td>Magnolia Petroleum Corporation</td>
<td>1</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>Pure Oil Company</td>
<td>2</td>
<td>44,000</td>
<td></td>
</tr>
<tr>
<td>Ruxana Petroleum Corporation</td>
<td>1</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>Sinclair Oil &amp; Gas Company</td>
<td>5</td>
<td>280,000</td>
<td></td>
</tr>
<tr>
<td>Victor Gasoline Company</td>
<td>4</td>
<td>34,000</td>
<td></td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>27</strong></td>
<td><strong>681,506</strong></td>
<td></td>
</tr>
</tbody>
</table>

(The gas from the oil wells is recycled and returned to flow the wells and the gasoline recovered.)
Summary of the Compression Plants Operating in this Area.

<table>
<thead>
<tr>
<th>Company</th>
<th>No. of Plants</th>
<th>Present Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carter Oil Company</td>
<td>4</td>
<td>35,000</td>
</tr>
<tr>
<td>Forrest E. Gilmore</td>
<td>8</td>
<td>21,000</td>
</tr>
<tr>
<td>Indian Territory Illuminating Oil Company</td>
<td>10</td>
<td>103,000</td>
</tr>
<tr>
<td>TOTALS</td>
<td>17</td>
<td>156,000</td>
</tr>
</tbody>
</table>

This is a total of 819,200 gallons of gasoline per day from 44 plants located in the western half of the county.

Production Statistics, Greater Seminole District as of January 1st, 1928.

<table>
<thead>
<tr>
<th>Field</th>
<th>No. Wells Producing</th>
<th>No. Acres Producing</th>
<th>Total Production up to Jan. 1st, 1928—Bbls.</th>
<th>Yield Per Acre April—Sept.</th>
<th>Yield Per Producing Well up to Jan. 1st, 1928</th>
<th>Yield Per Producing Well up to Jan. 1st, 1928</th>
<th>Acre Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminole</td>
<td>319</td>
<td>34,000</td>
<td>54,705,543</td>
<td>15,221</td>
<td>17,450</td>
<td>17,450</td>
<td>17,450</td>
</tr>
<tr>
<td>Searight</td>
<td>68</td>
<td>700</td>
<td>12,704,929</td>
<td>18,221</td>
<td>187,572</td>
<td>187,572</td>
<td>14,282</td>
</tr>
<tr>
<td>Earlboro</td>
<td>286</td>
<td>2830</td>
<td>37,775,722</td>
<td>13,348</td>
<td>132,858</td>
<td>132,858</td>
<td>13,348</td>
</tr>
<tr>
<td>Bowlegs</td>
<td>292</td>
<td>2980</td>
<td>37,617,193</td>
<td>12,623</td>
<td>128,825</td>
<td>128,825</td>
<td>12,623</td>
</tr>
<tr>
<td>Little River</td>
<td>93</td>
<td>940</td>
<td>5,198,633</td>
<td>5,510</td>
<td>55,791</td>
<td>55,791</td>
<td>6</td>
</tr>
<tr>
<td>TOTALS</td>
<td>1,069</td>
<td>11,050</td>
<td>148,197,080</td>
<td>13,490</td>
<td>139,741</td>
<td>139,741</td>
<td></td>
</tr>
</tbody>
</table>

NOWATA AND CRAIG COUNTIES

By
Edward Bloesch

INTRODUCTION

The writer has done geological work in Nowata and Craig counties occasionally for years, altogether probably more than any other geologist. Even so, he is aware that he was no e too familiar with the details of the petroleum geology of these counties. All recent publications on this area were consulted and the well logs published by the Corporation Commission were used. It was found necessary to make a number of field trips in order to straighten out dubious points, but only a limited amount of time could be devoted to field work. It will be seen that detailed observations can be given in some localities while other chapters are very generalized, but it is hoped that this publication is going to be of some benefit to people interested in the geology and in the oil and gas resources of Nowata and Craig counties.

The writer expresses his thanks to his assistant G. G. Senftleben for help in compiling the report and to Chas. N. Gould, Luther H. White, W. J. Sherry, and a number of others for helpful suggestions.

Figure 83. Index map of Oklahoma showing location of Nowata and Craig counties.

(Originally issued as Bulletin 49-EE, June, 1928).
NOWATA COUNTY

Location, Topography, and Drainage

Nowata County is located in the northeast part of Oklahoma bordering Kansas.

The topography of the county is shown on the Nowata and Vinita quadrangles of the U. S. G. S. topographic atlas scale 1:125,000 with 50 foot contours.

The Verdigris River flows in a north-south direction through the center of Nowata County. It drains all of the area of the county with the exception of the extreme western edge, where a number of creeks originate which flow into Caney River.

History of Oil Development

While Nowata County is now, in the days of the Seminole development, hardly ever mentioned as an oil producing area it was in the early development of the Oklahoma oil fields the most important territory. It was then known as the Cherokee shallow district. The Coody's Bluff-Alluwe pool is one of the largest almost solidly drilled oil fields in existence and almost continuous with it are the Delaware-Childers pool, the Delaware extension, and the Claggett pool.

Quite a number of wells had a considerable initial production and most of them are producing yet.

The first oil wells in this district were drilled in sec. 23, T. 24 N., R. 17 E., in the Chelsea extension of the Coody's Bluff-Alluwe pool in Rogers County. It is said that an oil seep and showings in water wells led to the drilling. Real activity started in 1904, when it became possible to acquire valid leases. Drilling soon extended into Nowata County where larger wells were encountered. In 1906 the maximum daily production in the Coody's Bluff-Alluwe-Chelsea pool was attained with more than 53,000 bbls. In 1907 the development extended into the Delaware-Childers pool but the main development there was in 1909 in which year 475 oil wells were completed and in 1910 with 673 new oil wells. The Delaware extension was in full activity in 1911. In the same year the gas on California Creek was discovered and the Adair oil pool in 1912.

New pools discovered since have been of less importance. Occasional drilling in the main pools is still going on but most of the wells are small. Practically all the drilling was done in periods of high prices for crude. While as late as 1911 wells with less than 10 bbls. initial production were plugged as uninteresting, in the last years properties where the initial production averages only a few barrels are drilled up with profit.

GEOLGY

Stratigraphy

SURFACE FORMATIONS

The areal geology of Nowata County was first mapped by D. W. Ohern. Unfortunately this map is so poorly printed, that the reader will get a better idea of the distribution of the surface formations by consulting the smaller scale map recently published by the United States Geological Survey. A short description of the different formations shown on this map together with lists of characteristic fossils was published by the Oklahoma Survey.

The following formations, starting with the oldest, form the surface of Nowata County:

Pennsylvanian

CHEROKEE SHALE

Only the top of the Cherokee shale is exposed in the southeast part of the county and this formation shall be described under the heading subsurface formations.

FORT SCOTT LIMESTONE

The Fort Scott limestone consisting of two limestone ledges separated by black shale has a thickness of about 60 feet. Just below there are some coal and thin limestone ledges. Ohern has included these with the Fort Scott proper into his Claremore formation. This series is known by the drillers as the Oswego lime.

For years most of the wells have been on vacuum, the casing head gasoline bringing a substantial income.

Very recently compressed air drive has been put in use on many leases, air intake wells are drilled and new wells showing for a fraction of a barrel natural are made to pay by this method. In the Elliott pool an increase in production of 240 per cent was obtained by repressuring the sand with gas and air.

While compressed air has shown very good results in Nowata County the author is of the opinion that underground mining would still increase materially the ultimate recovery at a cost which is not prohibitive.


LABETE SHALE

The Labette is a formation consisting principally of shale, but with a fairly prominent sandstone member in its upper part. The formation shows a decided increase in thickness from north to south. Near the Kansas line the thickness is only 100 feet (according to well logs), while in the southern end of Nowata County it is at least 200 feet.

PAWNEE LIMESTONE

The Pawnee, a massive fossiliferous limestone, varies in thickness from 25 to 50 feet in Nowata County. O hern 7 gives the following section four miles northeast of Nowata:

Section of Pawnee Limestone, Nowata County.

<table>
<thead>
<tr>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, massive, fine-grained</td>
<td>6</td>
</tr>
<tr>
<td>Shale, black, carbonaceous, fissile</td>
<td>5</td>
</tr>
<tr>
<td>Limestone, bluish, shaly in lower part</td>
<td>14</td>
</tr>
<tr>
<td>Shale, black (top of Labette)</td>
<td>25</td>
</tr>
</tbody>
</table>

BANDERA SHALE

The Bandera is a bluish to black carbonaceous clay shale varying in thickness from 20 feet or less to 50 feet (or even 70 feet according to well logs). It thins irregularly toward the south, and not far from the Nowata County line it pinches out entirely. The overlying and underlying limestones coalesce and are known as the Oologah limestone or “Big Lime” of the drillers.

ALTAMONT LIMESTONE

The Altamont is a cherty limestone 30 to 50 feet thick. It forms, together with the Pawnee limestone in the south part and with the Lenapah limestone in the north part, the high bluffs along the Verdigris River.

An interesting exposure is in the bed of the Verdigris River in sec. 21, T. 28 N., R. 16 E. There the top of the Altamont limestone is sandy and contains, besides cherty parts with marine fossils, some plant remains. Pieces of Sigillaria trunks several feet long can be seen with the bark changed to coal and the interior transformed into limestone. Smaller plant fragments are forming thin flakes of coal in the limestone, getting more numerous close to the coal-bearing shale lying on top of the limestone. To the writer’s knowledge the presence of coal in limestone and also fossilized wood with a limestone matrix are unique.


NOWATA COUNTY

In this location the following section was measured:

Section on Verdigris River, Sec. 21, T. 28 N., R. 16 E.

<table>
<thead>
<tr>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, cherty</td>
<td>10</td>
</tr>
<tr>
<td>Limestone, sandy and shaly</td>
<td>2</td>
</tr>
<tr>
<td>Shale</td>
<td>75</td>
</tr>
<tr>
<td>Shale, bluish, with coal</td>
<td>1</td>
</tr>
<tr>
<td>Limestone</td>
<td>3</td>
</tr>
</tbody>
</table>

NOWATA SHALE

The interval between the Altamont and the next higher limestone consists of shale locally with lenticular sandstone. It has been called the Nowata shale. This shale interval increases from north to south. Its thickness is about 75 feet northeast of Lenapah, 130 feet near Nowata and 140 feet or more in the south part of the county.

LENAPAH LIMESTONE

The Lenapah is a dense blue, partly crystalline, fossiliferous limestone. Chert occurs mostly in the northern area. On Mormon Creek northwest of Nowata the writer observed two beds of crinoid breccia separated by clay and black shale, the latter having been observed in other places. At the type locality the Lenapah limestone is 20 feet thick. It decreases in thickness southward and measures 6 to 8 feet at Nowata. Then the outcrop swings westward around the headwaters of Double Creek, where exposures are poor. A good ledge of limestone caps the hill in sec. 14, T. 25 N., R. 15 E., and from there on only scattered exposures of crinoidal limestone are seen. Near the southwest corner of sec. 22, T. 25 N., R. 15 E., the limestone becomes conglomeratic and a ferruginous breccia in the northeast corner of sec. 9, T. 24 N., R. 15 E., is the last observed exposure which the writer considers to be true Lenapah limestone.

The Lenapah limestone has generally been considered the equivalent of the Dawson coal. The writer thinks that this coal develops in the black shale mentioned above as being interstratified with the Lenapah limestone. No good exposures could be found of coal and limestone together. But in case there is but a single coal bed in the Dawson horizon, which is not absolutely certain, the Dawson coal with the adjacent black shales and local thin limestones is the exact equivalent of the Lenapah limestone.

COFFEYVILLE FORMATION

The Coffeyville formation has a thickness of 200 to 300 feet or even more, thickening from north to south. It consists principally of shale, also sandstone especially in the upper part, a limestone near the base in the south part of the county (Checkerboard limestone).
and also coal. The writer has observed a coal seam in sec. 16, T. 26 N., R. 14 E., of one foot thickness, which includes shale partings. A little lower in the section a three-inch lenticular coal bed is present. These coal beds are contained in the irregularly bedded sandstone near the top of the formation. The lower coal rests unconformably on the underlying sandstone.

**HOGSHOOTER LIMESTONE**

The Hogshooter is a massive, highly fossiliferous limestone of at least 10 feet thickness in the north part of the county but a little less in the south. It is the equivalent of the lower part of the Drum limestone of Kansas. In sec. 16, T. 28 N., R. 15 E., black carbonaceous shale was observed underlying the limestone, also on the M. K. & T. R. R. southwest of Coffeyville.

**NELLIE BLY FORMATION**

The shale-sandstone interval between the Hogshooter limestone and the Dewey limestone has been called the Nellie Bly formation. Its thickness near Wann is 50 feet but increases considerably towards the southwest as 100 feet is the reported thickness at Ramona.

The top of the Drum limestone of Kansas becomes conglomeratic at the State line. Near Noxie, Okla., layers of conglomeratic limestone are interstratified with sandstone. The hill in the northwest part of sec. 28, T. 29 N., R. 15 E., is capped by limestone, conglomerate, and coarse sandstone. In the northwest part of sec. 3, T. 28 N., R. 15 E., the limestone finally grades into coarse sandstone, which is a part of the Nellie Bly formation.

**DEWEY LIMESTONE**

The highly fossiliferous Dewey limestone varies in thickness from 20 feet at the type locality at Dewey to 5 feet at a point in sec. 19, T. 28 N., R. 15 E., thinning northeastward. Close to this place the Dewey horizon is represented only by four inches of fossiliferous sandstone and some lime concretions, but true limestone can be traced as far north as the center of sec. 13, T. 28 N., R. 14 E. Here cross-bedded sandstone can be observed for one-half mile, indicating a regular delta. This may have raised the sea floor so that no limestone could be deposited. In some places, for instance in sections 10, 11, and 15, T. 27 N., R. 14 E., the limestone rests on fissile, black carbonaceous shale. Oehrn* states correctly that the Dewey limestone is above the horizon of the Drum. Unfortunately the old erroneous idea was revived on the state map**.

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**NOWATA COUNTY**

**OCHELATA FORMATION**

The highest strata cropping out in Nowata County belong to the Ochelata formation, but only the lower 300 feet of it occur within the county. It consists of shale, considerable sandstone, and several limestone ledges, also traces of coal near the base (secs. 13 and 24, T. 28 N., R. 14 E.). In the upper part of this formation is the Stanton limestone exposed only in the northwest corner of the county. Two more limestone horizons have been observed within the lower part of the Ochelata formation north of Wann. One or the other may possibly be the equivalent of the Avant limestone, but present field data are insufficient to establish these relations.

**Pleistocene**

Terrace gravels consisting of flint pebbles along the Verdigris River Valley and the alluvial silts shall only be mentioned.

**SUBSURFACE FORMATIONS AND PRODUCING HORIZONS**

**Pennsylvanian**

**SHALLOW SANDS**

The shallowest producing horizons in Nowata County occur in a pool in sec. 23, T. 29 N., R. 15 E., where small oil wells have been completed recently at an average depth of only 100 feet. According to the well logs there are two producing sands, one just above and one just below the Lenapah limestone. The latter is probably the Wayside sand of Kansas**.

The sandstone occurring in the upper part of the Labette shale (Weiser sand of Kansas**) is reported in some well logs as having considerable thickness, as much as 80 feet in sec. 13, T. 27 N., R. 16 E., 65 feet in sec. 33, T. 26 N., R. 16 E., 60 feet in sec. 18, T. 26 N., R. 14 E., etc. Small gas production is reported from this sand in sec. 8, T. 28 N., R. 16 E., and in sec. 23, T. 28 N., R. 15 E. There are several wells in sec. 14, T. 28 N., R. 15 E., the largest of record being good for one-half million cu. ft. In sec. 2, T. 25 N., R. 14 E., a 12 barrel oil well was obtained in this horizon and a test in sec. 29, T. 28 N., R. 15 E., showed for two barrels.

The horizon of the Fort Scott limestone, called Oswego lime by the drillers, produces gas in a number of wells in different parts of the county. The largest wells on record had a capacity of 214 million cu. ft., and are located in sec. 36, T. 29 N., R. 14 E. The Oswego

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11. This is the Piqua limestone of the Independence formation. Correlations with the Kansas section are not too certain, as the mapping of this formation is in part erroneous.
gas does not always come from the same horizon. It is reported from the lime itself or from a break between the limestone ledges. Part of it really comes from the top of the Cherokee shale.

**CHEROKEE SHALE**

The Cherokee consists chiefly of shale of various kinds and includes several prominent sandstones and oil sands, thin limestones, and coal seams. The important coal near the top has already been mentioned with the Fort Scott limestone. As only the top of the Cherokee shale outcrops in Nowata County, its thickness had to be obtained from well logs only. These show a thickness of 500 feet at the State line, increasing toward the south to 600 or 700 feet in the south part of Nowata County, the maximum thickness being reported from sec. 23, T. 25 N., R. 16 E., and sec. 34, T. 25 N., R. 16 E. As the Cherokee shale was deposited on a rough erosional surface, the changes in thickness are irregular and variations of 100 feet occur in the same township.

There are three groups of producing sands in the Cherokee shale of Nowata County.

A sandstone series crops out between Chelsea and Catale. In this horizon several irregular sands of varying thickness are reported. These sands usually carry water. There is some scattered gas production, the only pool being located around the southeast corner of T. 29 N., R. 14 E. The largest well in sec. 31, T. 29 N., R. 15 E., is reported good for two million cu. ft. In sec. 3, T. 25 N., R. 17 E., a small oil pool was developed in this sand with initial productions of from two to five bbls. Oil from this horizon is reported from several places inside the Coody's Bluff-Alhwee pool. In sec. 11, T. 25 N., R. 14 E., a 10 barrel well was obtained.

**BARTLESVILLE SAND**

Most of the oil wells (all the large ones) in Nowata County produce from the Bartlesville sand, also some gas wells. This sand series, which crops out farther to the east, is known at the surface as the Bluejacket sandstone. Above the “main pay” there are often “stray sands” which produce in places and in others oil is reported from a “second pay.” What is termed the “main pay” does not seem to be the same horizon all over the county. At the type locality near Bartlesville, the Bartlesville sand is usually reported as a single thick sand but toward the east in Nowata county this sand body splits up into different sand streaks. The upper, or stray sands, produce oil and gas in a few scattered localities. Most of the large production is from the main pay, but the following localities seem to produce mainly from the lower or second pay: The Adair pool in T. 26 N., R. 14 E., and T. 26 N., R. 15 E.; all the Bartlesville wells in sec. 30, T. 25 N., R. 14 E.; most of the wells in T. 25 N., R. 16 E.; secs. 31 and 32, T. 25 N., R. 17 E.; and the Chelsea extension in T. 24 N., R. 17 E.

The thickness of the Bartlesville sand varies considerably and in many places it thins out or turns into shale. Where producing, from 10 to 30 feet of sand are usually present and 50 feet seems to be about the maximum thickness. Wells drilled in recent years are usually small, but during the main development initial productions of several hundred barrels were numerous and in the Delaware-Childers pool a maximum initial production of 1,000 bbls. was attained. The Bartlesville gas wells are usually small. The largest record is located in sec. 11, T. 26 N., R. 16 E., with a capacity of 1,800,000 cu. ft.

**BURGESS SAND**

At the base of the Cherokee or separated from the “Mississippi” lime by a thin body of shale many deep holes report a sand called Burgess. It is approximately at the horizon of the Hogshooter gas sand, which has been described as the fill of an old stream channel. Not enough deep holes have been drilled in Nowata county to properly outline its distribution. As it is a basal sand deposited along the unconformity the Burgess sand is not of exactly the same age in different localities. This sand is usually thin, averaging only about 10 feet, but in sec. 16, T. 29 N., R. 16 E., 40 feet are reported, and in sec. 8, T. 25 N., R. 17 E., even 60 feet.

The Burgess sand has furnished several gas pools, the largest wells on record being two million cu. ft. in sec. 7, T. 25 N., R. 17 E., and 2½ million cu. ft. in sec. 35, T. 26 N., R. 17 E. The only Burgess oil production, which came to the writer's notice, is in the northwest part of T. 25 N., R. 17 E., the largest reported initial production being 35 bbls.

**Mississippian**

**BOONE LIMESTONE**

The Mississippian is represented largely by the Boone formation, a cherty limestone. The well logs sometimes report thin shale partings and sands, but this is, at least in part, sandy and shaly limestone. The green shale near the bottom is of Kinderhook age. On account of an erosional unconformity on top the thickness of the Boone limestone varies considerably, according to available well records, from 210 feet in sec. 14, T. 26 N., R. 15 E., to 370 feet in sec. 22, T. 25 N.,


Porous streaks occur in the limestone carrying water or showings of oil or gas. No oil wells from this formation have come to the writer's attention in Nowata County, but there may be a few. Light gas production from the top of the Boone limestone occurs in the north part of the county, a well on record in sec. 14, T. 27 N., R. 16 E., having a capacity of one-half million cu. ft. In sec. 14, T. 26 N., R. 17 E., near Ruby, a well is said to have shown an initial volume of 15 million cu. ft., but this evidently did not hold up.

Recent discovery of Mayes deposits in Rogers County, Okla., and in Montgomery County, Kan., indicate that some of the so-called Boone chert in Nowata County may be younger, but the writer was unable to locate well samples, which would decide this question.

**CHATTANOOGA SHALE**

The Chattanooga is a black carbonaceous shale formerly considered to be of Devonian age but now thought to belong to the Mississippian. It is separated by an unconformity from the formations below, overlapping younger strata toward the south. Most deep logs in Nowata County report from 50 to 70 feet of Chattanooga shale with a minimum of 10 feet in sec. 25, T. 26 N., R. 14 E.

Siluro-Devonian

While upper Ordovician and Silurian sediments were probably deposited over the area, they are now missing. Most of the Devonian period was a time of erosion. The older sediments had been uplifted and were eroded in such a manner that the pre-Chattanooga sea floor consists of older formations the farther north one goes in Oklahoma. At least several hundred feet of sediments were removed in the area covered by this report and this erosional unconformity is more pronounced than any other unconformity above or below with the exception of the granite floor.

**Ordovician**

**ARBUCKLE LIMESTONE**

Below the Chattanooga shale deep wells encounter a series of siliceous limestones, dolomitic in part. This series has been correlated with part of the Arbuckle limestone, the top having been eroded. It is of lower Ordovician age, possibly extending into the upper Cambrian. Only one test in Nowata County, located in sec. 27, T. 27 N., R. 16 E., went through it and showed a thickness of 775 feet.

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17. Ulrich, E. O., Fossiliferous boulders in the Ouachita "Caney" shale and the age of the shale containing them; Oklahoma Geo. Survey, Bull. 45, Fig. 2, 1927.

**NOWATA COUNTY**

There are several porous horizons in this series, which usually carry sulphur water but may produce oil or gas. One such horizon, the only one, which has actually produced oil is at or near the top of the formation. Only two places have produced oil in the Arbuckle limestone in Nowata County. One pool is located southeast of Coffeyville in Kansas and extends into secs. 15 and 16, T. 29 N., R. 16 E., in Oklahoma. The other pool is in secs. 16 and 21, T. 28 N., R. 16 E. The pay is usually penetrated only a few feet, as sulphur water soon appears. The largest reported initial production is in sec. 16, T. 28 N., R. 16 E., with 400 bbls.

**Pre-Cambrian**

**GRANITE**

The deepest hole drilled in Nowata County is located in sec. 27, T. 27 N., R. 16 E. It was drilled to 2,070 feet and reports lime to the bottom. The samples showed granite from 1,955 on down. We may assume that in most places in Nowata County the Arbuckle limestone rests directly on granite or on reworked granite material.

**NOTES ON PENNSYLVANIAN SEDIMENTATION**

The Pennsylvanian, consisting mostly of shale with some sandstone and coal and an increasing amount of limestone from the Fort Scott on up, is essentially marine. No positive proof has been found of any fresh water or land deposits, but plant remains indicate the proximity of land in different periods. The various coals have been formed in coastal swamps, some beds of local extent probably in fresh water. Cross-bedding must have taken place in very shallow water and local unconformities may be due to temporary emergence or to submarine erosion. The sandstones are known to be lenticular partly pinching out, partly grading into shale. Shore lines were probably present, but the available logs can not be correlated with sufficient accuracy to work out such interesting and important details.

Several of the limestones also pinch out in this territory after becoming sandy and conglomeratic. This edge facies is usually characterized by crinoids and bryozoa.

Attention is called to deposits of black, carbonaceous shale connected with most limestone ledges and also with coal beds. To the writer's knowledge they have not been studied properly as to mode of deposition and contents of organic matter. A sample of such shale associated with the Hogshooter limestone collected behind the store at Hogshooter showed an oil content of two gallons to the ton. These shales must be considered as possible source rocks for oil and gas.

20. Dett, Robert H., Personal communication.
Structure

The normal dip of the surface beds is to the northwest at an average rate of 30 feet to the mile. On account of the southward increase in thickness of the section the strike of the lower beds is changed somewhat and local structural features are also modified with depth.

The normal dip is modified in numerous places by flattening, reverse dip, and by local changes in the strike, which form northwest plunging anticlines (noses). Very little detail work on the structure (surface or subsurface) of Nowata County has been done and none has been published. Reconnaissance work done by the writer indicates that anticlines (mostly domes) are fairly numerous, but that most of them are small. He has called attention to a small anticline east of Lenapah. The U.S. Bureau of Mines has published a map of the Elliott pool contoured on the producing sand. While such a sand surface only approximates structure, this map shows the presence of a northward plunging anticline.

On Map No. XXIX there is shown a cross-section north and south through R. 16 E., and two east-west cross-sections (through Nowata and Craig counties), one along the line between T. 28 N., and T. 29 N., the other one mile north of the south line of Nowata County. These cross-sections show the general attitude of the beds. The east-west sections show the west dip, while on the north-south section there is only a slight dip to the north. Some of the structural irregularities are also indicated, but only in a general way, as some logs had been projected into the plane of the section. The sections also show the stratigraphy of the region, hard beds forming escarpments, lensing of sands, variation of thickness of certain beds, the erosional unconformity on top of the "Mississippi lime," and so on. (The Fayetteville-Pitkin series cropping out east of Vinita is included in the Cherokee, as it could not be identified in the well logs, and some cherty Mayes may be included in the Doone.)

OIL AND GAS DEVELOPMENT

Accumulation

According to the anticlinal theory oil and gas accumulate on anticlines. This is only true where the sand is continuous, regular, and fully saturated. Where the sand is lenticular the accumulation takes place in the upper part of the sand lenses instead of the anticlines. Thickness and porosity may decrease sufficiently to act as a barrier without actual pinching out of the sand. Porous sands which carry lots of water in the lower places can only be expected to produce on closure (due entirely to structure or in part to lensing). Highly water bearing horizons in Nowata County are the sand in the Tabbert shale and the top of the Arbuckle limestone. Where sands are not fully saturated the high places contain gas only under pressure below normal and the oil is located down the dip. This condition is well known in some of the Appalachian fields and also occurs in eastern Kansas. In Nowata County there are indications of it, but some of the gas pools show normal pressure. Sometimes sand lenses are very large forming a blanket over a large area but terminating rather abruptly. Such sands may furnish extended oil pools with an irregular boundary, structural conditions only limiting the pool on the lower side where the water level follows structural contours. The Bartlesville sand group is famous for such pools (Glenn Pool, Burbank) and most of the Bartlesville oil pools in Nowata County are thought to be of such a nature.

MAIN POOLS OF NOWATA COUNTY

A map covering most of Nowata County and showing all the wells is contained in Bull. 19 of the Oklahoma Survey. While quite a number of wells have been drilled since, it still gives a good general idea of the production. A map showing the development in the whole area has recently been published by the U.S. Geological Survey.

COODY'S BLUFF-ALLUWE POOL

Including the so called Chelsea extension in Rogers County the Coody's Bluff-Alluwe pool covers an area of 70 square miles, the main production being from the Bartlesville sand group. An upper and a lower sand are present, but can not be discerned readily from the available well logs. The upper sand seems to furnish the production in the north end of the pool, while the lower is productive in the south end. In a few places there is oil production from shallower sands and the Burgess sand is producing oil and gas in places. In 1921 a check showed about 8,300 producing wells in this pool and most of them are producing yet.

The development started near Chelsea, the first real drilling campaign getting under way in 1904, but soon extended north on account
of larger wells. The wells near Coody's Bluff had initial productions of as much as 500 bbls., but also north of Alluwe initial productions of 200 and 300 bbls. were occasionally developed. The size of the wells depends on thickness and porosity of the sand, the porosity being of prime importance. Late drilling usually resulted in small wells, but an occasional big one inside of the pool indicates important changes in sand conditions and lenticularity, if not of the sand, at least of the porous streaks. In 1921 the average production per well in the south part of the pool between Alluwe and Chelsea was estimated at one-half barrel, the wells in the north part being somewhat larger. Since then repressuring with gas or air has been introduced on many properties with good results, but no actual production figures are available.

The Coody's Bluff-Alluwe pool is a typical large sand lens pool. The reported big anticline does not exist. The few logs of dry holes available on the east edge of the pool do not show water and the Bartlesville sand is thin or missing. Folding may have helped the accumulation of the Oklahoma sand more; for example, the wells in the north part are somewhat larger. Since then repressuring with gas or air has been introduced on many properties with good results, but no actual production figures are available.

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There are a few unimportant pools east of the Coody's Bluff-Alluwe pool, one of which, containing Burgess sand wells, is differentiated as the Salt Creek pool on the map of the U. S. Geological Survey.

DELAWARE-CHILDERS POOL

North of the Coody's Bluff-Alluwe pool and practically continuous with it is the Delaware-Childers pool. From the town of Delaware it extends east for nearly 7 miles and the Delaware extension, which is continuous with it, extends west-northwest for another 7 miles. Thus the pool has a length of 14 miles and a width varying from one-fourth mile to two miles. As far as could be learned all the production is from the Bartlesville sand and the pool is a typical sand lens pool, structure only affecting the water level on the west end. The Delaware extension even resembles the shoe string pools of Kansas. The wells in the extreme east end start near the top of the Labette shale and the ones in the extreme west end near the Dewey limestone. Thus it can be seen that the depth of the wells in the pool varies considerably from east to west.

NOWATA COUNTY

The first production in the Delaware-Childers pool was obtained in 1907 and most of the drilling was done from 1908 to 1910, while the Delaware extension was mainly developed in 1910 and 1911. Many wells had an initial production of several hundred barrels and in the Delaware-Childers pool a few wells up to 1,000 bbls. are said to have been obtained.

NOWATA OR CLAGGETT POOL

The Nowata or Claggett pool is located near the town of Nowata and almost joins the Coody's Bluff-Alluwe pool in the east and the Delaware pool in the north. It covers several square miles, but as most of the wells, which also produce from the Bartlesville sand, were small, development has not been as solid as in the pools already mentioned.

HOGSHOOTER GAS POOL

The Hogshooter gas pool at one time the most important one in Oklahoma, which furnished gas to Kansas City, is located mostly in Washington County but extends across the line into Nowata County. The producing sand lies on top of the "Mississippi" lime at the west edge of the pool. While the accumulation is essentially due to sand conditions, structure also plays a minor part in the outline of the pool.

ADAIR POOL

The Adair pool is located in and around the southeast part of T. 26 N., R. 14 E. It has several extensions, some of which have been termed Ogleby and Glen Oak pool. It was opened in 1912. The production is from the Bartlesville sand. Indications of anticlinal structure were noticed but no details worked out.

WANN

Near Wann on both sides of the county line there are a number of small pools producing oil from the Bartlesville sand and also some shallow gas.

CALIFORNIA CREEK OR ELLIOTT POOL

A pool extending nearly continuously from sec. 10, T. 27 N., R. 15 E., to sec. 11, T. 28 N., R. 15 E., is known as California Creek pool. It produces mostly gas but about 540 acres situated mostly in sec. 3, T. 27 N., R. 15 E., are oil producing. This oil pool has been described under the name of Elliott pool.

long, narrow pool is anticlinal and the accumulation is at least in part due to structure, but outside of the oil producing area the structure has not been worked out. The first well was drilled in 1909. Most of the oil area was developed in 1910 and in the spring of 1911, with an initial production of about 250 bbls. to the well and a maximum of 700 bbls. The Bartlesville sand is 900 to 1,000 feet deep.

SOUTH COFFEYVILLE

Drilling around South Coffeyville, mostly started in search of gas for use in Coffeyville, has opened several small pools.

In secs. 23 and 26, T. 29 N., R. 15 E., oil and gas were developed in 1915 and 1916 in the Bartlesville sand and recently small oil wells were drilled, which produce near the Lenapah limestone as stated above. Their depth is only 100 feet.

A number of gas wells producing from the Bartlesville sand (at least a few on which information is available) are located in secs. 16, 22, 27, and 34, T. 29 N., R. 15 E.

Along the State line east of Coffeyville an oil pool in the top of the Arbuckle limestone was developed in 1924 in an area which had already produced shallow gas. Only a few wells are located in Oklahoma in secs. 15 and 16, T. 29 N., R. 16 E. The pay is encountered between 1,200 and 1,300 feet at or near the top of the Arbuckle limestone. The producing stratum is thin and sulphur water is encountered immediately below. The largest well in this pool on the Oklahoma side had an initial production of 165 bbls. Surface and subsurface data show that this pool is located on a dome with at least 40 feet of closure.

Another Arbuckle lime pool opened shortly afterwards is located in secs. 16 and 21, T. 28 N., R. 16 E. The pay is at the same depth and an initial production of 400 bbls. is on record. There is also some gas production from the Oswego and from the Bartlesville sand in this pool. It is located on the same line of folding on a pronounced dome.

WEIMER GAS POOL

About 10 gas wells were drilled on a well defined dome, most of them located in sec. 1, T. 27 N., R. 17 E. The majority of these wells is still producing.

FUTURE POSSIBILITIES

Since 1912 new development in Nowata County resulted only in small pools and the new wells were, with notable exceptions, small. Most of the drilling took place in periods of a high oil market, while in times of low prices it was practically at a standstill. The same will take place in the future. While the county has been drilled up to such an extent that new important pools can hardly be expected, small new pools and new wells in the old fields can be looked for and the principal chances shall be pointed out.

New gas production can be expected in different parts of the county from the Oswego down to the top of the "Mississippi" lime, but these gas wells are likely to be small. Most of this gas will be found on anticlines, especially on domes, which in most places can be worked out from surface exposures, but some in the upper part of porous limes, especially in the Bartlesville sand.

Oil in the usual water bearing horizons will also mostly be found on anticlines, while production from lenticular sands is much harder to predict and can only be figured out from well logs.

Production in shallow sands can not only be expected in undrilled territory, but it seems likely that in developing the main pools small wells in the upper sands have been passed up. New Bartlesville sand wells inside or along the edges of the old main pools can be drilled in a number of places, but with some exceptions they are going to be very small. Some Bartlesville sand wells stopped in the upper pay where production in the lower pay may be possible and also some more Burgess sand production is likely to be found within the old Bartlesville sand pools.

Only a few tests in Nowata County have been drilled to the Arbuckle limestone and, as favorable structure is known to exist, there are chances for additional pools in this horizon. It may be said, that the top of the Arbuckle limestone is so porous (or possibly cavernous) and the water comes in so quick, that on a smaller dome one well located exactly on the apex would be sufficient to drain the pool. On the other hand the topmost part of the dome often shifts slightly from the surface to the depth of the Arbuckle pay on account of several pronounced unconformities and it takes several wells to locate the highest point. Therefore drilling to the Arbuckle horizon can only be recommended on fair sized domes. There are several porous horizons in the middle of the Arbuckle limestone to 500 or 600 feet below the top. In the only deep test in Nowata County no showings of oil or gas are reported from these horizons but the writer considers production not impossible as most limestones contain, when deposited, enough organic material to form oil or gas. This oil or gas could accumulate in the porous streaks, providing the location is on closed anticlinal structure.

The main future of the oil industry in Nowata County lies in increased recovery by new production methods such as repumping and underground mining.
CRAIG COUNTY
Location, Topography and Drainage

Craig County is located in the northeastern part of the State bordering Kansas and adjoining Nowata County on the east.

The topography of the county is shown on the Vinita quadrangle of the U. S. Geological Survey topographic atlas, scale 1: 125,000, (the extreme east portion on the Wyandotte quadrangle) with 50 foot contours.

While the Neosho River forms the boundary in the northeastern corner of the county practically all of the county is drained by Cabin Creek, which empties into the Neosho River after leaving the county on its south line. A small area in the northwest part of the county lies in the drainage basin of the Verdigris River.

GEOLGY
Stratigraphy

SURFACE FORMATIONS

The formations cropping out in Craig County are shown on the State map.

Mississippian

CHATTANOOGA SHALE

The Chattanooga shale, probably of Mississippian age but formerly considered Devonian, is a black, carbonaceous shale cropping out in a small area on Cabin Creek near the south line of the county. It well logs its thickness varies from 10 to 50 feet.

BOONE LIMESTONE

Unconformably above the Chattanooga shale is the Boone, a cherty limestone with a thickness of from 300 to about 400 feet. Some of the well logs show the green shale interstratified with the basal beds, denoting Kinderhook age. Near the surface the lime is leached out and only porous chert is left. While the upper part is all cherty, in the lower part layers of flint, which have been used as raw material for weapons by the Indians, alternate with more pure limestone, and Crinoid breccia has been observed.

MAYES FORMATION

The Boone surface is an erosional unconformity and the overlying formations have been deposited in depressions of this surface. The Mayes formation of lower Chester and upper Meramecian age consists mostly of limestone with some shale. It is poorly exposed, probably present only in a part of the area, either on account of non-deposition or later erosion, and has a reported maximum thickness of 50 feet. Snider has collected fossils from this formation in Little Cabin Creek east of Vinita.

FAYETTEVILLE SHALE

The Fayetteville consists mainly of dark shale, but limestone is also present. Exposures east and south of Vinita indicate a maximum thickness of at least 60 feet. This formation also seems to be missing in places.

PITKIN LIMESTONE

The Pitkin limestone, according to Snider has not been observed north of T. 18 N., due to erosion. According to Buchanan at least some patches of this formation have been preserved.

Recent investigations, not yet finished, indicate that the stratigraphy of the Mississippian of Craig County should be revised.

Pennsylvanian

CHEROKEE SHALE

The Cherokee shale rests unconformably on the Mississippian. Logs show a thickness of 500 feet in the northeast part (T. 28 N., R. 20 E., and T. 29 N., R. 19 E.) to 640 feet in the southwest part of the county (T. 26 N., R. 18 E.).

This formation consists largely of shale with sandstone, coal seams, and a few thin limestones. Near the middle is the Bluejacket sandstone, equivalent to the Bartslesville sand, a series of sandstones and sandy shales of variable character and of an aggregate thickness of 50 or 60 feet. It forms a prominent escarpment, as does another sandstone in the upper part of the formation. Close to the "Mississippi" lime there is also an oil sand, called the Burgess sand, which probably belongs to the Cherokee. Coal occurs at the base of the Bluejacket sandstone, the Cherokee coal above the Bluejacket, and the Fort Scott coal (several beds) at the top of the formation. Thin limestones near the top forms a transition to the Fort Scott limestone (Claremore formation of Ohern). Gas is known to occur close to the top of the Cherokee shale.

FORT SCOTT LIMESTONE

The Fort Scott limestone consists of a lower limestone member 5 to 18 feet thick, a middle member of black shale 7 to 10 feet thick,
and an upper limestone 4 to 10 feet thick (in well logs reported as much as 40 feet). Gas is known to occur at or near this horizon (Oswego lime gas).

**LABETTE SHALE**

The Labette is a shale formation which contains thin sandstone especially near the top. It occurs, like the higher beds, only in the northwest part of the county. A thickness of 100 to 120 feet is reported in Craig County, but a log in sec. 21, T. 29 N., R. 18 E., shows only 70 feet.

**PAWNEE LIMESTONE**

The Pawnee is a massive, somewhat cherty limestone of about 30 feet thickness.

**BANDERA SHALE**

The Bandera shale, which is arenaceous in places, has a thickness of about 100 feet at the Kansas line, thinning to the south.

**ALTAMONT LIMESTONE**

The Altamont limestone, the highest Pennsylvanian formation cropping out in Craig County has a thickness of about 30 feet.

**Pleistocene**

Flint gravels occur in Craig County, but they do not seem to be prominent and have not been studied.

**Recent**

An alluvial valley is developed along Neosho River and some valley fill is present along all the creeks.

Prominent talus deposits can be seen along bluffs of Boone chert, which are recent in part but in part probably older.

**SUBSURFACE FORMATIONS**

The following formations do not crop out in Craig County but are encountered in deep drilling:

**ORDOVICIAN**

**ARBUCKLE LIMESTONE**

Unconformably below the Chattanooga shale occurs a thick series of siliceous limestone and dolomite correlated with the Arbuckle lime-

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CRAIG COUNTY

stone of south-central Oklahoma. The top of this formation is a producing horizon. Only four well logs are available from Craig County, which go through this formation. They show the following thicknesses: 1,060 feet in sec. 34, T. 29 N., R. 19 E.; 1,208 feet in sec. 29, T. 25 N., R. 20 E.; 1,284 feet in sec. 32, T. 25 N., R. 21 E.; and 640 feet in sec. 29, T. 28 N., R. 21 E. The lower part of this formation may be of Cambrian age.

**CAMBRIAN**

**REAGAN (?) SANDSTONE**

In three of the deep wells a sand is reported below the Arbuckle series; 97 feet in sec. 29, T. 25 N., R. 20 E., 14 feet in sec. 32, T. 25 N., R. 21 E., and 50 feet with about 30 feet of sand and shale below in sec. 29, T. 28 N., R. 21 E. While these sands may be part of the Arbuckle series just as higher, more siliceous parts are reported as sands, they may be basal sands or may possibly represent an equivalent of the Reagan sandstone of the Arbuckle region or the Lamotte sandstone of Missouri.

**PRE-CAMBRIAN**

**GRANITE**

The three last mentioned wells went into granite below the Reagan (?), while the one in sec. 34, T. 29 N., R. 19 E., reached the granite at the base of the Arbuckle limestone. The well in sec. 29, T. 23 N., R. 20 E., penetrated the granite for 491 feet.

Another granite well is reported from sec. 24, T. 24 N., R. 19 E., but could not be found. The granite well mentioned in sec. 10, T. 25 N., R. 20 E., also could not be located and has probably been mixed up with the one in sec. 29, T. 25 N., R. 20 E.

**Structure**

The average dip of the surface strata in Craig County is to the northwest at a rate of about 30 feet to the mile.

Variations from this dip seem to be numerous, as flattening and reverse dips can be observed in many places. These reversals form anticlines which are usually short and dome-shaped. The writer has mapped an area in the north part of the county which shows the character of these low folds and is given on Figure 84. Most of the points are on top of the upper Fort Scott limestone. Erosion has removed the overlying Labette shale and it is noteworthy how closely drainage follows the structural details. Other similar domes are reported from the north and west part of the county.

OIL AND GAS IN OKLAHOMA

More pronounced structural conditions exist in the extreme southeast part of Craig County. There dips of over 5 degrees have been observed by the writer. The main structural feature is the Horse Creek anticline, which extends from the northwest part of Delaware County in a southwesterly direction into Craig County and is plainly visible on Cabin Creek. It has been described by Siebenthal.\footnote{Siebenthal, C. E., Mineral resources of northeastern Oklahoma: U. S. Geol. Survey, Bull. 540, p. 198, 1908.}

CRAIG COUNTY

OIL AND GAS DEVELOPMENT

Main Areas of Development

Quite a number of tests for oil or gas have been drilled in Craig County, but the results have been mostly disappointing.

A number of small scattered gas wells were obtained and three small oil pools, one of which straddles the Rogers County line.

Near Catale in Rogers County there are several small oil pools and one of these, extending into Craig County, is known in the literature as Vinita pool. The wells near Catale are producing oil and gas from the Burgess sand and also oil from the Arbuckle limestone, but the wells are small. No information is available on the few wells on the Craig County side in the northwest part of T. 24 N., R. 19 E.

A dozen oil wells were drilled near Booker school. The ones in sec. 28, T. 25 N., R. 18 E., are still producing. Judging from the log of a now abandoned oil well in sec. 32, T. 25 N., R. 18 E., this production is probably from the Burgess sand.

In sec. 20, T. 26 N., R. 18 E., an oil pool was opened in 1916 with several small wells in the Bartlesville and in the Burgess sand. These wells were never operated steadily.

In Bulletin 19 of the Oklahoma survey an oil pool producing from the Burgess sand is mentioned in T. 28 N., R. 18 E., under the name of Weimer oil pool.\footnote{Shannon, C. W., loc. cit. p. 159.} No oil wells are known in that area the only production being the Weimer gas pool across the line in Nowata County.

In sec. 21, T. 29 N., R. 18 E., a well reported good for 50 bbls. was completed in the Arbuckle limestone, but a second one proved dry and the first one has never produced for lack of pipeline facilities.

Future Possibilities

Judging from past performances no important oil or gas production can be expected from Craig County. Still there are numerous places in the county which could be drilled with the chance of getting small wells, but they are only of interest in times of big demand.

As to general chances the county can be divided into the northwest and the southeast part.

In the southeast part chances for production are practically confined to the Arbuckle limestone of which very little is known, with a possibility in the sand at the base [Reagan (?) sandstone].

In the northwest part there are also possibilities for production in the Pennsylvanian. In most any part of this area, where local
structural and sand conditions are favorable, it should be possible to obtain gas at least for local consumption. Oil possibilities are indicated by previous drilling as mentioned above. Pennsylvanian production especially from the Bartlesville sand can be expected to be limited to areas with exceptionally favorable sand conditions, while Arbuckle production occurs only on well defined domes.

Unless favorable sand conditions are already proved by previous drilling new tests ought to be located on the most favorable anticlines, as this would give a chance for production from several horizons. On the other hand pronounced doming alone is no guarantee for paying production. This may plainly be seen from Figure 84, where several domes were mapped. The only production is from a well only 35 feet deep drilled for water and which encountered gas just below the Fort Scott limestone. This well has been supplying a farm house with gas for 20 years. The Bartlesville sand in this area contains gas, but only in small quantities. The Burgess sand is missing. Three tests, well located as to structure, were drilled to the Arbuckle limestone, one with a slight showing of oil. All three encountered water. Additional drilling for this horizon in Craig County should only be done on higher domes than these or in localities closer to actual Arbuckle production.

MUSKOGEE COUNTY

By
Hale B. Soyster and Thos. G. Taylor*

ACKNOWLEDGMENTS

Many sources of information have been drawn upon in the writing of this report. Those which have been referred to most frequently are: Oklahoma Geological Survey Bulletin No. 19, Part II, Petroleum and Natural Gas in Oklahoma; Bulletin No. 35, Index to the Stratigraphy of Oklahoma by Chas. N. Gould; U. S. Geological Survey, Tahlequah and Muskogee folios by Joseph A. Taff; Notes on the Subsurface pre-Pennsylvanian stratigraphy of the north Mid-Continent oil fields by Aurin, Clark and Trager, published in the Bulletin of American Association of Petroleum Geologists, Vol. 5, No. 2, and an article with a map published in the Oil and Gas Journal, April 1, 1926, by Luther White, entitled “Oklahoma’s Deep Horizons Correlated. Microscopic correlations were made by H. S. Thomas of the Tidal Oil Company, to whom the writers are gratefully indebted.

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AREA COVERED BY THIS REPORT

Muskogee County is situated in the east-central section of the State of Oklahoma between 35° and 36° N. latitude and 95° and 96° W. longitude. The total area of the county amounts to approximately 826 square miles, of which probably 65 square miles are either proven or semi-proven oil or gas producing territory. The county is comprised of sixteen full townships and parts of fourteen townships, all within Tps. 9 to 16 N., Rs. 15 to 21 E., inclusive.

TOPOGRAPHY

The county may be divided into two physiographic areas; one east of the Arkansas River, the other west. The region west of the river is generally known as the prairie plains. This area, as described by Taff, is characterized by rolling or undulating land interspersed by hills and ridges, having a northeastern and southwestern trend, the ridges being characterized by table land and escarpment type of topography. The escarpments and terraces face eastward and the table lands and benches slope to the west. The general area east of the Arkansas River has been termed as the Ozark Highlands and is characterized by gently rolling hills with wide shallow valleys.

The relief throughout Muskogee County appears to have comparatively close relationship to structure, as the hills and ridges generally occupy the synclinal troughs while the anticlinal structures usually underlie the valleys. It has been found, generally, that the hills are capped with sandstone or sandy lime, which formations are usually quite resistant to erosion. The valleys are occupied by shale beds or alluvial deposits. Erosion in the valleys is comparatively negligible, as the streams are sluggish, due to low gradient.

MUSKOGEE COUNTY

SUBSURFACE GEOLOGY

The accompanying cross-sections of Muskogee County have been drawn from a study of the well logs in the county. Section “AA” extends from the NE 1/4 sec. 22, T. 15 N., R. 19 E., southwest to the NW 1/4 sec. 12, T. 15 N., R. 18 E., south to NW 1/4 sec. 33, T. 14 N., R. 19 E. From data compiled by Luther White and others it appears that in the northwestern part of the county the St. Clair marl, and also the beds to which he and other Oklahoma geologists apply the names Sylvan shale and Viola limestone (“white lime”), disappear toward the northeast and the Chattanooga shale that rests upon older and older formations in this direction. This is due to folding and a long erosional interval preceding the deposition of the Chattanooga.

Pre-Cambrian
GRANITE

In Muskogee County granite has been penetrated in two wells underneath the limestone of Cambro-Ordovician age. The definite age of the granite is more or less a matter of conjecture, although it is generally believed to be of pre-Cambrian age. It is a reddish brown, mottled, medium to fine grained granite and resembles the granite that crops out at Spavinaw, Oklahoma. The predominate constituents of this granite are; red orthoclase feldspar, quartz, hornblende, and biotite mica. One of the two wells above mentioned was drilled 320 feet into the granite.

Cambrian and Ordovician
UPPER CAMBRIAN
LIMESTONE

In Muskogee County there is a great thickness of limestone—(Arbuckle of some geologists) as much as 1,100 feet in the central part. A sandstone considered by some to be “Reagan” may underlie the limestone although generally the limestone rests directly on granite pre-Cambrian age, which the writers believe to be similar to that exposed near Spavinaw, Oklahoma.

“TURKEY MOUNTAIN” SAND

The “Turkey Mountain” sand is generally considered to be a porosity zone in the top of the “Arbuckle limestone” which is dolomitic and silicious. It has not been definitely worked out whether the “Turkey Mountain” is of the age of the Simpson formation of the Arbuckle Mountains or is of the age of the upper part of the Arbuckle limestone of those mountains. The thickness may be 25 feet or more, although due to its occurrence in lenses it is missing locally. The color is gray to white. Only a few wells have been drilled to this horizon and to date none have been productive of oil or gas in commercial quantities.
MUSKOGEE COUNTY

(ST. PETER SANDSTONE ("Burgen")

The St. Peter sandstone, also known as the "Burgen sandstone", generally consists of well cemented quartz grains. This formation is usually massive, light gray to yellowish brown in color, fine-grained sandstone varying in thickness up to 100 feet and is generally so well cemented that it has not been productive.

Ordovician

TYNER FORMATION

Samples taken from wells drilled near Muskogee show the Tyner formation to be mainly green and red shale with some green sand. Near the top a small amount of green sand may be present while near the base the formation becomes more dolomitic. The thickness has been found to range from 100 to 150 feet.

"WILCOX SAND"

The "Wilcox sand" is believed to exist throughout the entire county. However, it thins to the east and in the NW, cor. SE 1/4, sec. 12, T. 15 N., R. 18 E., only two feet of "Wilcox" was found. It is probably found in the "Wilcox" near Muskogee and in other parts of the county. Gas has been found in the "Wilcox", it may be expected to be commercially productive of oil or gas wherever favorable sand or structural conditions exist. A period of erosion followed the deposition of the "Wilcox".

"POST-WILCOX"—(SIMPSON AGE)

In the York Oil and Gas Company's well located in the NW, cor. SE 1/4, sec. 12, T. 15 N., R. 18 E., 15 feet of lithographic and dolomitc limestone was found above the "Wilcox". The log of the well is as follows:

The York Oil Company's Gertrude Jobe Well No. 1.
Dry hole—NW, cor. SE 1/4, sec. 12, T. 15 N., R. 18 E. Elevation 534.5'.
Commenced January 23, 1927; Completed May 1, 1928.
C. F. Finney, Contractor.

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<th>Bottom</th>
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(Continued on page 382)
The Sylvan shale, so recognized by various Oklahoma geologists, is a light blue calcareous shale which may have a greenish tinge. The maximum thickness in Muskogee County is probably not over 50 feet with an average thickness of approximately 30 feet. It is not present directly on older formations. It is generally agreed that the Sylvan is of Richmond age. Some geologists place the Ordovician-Silurian boundary at the base of the Richmond but others place it at the top of the Richmond.

**Silurian**

**ST. CLAIR MARBLE**

The St. Clair marble varies from yellowish blue to pinkish white in color and varies in thickness up to 150 feet. It reaches its greatest thickness in the southern part of the county and as previously stated has been eroded away in the northern part or may be locally absent due to original non-deposition. According to Luther White, the St. Clair marble is equivalent to the Chimneyhill limestone member of the Hunton formation. His reasons for correlating the St. Clair marble with the base of the Hunton are set forth in Bulletin 40-B of the Oklahoma Geological Survey.

**Devonian (?)**

**CHATTANOOGA SHALE**

The Chattanooga shale is a black, slaty shale which is generally bituminous, non-calcareous and of even texture. It varies in thickness up to 100 feet. The Chattanooga shale is here doubtfully placed in the late Devonian as there is an unconformity above as well as below.

The majority of the students of stratigraphy of Oklahoma, Missouri, and Arkansas, classify the Chattanooga shale as Mississippian in age ("Kinderhookian"). Gould states, "In former years it has usually been classified as upper Devonian, although the upper portion of the black shale in Kentucky and elsewhere is known to contain Mississippian fossils. It therefore appears to be transitional and represents upper Devonian and early Mississippian time."

**CARBONIFEROUS**

**Mississippian**

**BOONE LIMESTONE**

The Boone limestone, also called the Boone chert, constitutes the oldest rocks which crop out in Muskogee County. The exposures are very limited and are to be found in the N.1/2 sec. 13, T. 15 N., R. 20 E. The Boone varies in thickness up to 450 feet in the type locality and is composed of interstratified chert and cherty limestone. The basal member of the Boone is known as the St. Joe limestone. The extent of the Boone formation in Muskogee County is not known.

1. White, Luther H. Subsurface distribution and correlation of the pre-Chattanooga ("Wilcox" sand) series of northeastern Oklahoma.
The Morrow formation crops out over a region of approximately 13 square miles in the east-central and northeast section of Muskogee County. This formation consists of sandstone, fossiliferous limestone, and blue-black shale; the limestone greatly predominates. The upper 10 to 18 feet of an oolitic brown limestone, which from sample determination has been correlated with the Trentwood limestone in this district, forms the uppermost part of the Morrow formation. The middle of the section is composed of hard dark blue limestone. The extreme lower part in the type section is sandy with local beds of fossiliferous limestone, this part is commonly known as the Hale sandstone member of the Morrow formation. The thickness of the Morrow formation in Muskogee County probably ranges from 100 to 150 feet. An unconformity has been reported at the top of the Morrow by Aurin, Clark, and Trager.

**Winslow Formation**

The Winslow formation crops out over a larger area of Muskogee County than any other formation and occupies approximately 35 square miles. It is composed of bluish to blackish clay shale and sand lenses. The Dutcher sands occurring in the lower part of the formation are locally known as the Muskogee, Gas Sand, Timber Ridge, Boynton, Leidecker, etc., and are productive of oil and gas in commercial quantities where sand and structural conditions are favorable.

The Booch sand and Salt sand (Bartlesville) are found in the upper part of the formation and crop out near Muskogee. A bed of limestone which ranges from 40 to 90 feet in thickness has been logged by drillers above the Dutcher series of sands. The base of this lime is approximately 100 feet above the uppermost sand in the series.

**McAlester Shale**

According to Taff, the McAlester shale may be divided into three parts: upper, middle, and lower. The upper member consists almost wholly of a shale which also contains the McAlester coal; the middle section is composed of several strata of sandstone interbedded with shale; the lower consists of shale with sandstone and contains the Hartshorne coal.

On Miser's geologic map of Oklahoma, the McAlester shale is shown to crop out over a considerable area of the southern part of the county. Gould in Bulletin 35 of the Oklahoma Geological Survey correlates the McAlester with the upper part of the Winslow formation and states that in the vicinity of the Arkansas River the McAlester merges with the Winslow.

**Savanna Sandstone**

The Savanna formation is made up of interbedded brown to gray sandstone and shale, which crops out over an area of approximately
15 square miles in the southwestern part of the county in the vicinity of Porum, Oklahoma.

**BOGGY SHALE**

This formation consists almost wholly of shale but includes some thick bedded sandstones and limestones, usually occurring in the upper part of the formation. The Boggy Shale covers an area of approximately 190 square miles in the southwestern part of Muskogee County. According to Aurin, Clark, and Trager, there is an unconformity at the base of the Boggy. The unconformity is also shown by Taff in the Muskogee folio.

**THURMAN SANDSTONE, STUART SHALE, AND SENORA FORMATION**

These formations are found only in the extreme northwestern part of the county where they occupy an area of approximately 28 square miles. The Thurman sandstone varies in texture from coarse conglomeratic to shaly sandstone beds with some interbedded lime. The Stuart Shale is blue to black in color and is found interbedded with thin sandstone strata.

The Senora Formation is brown sandstone which in some localities is thin and shaly, while in others it is thick bedded. Inasmuch as the Thurman sandstone and Stuart Shale are the oldest formations of this group it is possible that they are the only ones which crop out in the county.

**Quaternary**

**PLEISTOCENE**

The terrace deposits and wind-blown dune sand which constitute the Pleistocene consist of unconsolidated sands and gravels. The terrace deposits were probably laid down during a period of time when the elevation of the Arkansas River was considerably higher than its present elevation. These deposits occur as a thin covering overlying the Winslow formation in the SW 1/4 T. 14 N., R. 20 E., NE 1/4 T. 13 N., R. 20 E., NE 1/4 T. 13 N., R. 19 E., and SE 1/4 T. 14 N., R. 19 E. They are also found in the southern part of Muskogee County between Briartown and Porum in T. 10 N., R. 19 E. Here the Pleistocene overlies the Boggy shale, Savanna sandstone, and the McAlester shale, which is probably equivalent to the upper portion of the Winslow formation which occupies a large part of northeastern Muskogee County. (Taff, Muskogee folio No. 132).

**RECENT**

The youngest and most recent deposits are alluvial and are found in the Arkansas River drainage channel. These deposits consist almost wholly of fine sand and silt.

**MUSKOGEE COUNTY**

**STRUCTURE**

Muskogee County can be divided into two parts structurally as well as topographically. The Arkansas River in the county follows approximately the western limit of the Ozark uplift and the eastern edge of the Prairie Plains monocline. In general, it may be said that the formations in Muskogee County dip west and southwestward; however, the prevailing dip may vary locally. In the Ozark uplift area the average dip of the formations is less than 20 feet per mile to the southwest while immediately west of the Ozark uplift the inclination of the beds of the Prairie Plains monocline amounts to 125 feet per mile or more. Farther to the west this dip gradually diminishes.

A fault enters Muskogee County near the NE. cor. sec. 6, T. 15 N., R. 20 E., and extends in a southwest direction. It appears to die out a short distance south of the town of Muskogee. This fault has brought the Winslow formation in contact with the Pitkin limestone and Fayetteville shale. Other faults are known to exist in the southern and northwestern parts of the county. The Seneca fault zone cuts across the northwestern part of the county. These faults have created a very broken structural condition which causes the producing horizons to be found at irregular depths.

Accompanying this report are two cross-sections, one a north and south section "BB", while the other section "AA" extends from the northeast part of the county in a southwesterly direction through the major producing fields to the western edge of the county. These sections, of course, do not reveal the actual structural and sand conditions existing throughout the county. From the study of numerous well logs and formation samples examined, it appears that local sand conditions such as lensing, porosity, thickness, etc., are probably as important a factor in the accumulation of commercial deposits of oil and gas as local structural conditions.

**DEVELOPMENT**

Muskogee County, prior to 1914, held the foremost place among the light oil producing areas of the State. There are only two large fields in Muskogee County, Boynton and Muskogee. Other producing fields are the Beland, Bouch Sand, Brushy Mountain, Butler, Boyle, Cole, Coody, Haskell, Jolly-Patton, Keefton, Link, Peterson, Robinson, Shepard, Somerville, Summers, Terra-Okla., Timber Ridge, Transcontinental, Wainwright, and Yahola. The production map accompanying this report shows the location and extent of these fields. The older fields are now making considerable water with the oil.

**BOYNTON FIELD**

The Boynton field is one of the largest producing areas in Muskogee County. It was opened in May, 1914. The first well was completed by Cameron, et al., in the NE 1/4 section 21. A good gas well was completed a short time later by H. H. Galbraith at a depth of about

1. See maps Nos. XXXI and XXXII in folio.
2. See map No. XXXIII in folio.
1,800 feet in section 19. June 12, 1914, the Merit Oil and Gas Company completed a well in the SE¼ SW¼ NW¼ section 15; the oil sand was found from 1,530 to 1,536 feet which after a 40-quart shot produced 6 barrels. The well was then deepened and 3 million cubic feet of gas was found from 1,570 to 1,590 feet. The Carter Oil Company completed its Simon Morrison in the SW¼ section 15, on August 14, 1914. The Boynton sand, found from 1,520 to 1,560 feet, was shot with 200 quarts and the Leidkecker sand, found from 1,394 to 1,400 feet, was shot with 50 quarts. The initial production was 90 barrels per day. A rig was built on the Cherry lease in June, 1915, by Neely, et al., of the Ma Lou Oil Company in the SW¼ SE¼ NW¼ section 14, one-half mile north of the discovery well. The hole was not started at once as the location did not look very good, but on September 17, 1915, the well was completed as the largest well in the field. After drilling 7 feet of sand, from 1,432 to 1,439 feet the well flowed 85 barrels an hour. It was then deepened to 1,445 feet and flowed 144 barrels the first hour. Cherry No. 2 was completed October 8, 1915, with sand from 1,478 to 1,491 feet and made 800 barrels the first 24 hours. The offset in the SE¼ SW¼ NW¼ section 14 was completed the same day and produced 1,500 barrels from a sand found at 1,441 to 1,464 feet. The Cameron Oil Company, George McIntosh No. 1, in the NW¼ NE¼ SW¼ section 14, a direct offset south of the Neely well, made 70 barrels from 1,458 to 1,478 feet. The offset north of this well was dry in all sands to a depth of 1,765 feet. The last good well drilled in this field was completed in July, 1927.

The structure contour map of the Boynton sand was drawn after the Carter Oil Company map furnished through the courtesy of L. Murray Neumann, Chief Geologist. The Boynton sand is the chief producing horizon although the Leidkecker sand above it has also been very prolific. These sands correlate with the Dutcher series and are found to vary considerably in porosity and productivity. The average thickness is 25 feet. Through the middle of the field the approximate depths of the sands are as follows: The salt sand 300 feet, Booch sand 700 feet, Leidkecker sand at 1,385 feet, and the Boynton sand at 1,530 feet. The Wilcox sand should be found at approximately 2,100 feet and the Turkey Mountain at 2,300 feet in this area. (See Fig. 87).

The average initial production from wells in the Boynton field was from 50 to 150 barrels. Some dry holes and some large producers were drilled as noted above. In 1915 about 7,500 barrels of oil were produced daily but at present the production from this field is about 275 barrels. The gravity of the oil is about 36° and has held fairly constant. There are approximately 150 wells producing and there are 25 to 50 depleted wells which have been plugged. Very little gas has been found in this field. The wells also make a considerable amount of water.
The chief operators in the field are the Carter Oil Company and the Pure Oil Company. Other operators are; the Halcyon Oil Company, Volger and Lightner Petroleum Company, Aiken Oil Company, Gypsy-Margay and Giberson and Decius.

**BELAND FIELD**

The Beland field comprises sections 16, 17, and 18. The first well was drilled by Vin Truman, et al., on the Newbold farm in the SE 1/4 NW 1/4 section 16. It was started in August, 1913, and completed October 18, 1913, to a depth of 1,400 feet. After being shot it produced 10 barrels a day.

Wells in this field have been small although they have held up well. The average initial production was about 20 barrels. However, present the production from this small area amounts to only about 5 barrels daily. Very few wells have been drilled in recent years. Gas wells are now being drilled to the 500-foot sand; the gas is to be used to repressure the oil sand in the depleted area.

In this field the productive sands are the Boynton, found at about 1,370 to 1,400 feet, and a sand found at 1,530 feet; below this, sands found at 1,650 and 1,770 feet were not productive.

Operators in this area are W. B. Pine, Haskoee Oil Company, and W. A. Peterson.

**BOOCH SAND FIELD**

The few wells in the SW 1/4 section 31 are referred to as the Booch Sand field of Muskogee County, and is considered to be the northeast extension of the real Booch Sand field in sec. 1, T. 13 N., R. 14 E., Okmulgee County, and production is obtained by shooting after the wells have been drilled into the sand. The Booch sand is found at about 1,075 feet. At present this area produces about 6 barrels a day.

**BOYLE FIELD**

This field was opened by Philip Boyle, October 25, 1927, when he completed a well in the NE 1/4 SE 1/4 section 8. The productive sand which is believed to be one of the Dutcher sands was found at a depth of 1,617 feet and the well flowed 165 barrels the first 24 hours. The east offset has been completed making some oil and water from the same sand, and the west offset produced 150 barrels initially. Several new locations have been made.

**BRUSHY MOUNTAIN FIELD**

The Brushy Mountain field, located in sections 32 and 33, is chiefly a gas field. The first well was commenced November 27, 1915, and completed February 8, 1916 by M. S. Mussellem in the SE 1/4 section 33 with an initial production of 7 million cubic feet of gas and a rock pressure of 590 pounds. The log of this well is as follows:

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<tr>
<th>Formation</th>
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<tr>
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<tr>
<td>Blue mud</td>
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<td>Lime</td>
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<td>447</td>
</tr>
<tr>
<td>Black slate</td>
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<td>485</td>
</tr>
<tr>
<td>White slate</td>
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<td>555</td>
</tr>
<tr>
<td>White sand</td>
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<tr>
<td>Black slate</td>
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<tr>
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</tbody>
</table>

Wells in this field lasted about a year as they were pulled too hard which resulted in rapid water encroachment. Some of the wells made from 3 to 5 barrels of oil but there being no pipe line to this field they have never been produced.

**MUSKOGEE COUNTY**

$\log$ of M. S. Mussellem well, sec. 33, T. 14 N., R. 19 E.

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<tr>
<th>Formation</th>
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<td>982</td>
</tr>
<tr>
<td>Slate</td>
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<td>994</td>
</tr>
<tr>
<td>Shell</td>
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<tr>
<td>Sand</td>
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<tr>
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<tr>
<td>Sand</td>
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<tr>
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<tr>
<td>Very hard shell</td>
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<td>Sand</td>
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<tr>
<td>Shell, black</td>
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<td>1482</td>
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<tr>
<td>Sand-gas</td>
<td>1482</td>
<td>1477</td>
</tr>
<tr>
<td>Stopped in sand.</td>
<td>1477</td>
<td>1477</td>
</tr>
</tbody>
</table>

The Caney River Gas Company drilled several gas wells in this area before L. C. Butler drilled the first oil well. Some of the gas wells were later deepened to the oil sand.

The discovery well was L. C. Butler, Ross Franklin No. 3, located in the NW 1/4 NE 1/4 NW 1/4 section 30, completed August 15, 1918, producing 100 barrels from a sand found from 1,213 to 1,257 feet. On August 15, 1918, B. G. Goble, Ross Franklin No. 1, was completed in the NE 1/4 NW 1/4 NW 1/4 section 30 as a 20 barrel well. The sand was found from 1,244 to 1,268 feet but was drilled to 1,300 feet. September 27, 1918, L. C. Butler, Ross Franklin No. 4, located in the NE 1/4 NW 1/4 section 30, was completed and produced 100 barrels initially. There was 500,000 cubic feet of gas in a sand found from 860 to 960 feet. B. G. Goble, Ross Franklin No. 3, located in the NW 1/4 SE 1/4 NW 1/4 section 30, was completed October 10, 1918, as a 10 barrel well. The sand was found from 1,255 to 1,263 feet but the well was drilled to a total depth of 1,435 feet.

**BUTLER FIELD**

The Caney River Gas Company drilled several gas wells in this area before L. C. Butler drilled the first oil well. Some of the gas wells were later deepened to the oil sand.

The discovery well was L. C. Butler, Ross Franklin No. 3, located in the NW 1/4 NE 1/4 NW 1/4 section 30, completed August 15, 1918, producing 100 barrels from a sand found from 1,213 to 1,257 feet. On August 15, 1918, B. G. Goble, Ross Franklin No. 1, was completed in the NE 1/4 NW 1/4 NW 1/4 section 30 as a 20 barrel well. The sand was found from 1,244 to 1,268 feet but was drilled to 1,300 feet. September 27, 1918, L. C. Butler, Ross Franklin No. 4, located in the NE 1/4 NW 1/4 section 30, was completed and produced 100 barrels initially. There was 500,000 cubic feet of gas in a sand found from 860 to 960 feet. B. G. Goble, Ross Franklin No. 3, located in the NW 1/4 SE 1/4 NW 1/4 section 30, was completed October 10, 1918, as a 10 barrel well. The sand was found from 1,255 to 1,263 feet but the well was drilled to a total depth of 1,435 feet.
Other operators in this field, besides L. C. Butler, are Dame-Pringle and the Devonian Oil Company. The present production from this area is about 20 barrels a day.

**COLE FIELD**

The first wells drilled in the Cole field were gas wells. M. J. Sullivan, et al., completed their H. Smith No. 1 well in the NW 1/4 NE 1/4 section 10, August 7, 1914, for a big gas well. The sand was found from 1,478 to 1,485 feet. On August 14, 1914, the same company brought in a 20-million cubic foot gas well in the center of the NW 1/4 section 10.

M. J. Sullivan and Litchfield brought in the discovery oil well on the Charles Davis farm in the SW 1/4 NW 1/4 section 11 in the early summer of 1914. The sand was found at 1,610 to 1,630 feet and the initial production was about 300 barrels. The gravity of the oil was 35.4°. Charles Davis No. 2 produced 700 barrels natural from a sand found at 1,593 to 1,621 feet.

The initial production from wells in this area ranged from 40 to 125 barrels. The present production from the pool is about 70 barrels daily.

**COODY FIELD**

This field, located in section 19, was largely drilled by the Coody Oil Company in 1909 and 1910. The first well drilled was a rank wildcat and few people even knew about it until long after it was completed. There are no records available regarding the history of the development of this field. The production from this area is about 10 barrels a day at present. A large part of the production is now owned by the Tidal Oil Company.

**HASKELL FIELD**

The Haskell field is located in sections 29, 30, and 31. The discovery well was drilled by the Fay Drilling Company, contractors for Brown, et al., on the Aggie Lees farm in section 29. The well was completed December 3, 1915, from a sand found from 1,393 to 1,410 feet. The present production from this pool is about 15 barrels a day.

**JOLLY—PATTON FIELD**

This field was discovered in August, 1920, by H. L. Jolly and John Patton. The first well was drilled on the J. L. Compton farm in the NW. cor. of section 8. The sand was found from 662 to 674 feet and produced 150 barrels initially. Following the discovery, 14 wells were completed as producers. Most of the development came in the fall of 1920 as several dry holes were drilled which caused operations to be shut down.

Interest was renewed in April, 1926, when C. M. Bradley and John Heinigman brought in a 150 barrel well on the Riley farm in the SW 1/4 NW 1/4 SW 1/4 section 5. It was drilled to a total depth of 718 feet with 16 feet of Timber Ridge sand. The Muskogee sand overlying the Timber Ridge sand had only a showing of oil in this well while other wells in this area produce from both the Muskogee and Timber Ridge sands. This part of the field is an extension of the original Jolly-Patton field and is locally called the Bradley pool. The Muskogee sand is found at about 675 feet; its average thickness is 12 feet and after a 20 foot break, 10 feet of Timber Ridge sand is found. Riley No. 3 and No. 12 were drilled through the Wilcox sand which showed water. In September, 1927, 16 wells had been drilled but the maximum production was obtained in August, 1927, when 280 barrels of oil were produced daily.

The field was recently extended into section 6 by the discovery of oil in the 500 foot sand. The Hale-Ford Oil Company drilled the discovery well in the SE 1/4 SW 1/4 NW 1/4 section 6 on the N. I. Clark farm. The well was commenced January 30 and completed February 4, 1928, and flowed 150 barrels a day natural of 43° gravity oil. A log of the well follows:

**Hale-Ford Oil Company, N. I. Clark No. 2.**

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<tr>
<th>Formation</th>
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</tr>
</thead>
<tbody>
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<tr>
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<td>518</td>
</tr>
<tr>
<td>Oil sand</td>
<td>518</td>
<td>532</td>
</tr>
</tbody>
</table>

Throughout Muskogee County there appears to be a limestone in the Winslow formation which is used as a marker by drillers, and is found locally at a depth of approximately 400 feet. The producing sand in this area has been found about 100 feet below the top of this lime.

This area has been called "Little Seminole" locally although there is nothing analogous between it and the Seminole fields.

**KEEFETON FIELD**

The Keefetop field is located in section 14, about a mile northwest of the town of Keefetop, and is a gas area. The Herbert Oil Company drilled the discovery well on the Charlie Jordan farm, the well being completed December 24, 1925. The producing sand was found from 748 to 759 feet, and it is estimated that the well produced 12 million cubic feet of gas initially.
LINK FIELD

This field consists of a few wells in sections 32 and 33. The discovery well, located in the SE 1/4 SE 1/4 section 32, was completed June 1, 1927, by the Link Oil Company. The initial production was 90 barrels a day from a sand found from 2,044 to 2,052 feet. The north offset to this well was dry, while the offset east was completed by the Future Oil Company as a 100 barrel well. A well southeast of the discovery well in the NW 1/4 SW 1/4 section 33, is a dry hole. The present production from the area is about 25 barrels a day.

MUSKOGEE FIELD

The accompanying production map will show the approximate area of the Muskogee field which is the oldest and one of the largest in the county. Muskogee townsite was first developed in 1894 by a company drilling for the Cudahy Oil Company at which time small production of light oil resulted but the discovery was not followed up until 1904 because of the difficulty of securing good titles. During that year between 30 and 40 wells were drilled in the southern part of the present townsite, near the Missouri, Kansas, and Texas Railroad tracks. The wells were all small producers of high grade, amber colored oil of 42° gravity. The Muskogee sand was found in these wells at about 1,050 feet. By 1905 the pool had been fairly well tested out and operations began to slacken.

About 1906 the field was extended to the southwest and drilling continued for several years in spite of the spottedness of the production. Practically one-third of all the wells drilled were gas producers; these were irregularly distributed over the field.

During 1913 the Muskogee field produced almost one-half million barrels of oil; now the field is producing about 225 barrels a day. In 1913 the Prairie Pipe Line Company ran 1,500 to 1,600 barrels a day from their leases; now they are running about 21 barrels a day.

The depth of the Muskogee sand, which is the main source of production, varies from about 1,000 feet on the top of the structure to 1,750 on the south side of the field. The Timber Ridge sand is found below the Muskogee with an interval of only a few feet of shale between them. The Wilcox sand should be found from 625 to 675 feet below the top of the Muskogee sand and the Turkey Mountain sand about 200 feet below the Wilcox. The Wilcox in the Gypsy Oil Company Maud Sanders No. 27, located in the NE 1/4 SW 1/4 SW 1/4 sec. 34, T. 15 N., R. 18 E., was found at approximately 1,655 feet, and initially produced 4,552,860 cubic feet of gas with a rock pressure of 750 pounds. Discovery of Wilcox production in this area opens up future possibilities.

The principal operators in this field are: Arthur Oil Company, Gypsy Oil Company, Prairie Oil and Gas Company, Paraffin Oil Company, the Tidal Oil Company, and the Jolly-Ogg Oil Company.

PETROGEE COUNTY

The first well in this pool was a gas well drilled by the Caney River Gas Company. It was brought in July 7, 1916, with an initial production of 30 million cubic feet of gas and a rock pressure of 380 pounds, on the John Howard farm in the NW 1/4 SW 1/4 section 19.

The north offset to the discovery well was the C. L. McMahon Harrison No. 3, located in the SW 1/4 NW 1/4 section 19. It was completed with an initial production of 11 million cubic feet of gas per day from a sand found from 680 to 692 feet. C. L. McMahon well No. 4 in the SE 1/4 NW 1/4 section 19, made 12 million cubic feet of gas from a sand found from 705 to 710 feet and C. L. McMahon No. 6 made 13 million cubic feet of gas from a formation found from 660 to 672 feet.

The first oil well was the C. L. McMahon Nellie Harrison No. 5 located in the center of the NW 1/4 NW 1/4 section 19, in which the sand was found from 1,208 to 1,218 feet and initially produced 10 barrels of oil on February 16, 1917. A 50 barrel well was brought in September 20, 1917, by the Terra-Okla Oil Company in the cen. SW 1/4 section 16. The sand was found from 1,302 to 1,312 feet. The Terra-Okla Oil Company No. 2 in the SW 1/4 SW 1/4 section 16 was completed November 13, 1917, and produced 25 barrels initial production from a sand at 1,307 to 1,315 feet. The largest well in the field was John Harrison No. 3, drilled by Carr Peterson and others in the NE 1/4 SE 1/4 SW 1/4 section 17, which was completed for 930 barrels on March 7, 1918. The sand was found from 1,212 to 1,214 feet.

The present production from this pool is about 50 barrels daily. The operators are: Roxana Petroleum Corporation, Devonian Oil Company, and Carr Peterson.

At the end of two years this well was still producing 150 barrels a day natural but later deepening brought water into the hole which drowned out the oil. The sand was found from 1,323 to 1,343 feet. In a sand Eddie Robinson in the fall of 1914 opened this field by completing a well on the June Jackson farm with an initial production of 750 barrels. This well was located in the cen. SE 1/4 SE 1/4 section 13.

ROBINSON FIELD

from 1,080 to 1,108 feet, 2 million cubic feet of gas was found. Quite a number of wells were drilled around the discovery well but no wells were completed as producers; however, in section 18 the Commercial Land Company drilled two wells which made about 12 barrels each initially from the Muskogee sand found from 1,310 to 1,328 feet. These wells have held up very well. In 1915 De Clark drilled a well in the NE 1/4 NW 1/4 section 19 which was completed for 800 barrels from 1,256 to 1,274 feet. Several other wells have been drilled in this area, the last one being completed in the spring of 1922.

These wells produce 41° to 42° gravity oil with a small amount of water. Sufficient gas is produced with the oil for lease purposes. The Muskogee Oil Corporation is the only operator and is now producing about 5 barrels a day.
SHEPPARD FIELD

The Sheppard field found in sections 11, 12, and 15 was discovered by the Penn-Wyoming Oil Company. This company completed a well on June 7, 1917, in the NW. cor. NE. 34 NW. 34 section 14 on the SI Dan farm. The initial production was 600 barrels of 34.9° gravity oil from a sand found from 1,968 to 1,989 feet. SI Dan No. 3 in the NE. 34 NW. 34 NW. 34 section 14, a direct offset west of the discovery well, made 250 barrels from a sand from 1,940 to 1,960 feet on July 26, 1917. Penn-Wyoming, SI Dan No. 6 produced 100 barrels from a sand found from 1,954 to 1,985 feet. This well was completed December 13, 1918. In the Penn-Wyoming, H. Sandy No. 1, SE. 34 NE. 34 NE. 34 section 15, the sand was found from 1,961 to 1,982 feet, and the well produced 50 barrels the first day.

SOMMERVILLE FIELD

The discovery well was the only oil well in the field. It was drilled by W. R. Sommerville on the E. Warrior farm in the NE. cor. section 17. This well produced 375 barrels, September 9, 1926, but was plugged by January 1, 1928. The sand was found from 1,439 to 1,450 feet. A well completed January 13, 1927, in the SW. 34 NW. 34 NE. 34 section 17, by Sommerville made 2 million cubic feet of gas from a formation found from 1,260 to 1,278 feet and made 50 million cubic feet of gas with a rock pressure of 545 pounds from a sand at 1,433 to 1,434 feet. Jolly-Ogg, Lewis No. 2 in the NW. 34 SW. 34 NW. 34 section 17 was completed February 17, 1927, producing 28.8 million cubic feet of gas with a rock pressure of 450 pounds from a sand found from 1,382 to 1,393 feet. These two wells were the largest in the field. The maximum production of the field reached approximately 100 million cubic feet of gas daily. The operators are: W. R. Sommerville, et al., Jolly-Ogg Oil Company, and H. E. Williams.

SUMMERS FIELD

In the latter part of 1914, W. B. Pine drilled the discovery well in the NE. 34 NW. 34 SW. 34 section 36. The east offset was dry. February 11, 1916, W. B. Pine brought in his Glen Franklin No. 2, a short location south from the discovery well. The sand was found from 1,443 to 1,445 feet and the initial production was 300 barrels. The Pine well in the center of the W. 34 SE. 34 section 35, produced 50 barrels a day for a long time. W. B. Pine, G. Franklin No. 4, located in the NW. 34 SW. 34 section 36 made 400 barrels. W. B. Pine on the Z. Franklin in the SW. 34 NW. 34 section 36 produced 580 barrels from a sand found from 1,456 to 1,477 feet. D. Canada No. 2 in the NE. 34 section 35 was brought in September 6, 1917, with an initial production of 800 barrels. The sand was found from 1,441 to 1,464 feet. This field now produces about 75 barrels a day.

MUSKOGEE COUNTY

TERRA-OKLA FIELD

The Terra-Okla Oil Company completed its V. Sango No. 1 in the NE. 34 SE. 34 section 29 on June 26, 1919; the sand was found from 1,774 to 1,786 feet with an initial production of 200 barrels. The next well to be completed was the Transcontinental Oil Company, E. Sango No. 3 in the NW. 34 NW. 34 section 28, producing 250 barrels on August 9, 1919, from a sand found from 1,744 to 1,754 feet. On the same date the Oklahoma Producers and Refiners Corporation completed its E. Sango No. 1 in the NE. 34 SE. 34 NE. 34 section 29, with an initial production of 75 barrels. The sand was found from 1,747 to 1,756 feet. M. M. Brown drilled a 600 barrel well in the NW. 34 SW. 34 section 28 on the S. Sango farm. This well was completed on September 27, 1919. Link Oil Company, E. Sango No. 4 was a direct offset to this well, being located in the SW. 34 NW. 34 section 28, and was completed October 18, 1919, with an initial production of 1,400 barrels and was the largest well in the field. The sand was found from 1,789 to 1,807 feet. Link Oil Company, E. Sango No. 3, located in the NE. 34 SW. 34 NW. 34 section 28, was completed the same date as a 500 barrel well with the producing sand from 1,773 to 1,795 feet. At 1,768 feet 2 million cubic feet of gas was found.

Most of the development had been completed by the summer of 1920. The gravity of the oil was about 39° A. P. I. The present production from this area is approximately 80 barrels a day. The main operators are the Link Oil Company, Fay Drilling Company, and Culp, et al.

TIMBER RIDGE FIELD

J. B. Schoenfelt drilled the discovery well about January, 1910, on the W. Harjo farm in the SE. 34 section 11. The second well was a gas well drilled by H. Van Smith in the NW. 34 section 13. Development of this field was practically completed by 1912. The initial production of the field was approximately 800 barrels a day but has since declined to about 20 barrels a day. Individual wells produced from 50 to 250 barrels when first completed.

The Bad Hole sand is found from approximately 1,385 to 1,407 feet, the Muskogee sand from about 1,480 to 1,510 feet, and the Timber Ridge sand from about 1,540 to 1,560 feet. A good gas sand is also found from 1,050 to 1,100 feet.

The principal operators in this field are the Prairie Oil and Gas Company and the Tidal Oil Company.

TRANSCONTINENTAL FIELD

This area was discovered by J. S. McCutcheon, who completed B. Fulson No. 1, located in the SE. 34 NE. 34 section 7 for a 75 barrel well October 3, 1918. The sand was found from 1,863 to 1,878 feet. Other good wells were drilled in this pool with an initial production of 50 to 100 barrels each.
WAINWRIGHT FIELD

The discovery well in this area was a gas well. The first oil well was drilled in the SE 1/4 SE 1/4 section 16 by the Bell Oil Company. The sand was found from 1,910 to 1,930 feet and produced 300 to 600 barrels natural. This well was drilled in 1910. Development of the pool immediately followed; three good wells were completed, all of which made over a hundred barrels each. However, present production is very small.

YAHOLA FIELD

April 4, 1918, the Lucky Star completed its Doyle No. 2 in the SW 1/4 NW 1/4 NW 1/4 section 27. This well made 20 barrels from a sand found from 1,605 to 1,675 feet. About 25 producing wells have been drilled in this field, of which approximately half were gas wells. The gas wells produced from 4 to 10 million cubic feet of gas per day when first completed and the oil wells each initially produced 25 to 30 barrels a day.

FUTURE POSSIBILITIES

In the writing of this report very little detailed work has been done in the field or on the correlation of the producing sands. For this reason it is not definitely known how many wells have been drilled to the Wilcox or Turkey Mountain sands, but it is quite certain that these sands have not been thoroughly tested in all parts of the county. There are also several shallow sands which were drilled through hurriedly which had a show of oil but were not shot or thoroughly tested.

It is possible that production throughout the county might be stimulated by repurposing some of the older producing sands or by other methods used for increasing the percentage of recovery from producing formations. It is believed that at least some of the fields herein described are suitable for the installation of such methods, although local sand conditions may be found unsuitable.

COAL AND PITTSBURG COUNTIES

By

W. W. Clawson, Jr.

INTRODUCTION

During 1927 Coal and Pittsburg counties attracted unusual attention from the major oil producing companies. This interest is largely due to the activities of the Indian Territory Illuminating Oil Company, which, at the instigation of R. J. Riggs, has attempted to develop oil or gas production on the Coalgate anticline.

This paper does not contain a thorough treatment of the geology of these counties in all of its phases, but is limited to a discussion of the geology as affecting the oil and gas possibilities of the area.

Figure 88. Index map of Oklahoma showing area covered by Coal and Pittsburg counties.

The geology of the area in southeastern Pittsburg County, which lies south of the Choctaw fault, has not been gone into in detail, since the geological features of this part of the county are typically of the Ouachita Mountain type and have been ably described in previous reports.


(Originally published as Bulletin 40-JJ, November, 1928)
Coal and Pittsburg counties have a combined area of approximately 1,875 square miles and are located in the southeastern part of the State. The northern boundary of Pittsburg County is the South Canadian River.

These counties lie mainly in the western extension of the Arkansas Valley geosyncline. A small area in southeastern Pittsburg County is included in the Ouachita Mountain province.

Coal County drains into the Red River through the various Boggy Creeks and their tributaries. The drainage in Pittsburg County is largely into South Canadian River through Gaines Creek and tributary streams.

The topography in general is rather rugged, with a heavy growth of post oak timber marking the areas of sandstone outcrops. The steeply folded areas are characterized by anticlinal valleys developed in the softer shales and separated by ranges of synclinal hills. Farming is carried on rather extensively in the more accessible areas.

Two main railroads, the Missouri, Kansas and Texas, and the Chicago, Rock Island and Pacific, cross the area and serve the county seat towns of McAlester and Coalgiate in Pittsburg and Coal counties respectively. Three branch line railroads, the K. O. & G., Oklahoma City, Ada & Atoka, and the Oklahoma Central, serve the small towns in western Coal County.

Acknowledgments

In the preparation of this report the literature on this and adjoining areas has been freely consulted and notations to that effect given in the text.

The author wishes to particularly acknowledge the help and suggestions of R. J. Riggs of the Indian Territory Illuminating Oil Company, under whose direction the field work in this area was carried on.

M. K. Jensen, chief draftsman of the Indian Territory Illuminating Oil Company, rendered valuable assistance in the drafting of maps and preparation of illustrations. John Pitts of Ada contributed freely from his intimate knowledge of this part of the State. Thanks are expressed to W. A. Clark, Jr., for the use of his maps on the Quinton-Kinta anticline.

Appreciation is expressed to the management of the Indian Territory Illuminating Oil Company, by whose permission this report is published.

General Features

Stratigraphically the lowest formation occurring at the surface in Coal and Pittsburg counties is the Viola limestone. This limestone outcrops in a small area in southwestern Coal County on the flanks of the Hunton anticline. Next in order of occurrence are the Sylvan shale, Hunton limestone, Woodford chert, Sycamore limestone, and Caney shale, the Caney representing the transitional zone between rocks of Mississippian and Pennsylvanian age. These formations have been studied and described in detail in previous publications, hence further description is omitted from this report.

Wapanucka Limestone

The Wapanucka limestone overlying the Caney shale in southwestern Coal County is a massive white to light brown fossiliferous limestone, locally olitic, and contains varying amounts of chert. This limestone also outcrops in long narrow ridges, repeated by faulting, south of and paralleling the Choctaw fault in southeastern Pittsburg County.

The Wapanucka is the equivalent of the upper part of the Morrow formation of northeastern Oklahoma and was arbitrarily chosen as the lower marker in the preparation of the coverage map (fig. 89.) since it occurs at the approximate horizon of the group of producing sands to the north, known as the Cromwell-Papoose series. It is also the most persistent marker near the base of the Pennsylvanian.

Atoka Formation

The Atoka formation is a series of alternating sandstones and shales ranging in thickness from 3,500 to 7,000 feet, the latter figure being the thickness represented on the Heavener anticline in central LeFlore County. This formation outcrops in broad belts in southwestern Coal and southern Pittsburg counties, and is found in many wells drilled throughout the area. At the outcrop in southeastern Coal County, the Atoka consists of four main sandstone groups separated by beds of brownish clay shales. The sandstones are usually light brown in color and of thin-beded or platy structure. Some of the sands in the Atoka carry gas when found on structure, but to date no commercial oil production has been developed in this formation.

Hartshorne Sandstone

A thin series of sandstones and sandy shales, known as the Hartshorne, occurs as a narrow, sinuous outcrop above the Atoka. The character of this group of beds changes rapidly along the outcrop, massive beds often giving way to thin-beded sands and sandy shales in the distance of one mile. This irregularity of deposition is borne out

by the rapid horizontal changes noted where this formation has been encountered in wells. In Pittsburg County the Hartshorne sometimes contains three beds of sandstone separated by shales. The lower Hartshorne coal lies about 50 feet below the top of the formation and has been mined extensively in the vicinity of McAlester and Wilburton.

The Hartshorne ranges in thickness from 100 to 200 feet and is the main gas producing sand on the Quinton-Kinta anticline in northeastern Pittsburg County.

**McAlester Shale**

The McAlester shale lies directly above the Hartshorne sandstone and has an estimated thickness of from 1,300 feet on the Coalgate anticline to 2,500 feet in southeastern Pittsburg County. It consists principally of bluish gray to black shales, lenticular sandstones and coal beds.

The McAlester is typically exposed along the tops of the Major folds in this area, where it constitutes broad valleys and prairie lands bordered by the precipitous wooded hills of the overlying Savanna sandstone. A characteristic feature of the McAlester is the occurrence of numerous hummocks or low mounds irregularly spaced over the area of outcrop. "These mounds are usually less than 100 feet in diameter and stand on an average of 5 feet above the general level of the flats". In cross-section there is no observable change in the physical character of the shales and the reason for their occurrence has not been fully explained.

The upper Hartshorne coal forms the lower limit of the McAlester. Another workable coal bed known as the Lehigh or McAlester coal occurs near the top of the formation.

**Savanna Sandstone**

As previously stated the Savanna sandstone occurs immediately above the McAlester shale, forming rugged topography heavily timbered with post and scrub oak. The Savanna has been estimated to range in thickness from 1,000 to 1,750 feet. In the vicinity of Coalgate measurements have been made by several different field parties and a thickness of from 1,600 to 1,750 feet was found. Accurate measurement is made difficult if not impossible by the occurrence of strike faults of unknown magnitude and by the indefinite limits of the formation.

**Boggy Shale**

The Boggy shale outcrops in broad rolling, sparsely timbered areas throughout the northern part of Coal and Pittsburg counties. It consists mainly of shale with scattered thin sandstone beds. Impure limestones occur locally near the top of the formation and thin lignitic coal beds are found near the base in northeastern Pittsburg County.

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7. Sanders, C. W., Jr., Personal communication.

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**Correlation Table**

<table>
<thead>
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<th>AGE</th>
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<td>Stream deposits and alluvium</td>
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<td>Jackfork sandstone 3,800 ± Stanley shale 6,100</td>
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*Partly after Ulrich (Oklahoma Geol. Survey, Bull. 45, figs. 3 and 4. 1927.)
OIL AND GAS IN OKLAHOMA

THURMAN SANDSTONE

The Thurman sandstone represents a marked change in deposition from the fine shales and soft sandstones of the underlying Bogggy to the conglomerate and coarse sands at the base of the Thurman. This formation outcrops in a belt of very rugged land, from two to four miles wide in the northern part of Coal and northwestern Pittsburg counties. The dip is normally north and northwest at a rate of approximately 100 feet per mile.

STUART SHALE

The Stuart shale forms a narrow belt of sparsely timbered country in the extreme northern part of Coal County and northwestern Pittsburg County. The formation consists mainly of shale with a few thin sandstone beds.

SEONORA FORMATION

The Senora consists of bluish clay shales, interstratified with sandy shales and sands. It outcrops in a broad belt in northwestern Pittsburg County and southern Hughes County, attaining a maximum thickness of 500 feet. The Senora and the underlying Stuart shale and Thurman sandstone all thicken and become more shaly toward the northeast.

STRUCTURE

Considered structurally, Coal and Pittsburg counties can be divided into two parts; first, the area of steep folding and wavelike structure of the northern Ouachita and adjacent country, and second, the area of more gentle folding on the northwestward dipping monocline in the northern part of these counties. The surface structure of these areas is of a distinctly different type both in magnitude and direction of trends of folding and they will be treated separately in this report. For convenience they are designated as the Coalgate-McAlester and the northern areas.

Coalgate-McAlester Area

The major structural features of the Coalgate-McAlester area, named in order as they occur from north to south are: Canadian anticline, Porum syncline, Enterprise anticline, Cowlington syncline, Kinta anticline, Kiowa syncline, Coalgate anticline, and Lehigh syncline. These folds are all approximately parallel with the Chocktaw fault and are shown in their respective position on the map (Map No. XXXIV). Since the essential features of these folds are very similar, only those which have been studied in detail are described in this paper. Conclusions drawn regarding structural features, sedimentary conditions, and productive possibilities can be applied in general to all similar folds in this area.

COAL AND PITTSBURG COUNTIES

COALGATE ANTICLINE

Detailed mapping of the Coalgate anticline in the vicinity of Coalgate verifies in detail the description of this fold as given in the following paragraph:

This anticline is a peculiar structural feature. From Coalgate southwestward this fold is broad and very obtuse. The strata below the Lehigh coal bear westward around the south end of the Lehigh basin and then northward toward Coalgate. Southwest of Coalgate these beds curve gradually westward and then southwestward into the bogggy swamps of Clear Boggy Creek. The Lehigh coal bed in it's outcrop emphasizes the character of this anticlinal structure more strongly. From Lehigh the strike of the coal bears nearly due north, with low east dip to Coalgate, where it turns abruptly southwestward. One mile northwest of Coalgate this coal rises and is exposed for nearly 8 miles in an elongated dome bearing northeastward. The Lehigh coal and the sandstones and shales for several hundred feet above the coal dip 10° to 15° from the axis of this dome. From a point about 7 miles northeast of Coalgate the rocks upon the axis of the Coalgate anticline pitch rapidly northeastward. This pitch gradually grows less until the anticline is lost as a structural feature in the center of the Kiowa syncline near the west end of the Kiowa hills, southwest of Kiowa.

Three to five miles northwest of the axis of the Coalgate anticline there is a parallel shallow syncline whose axis is nearly parallel to that of the Coalgate. The axis of this syncline rises toward the northeast and the syncline dies out or continues with the Kiowa syncline opposite the northeast end of the Coalgate anticline.

From a wide indistinct fold at the southern border of the quadrangle the Coalgate anticline contracts and pitches toward Coalgate and then rises beyond in an elongated dome-like arch in Coal Creek Valley. Beyond Coal Creek IT pitches rapidly northeastward for 2 miles and then the axial portion becomes nearly level and continues so to near the end of the fold, where it is lost in the south limb of the Kiowa syncline in the McAlester quadrangle. The rocks on the northern side of this arch also have steeper dip than on the southern side. This is especially the case west of Coal Creek.

The map (Map No. XXXV) shows the magnitude and general shape of the portion of this fold in the vicinity of Coalgate and Cairo in Coal County. Approximately 700 to 800 feet of McAlester shale remains on the crest of this anticline, the basal coal bed and underlying Hartshorne sand being found between these depths in several wells drilled near the top of the structure.

SAVANNA ANTICLINE

The axis of the Savanna anticline in Pittsburg County trends in a northeastward direction from the southwestern corner of sec. 18, T. 3 N., R. 13 E., to a point about 2 miles east of the town of Krebs where it joins the McAlester anticline. In Coal County the fold pitches rapidly east and west from an elongated dome-like uplift near the Coal-

Pittsburg County line. Information available from logs of gas wells drilled on this portion of the anticline indicates very steep dips on the flanks of the structure with a possibility of minor faulting in the surface rocks. The steeper dips on the northwest side of the structure are associated with some faulting in the Savanna sandstone.

Shallow wells drilled near the top of this structure encountered gas bearing sands at approximately 400 and 1,300 feet. The sand at 400 feet is doubtless the Hartshorne, as total thickness of the McAlester at this point is about 1,000 feet.

**Chiles Anticline**

Some development has taken place on the Chiles ranch north of the western end of the Savanna anticline. The axis of the structure in this vicinity runs nearly east and west, passing through the cen. S 1/2 sec. 29 and 30, T. 3 N., R. 10 E., and sec. 25 T. 3 N., R. 9 E. The dips are much more gentle in this area than on the Savanna anticline proper, averaging 200 to 250 feet per mile.

Gas was obtained on this structure in the basal Boggy or upper Savanna at depths of approximately 300 feet.

**Kinta Anticline**

The axis of the Kinta anticline runs in a direction about N. 60° E. from a point near the town of Blocker, Pittsburg County, to a point approximately one mile south of Quinton, where it leaves the county, continuing in a more easterly direction and crossing the Fort Smith and Western Railroad at Kinta. This is an asymmetrical fold, dips on the south flank averaging about 7 degrees and those on the north around 11 degrees. The axis of the anticline as shown by subsurface contours on the gas producing sand (Hartshorne), follows very closely that on the surface.

There is between 150 and 200 feet of closure on this structure near Kinta. However, the best gas production is not obtained within this higher portion of the structure, but comes from wells located on the westward plunging dip just south of the axis in secs. 10 and 11, T. 7 N., R. 18 E. Some of the wells in these sections have an initial daily capacity of 30 to 40 million cubic feet of dry gas. This fact together with information obtained locally indicates that sand conditions play an important part in the localization of gas in this area.

**Northern Area**

The structure of the area lying northwest of the steeply folded Coalgate-McAlester region is typically a northwestern dipping monocline with a normal dip of approximately 100 feet per mile. Northward and northwestern plunging noses occur at intervals on this monocline. Closures on the surface are very rare in this area. However, the rapid convergence of the Pennsylvanian sediments toward the northwest might cause noses of the type found here to assume some closure on the lower formations. Emphasis is given to the fact that the structures developed in the upper Boggy and younger formations trend north and northwest, a direction diametrically opposite to that of the folds in the older rocks to the south.

The northwest surface dip in this area is not a reflection of the attitude of the formations in the lower Pennsylvanian and below. The tremendous thickening of the lower Pennsylvanian sediments toward the southeast is shown on the map (fig. 89). Development to the north in Pontotoc, Seminole, and Hughes counties indicate that the lower horizons which are productive there are dipping southeastward in northern Coal County.
CONCLUSIONS REGARDING AGE OF FOLDING

A study of the structure in Coal and Pittsburg counties and the adjacent region to the northwest leads to the conclusion that two periods of deformation differing widely in intensity and direction of forces are represented in this area.

In the writer’s opinion, the large steeply folded structural features typical of the Coalgate-McAlester area and associated with the Ouachita overthrust were well developed by middle or late Boggy time, subsequent folding consisting more of a tilting and gentle warping with compressive forces acting from the northeast and southwest, rather than from the direction of the Ouachita mass to the southeast. A minor oscillation no doubt took place in this area during the deposition of the Boggy as suggested by Morgan in his discussion of the Boggy overlap.

The small Chiles gas structure probably represents the closing effect of this period of deformation, as folds developed in younger rocks have a different trend.

The following observations are suggested as evidence tending to confirm this belief:

1. The sudden termination of the steeply folded structural features near the middle of the Boggy shale. If the sediments above the Boggy were present during the development of the closely folded, wave-like structure typical of the Coalgate-McAlester area, it would be logical to expect a series of more or less parallel folds gradually diminishing in size toward the northwest. This condition is represented farther east where beds younger than Boggy are not involved. However, this does not seem to be the case, since the Savanna anticline, a very closely folded structure, and the McAlester anticline of only slightly less magnitude abruptly terminate this type of folding and the structures developed in the Thurman sandstone and younger beds to the north are of an entirely different nature and follow an almost diametrically opposite trend.

Subsurface studies to the north indicate that some of the larger anticlines extend westward under the cover of upper Boggy and Thurman sediments beyond their limits as discernible on the surface.

2. Rapid change of dip between Savanna and Boggy and again at the base of Thurman sandstone. Field evidence suggests that the sudden decrease in rate as well as change in direction of dip noticeable near the contact of the Boggy shale and Savanna sandstone and again at the base of the Thurman sandstone is not merely a normal flattening but due, in part at least, to deposition on a previously folded surface.

3. Different trend of structures developed in Thurman and younger beds from those in the older rocks to the south. Folding exhibited at the surface in the Thurman sandstone and younger rocks imme-

diately to the north consists of north north and northwestward plunging noses indicating compressive forces from the northeast and southwest and showing very little effect of thrusting from the direction of the Ouachita Mountains.

4. Thin section of Savanna found at Centrahoma and on Chiles anticline. Correlation of well logs shows an unusually small thickness of the Savanna in the gas wells drilled on a small structure near Centrahoma in sec. 34, T. 2 N., R. 9 E., and again on the Chiles ranch in sec. 30, T. 3 N., R. 10 E. The wells drilled at Centrahoma started a considerable distance above the base of the Boggy shale and encountered the McAlester at less than 900 feet after penetrating not more than 500 or 600 feet of Savanna. Similar conditions are found on the Chiles ranch in sec. 30, T. 3 N., R. 10 E. This is taken as evidence of thinning of the section over structure and doubtless will be found to apply to the lower formations as well.

DEVELOPMENT

Coal and Pittsburg counties, up to the present time, have produced some gas but no oil in commercial quantities. The well of the McCraw Oil and Gas Company in the SE 1/4 NE 1/4 NW 1/4 sec. 35, T. 1 N., R. 8 E., Coal County, recently encountered a favorable showing of high gravity oil in a lime formation topped at 1,838 feet and correlated as basal Wapanucka. The production from this well has not been fully tested.

Small gas wells have been drilled on several of the large folds throughout the area and commercial gas production has been obtained on the Kinta anticline near Quinton, Pittsburg County. Wells in the Quinton field yielded as high as 40 million cubic feet per day. The total open flow of the field at the present time is approximately 200,000 cubic feet per day. The Quinton Spelter Company and the towns of Quinton and McAlester are supplied with gas from this field.

Other gas wells drilled throughout these counties have not yielded gas in sufficient quantities to justify transportation to a market and their production has not been utilized.

During 1927 the Indian Territory Illuminating Oil Company of Bartlesville, assembled a large block of acreage on the Coalgate anticline in the northern part of T. 1 N., R. 11 E., and are now preparing to drill a deep test in sec. 10, to test the lower marine horizons.

A well being drilled by Pattison & Phillips on the McDuff farm, cen. NW 1/4 SE 1/4 sec. 32, T. 9 N., R. 16 E., Pittsburg County, has reached a depth of 5,300 feet at the time of writing and is drilling in a white lime topped at 5,268. The section encountered in the lower part of this well indicates that this lime is probably the Kinta. Definite correlation is made difficult by the distance to other wells penetrating these rocks and the changes which may have taken place in that distance. Gas estimated at 15,000,000 cubic feet per day was found in the Cromwell sand at approximately 4,500 feet.
The map (No. XXXIV) shows the location and depths of the scattered tests in Coal and Pittsburg counties and the locations of groups of gas wells by cross-hatching.

Oil and Gas Prospects

Exploration on the large anticlines in Coal and Pittsburg counties has been disappointing from a standpoint of oil production. Gas has been found at various points although the wells in general have been small and the producing area spotted.

The apparent absence of oil in commercial quantities in the Pennsylvanian beds throughout this area has been generally explained on the basis of the carbon ratio theory. It has been suggested, particularly by Tarr, that the finding of gas only may be in part due to the fact that the Pennsylvanian beds are largely non-marine or at least shallow water deposits.

The lower horizons, of more typical marine origin, have not been tested in this area, mainly on account of the depth at which they occur. Consequently their productive possibilities are unknown.

GEOLGY OF HASKELL, LATIMER, LEFLORE, AND SEQUOYAH COUNTIES

By
J. A. Stone and C. L. Cooper

LOCATION

Haskell, Latimer, LeFlore, and Sequoyah counties are located in the southeastern and central-eastern part of the State. The total area of the four counties is 3,719 square miles (Haskell, 616; Latimer, 732; LeFlore, 1,637; Sequoyah, 734).

Figure 90. Index map of Oklahoma showing area covered by Haskell, Latimer, LeFlore and Sequoyah counties.

The four counties, Haskell, Latimer, LeFlore, and Sequoyah, comprise parts of three topographic regions. Southern Latimer and southern LeFlore counties are in the Ouachita Mountain region; northern Latimer and northern LeFlore counties, all of Haskell County, and most of Sequoyah County lie in the sandstone Hills region; the north-central part of Sequoyah County is in the Ozark Plateau region.

ACKNOWLEDGMENTS

The authors have drawn freely from Oklahoma Geological Survey Bulletin 19, Pt. II, for the geology and structure of the four


(Originally published as Bulletin 40-II, August, 1929)
counties contained in this report. Part of the stratigraphy was taken from Oklahoma Geological Survey Bulletin 35.1 Data on development were obtained in a personal canvass of the producers within the counties. Most hearty co-operation was received from Mr. James B. Millar of the LeFlore County Gas and Electric Company on LeFlore and Sequoyah counties, and Mr. L. P. Coblenz of the Quinton Spelter Company, on the Quinton and Kinta gas fields. Valuable information was also given by Judge C. R. Hunt and Mr. Carlton Weaver of Wilburton, Mr. A. A. Ash of Red Oak, and Mr. Robertson, Postmaster of Talihina, on the development in Latimer County.

Much constructive criticism and advice have been given by members of the Oklahoma Geological Survey Staff, Dr. C. W. Honess, Geologist of the Gypsy Oil Company, and Mr. Millar.

**GEOLOGY**

Haskell, Latimer, LeFlore, and Sequoyah counties are covered with formations ranging in age from lower Ordovician to lower Pennsylvanian. These formations will be described very briefly in this report, because they have been described fully in earlier reports in this series, and in other bulletins of the Oklahoma Geological Survey.2

**STRATIGRAPHY**

**SOUTH OF CHOCTAW FAULT**

**STRINGTOWN SHALE**

This formation outcrops in a narrow band paralleling the south side of the Choctaw fault in southern Latimer County. The Stringtown is made of black, bluish, greenish, and white cherts, clay shales, and thin lentils of blue limestone. The age is lower Ordovician.

**TALIHINA CHERT**

This formation outcrops in southeastern Latimer County. It is made up of black, bluish, greenish, and white cherts, cherty shales, and thin lentils of blue limestone near the bottom. The age of the Talihina is Ordovician, Silurian, and Devonian.

**STANLEY SHALE**

This formation is exposed at the surface in the southern part of Latimer and LeFlore counties, south of the Choctaw fault. It is made up of thin-beded, fine-grained, dark-colored, hard sandstones, and blue clay shales and slates. The Stanley also contains a bed of tuff, a layer of cone-in-cone concretions, and a bed of black chert. The age of this formation is Mississippian.


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**HASKELL, LATIMER, LEFLORE, AND SEQUOYAH COUNTIES**

**Correlation Table**

<table>
<thead>
<tr>
<th>AGE</th>
<th>SOUTHEASTERN OKLAHOMA</th>
<th>CENTRAL-EASTERN OKLAHOMA</th>
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<tr>
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<tr>
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<td>Winslow fm. 1050-1100</td>
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<tr>
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<tr>
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<td>Morrow fm. 100-120</td>
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<td>Pitkin ls. 0-80</td>
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<td>Fayetteville sh. 20-200</td>
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<td>Batesville ss.</td>
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</tr>
<tr>
<td>CAMBRIAN</td>
<td>Not exposed</td>
<td>Not exposed</td>
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</table>

**JACKFORK SANDSTONE**

The Jackfork is the mountain-forming formation of southern Latimer and LeFlore counties, south of the Choctaw fault. It is made up of heavy-beded, massive gray sandstones, interbedded with dark shales. The age of the Jackfork is Mississippian.

**CANEY SHALE**

This formation is exposed in various places in southern Latimer and LeFlore counties. It is made up of black shales and slates with limestone lentils, and lighter colored blue and greenish-blue shales with sandy members. The Caney is of upper Mississippian and lower Pennsylvanian in age.

**WAPANUCKA LIMESTONE**

The Wapanucka formation is exposed in southern Latimer County, paralleling the north flank of the Ouachita Mountains. It is com-
posed of light-brown limestones, sometimes oolitic, with cherts, sandstones, and shales. The Wapanucka is lower Pennsylvanian in age.

**ATOKA FORMATION**

The Atoka formation is exposed at the surface in two small areas in Haskell County, and across the central part of Latimer and LeFlore counties north of, and parallel to, and south of, the Choctaw fault. It is made up of beds of shales and sandstones. This formation contains the gas producing sands in the Mansfield (Fort Smith) gas field in Arkansas. It is lower Pennsylvanian in age.

**NORTH OF CHOCTAW FAULT**

**ST. CLAIR MARBLE**

The St. Clair marble is exposed just north of Marble City in northeastern Sequoyah County. It is a pinkish-white, coarsely crystalline rock. This marble has been quarried near Marble City for building stone. It is of Silurian age.

**CHATTANOOGA SHALE**

The Chattanooga outcrops in northern Sequoyah County. It is a black, slaty, bituminous shale, usually non-calcareous. This formation is probably a transition between the Devonian and Mississippian ages.

**BOONE FORMATION**

The Boone shales, limestones, and cherts outcrop in northern Sequoyah County. This formation is Mississippian (Fern Glen to Warsaw) age.

**FAYETTEVILLE SHALE**

There are scattered outcrops of Fayetteville shale near the northwestern corner of Sequoyah County. This is a dark bituminous shale with a few sandstone and limestone lentils. The age of the Fayetteville is upper Mississippian (Chester).

**PITKIN LIMESTONE**

The Pitkin limestone is exposed to the surface in the same areas with the Fayetteville shales, in northwestern Sequoyah County. This formation varies from brown, earthy, shaly limestone, to fine-textured, massive, bluish limestone. Oolitic types are common. It is upper Mississippian in age.

**MORROW FORMATION**

This formation outcrops in the northwestern part of Sequoyah County. The Morrow is made up of sandstones, shales, and lime-

**HASKELL, LATIMER, LEFLORE, AND SEQUOYAH COUNTIES 415**

stones. It is lower Pennsylvanian in age, and correlates with the Wapanucka.

**HARTSHORNE SANDSTONE**

The Hartshorne outcrops in a narrow strip just above the Atoka in Latimer, Haskell, LeFlore, and the south part of Sequoyah counties. This formation consists of sandstones, shales, and coal beds. It is of lower Pennsylvanian age.

**MCALESTER SHALE**

The McAlester outcrops over most of Haskell, the north-central and northeastern parts of Latimer, northwestern and eastern LeFlore, and most of Sequoyah counties. The beds mapped as Winslow in northern Sequoyah County are McAlester. It is made up of shales, with some lenticular sandstones and coal beds. The age of the McAlester is lower Pennsylvanian.

**SAVANNA FORMATION**

This formation is exposed irregularly over areas in Haskell, Latimer, and LeFlore counties, between the McAlester and Boggy shales. It is made up of three massive sandstone beds divided by sandy shales. The age of the Savanna is lower Pennsylvanian.

**BOGGY SHALE**

The Boggy shale forms the surface rocks of west-central and southeastern Haskell County, north-central Latimer County, and the southwestern part of LeFlore County. This formation is made up of great thicknesses of shales with thin sandstone lentils. The age of the Boggy is lower Pennsylvanian.

**ALLUVIUM AND TERRACE DEPOSITS**

The sands and gravels along the streams are of Recent age.

**HASKELL COUNTY**

**Structure**

The relation of the structure to topography is intimate. All of the larger hills or mountains are synclinal, and many of the smaller features are also related to structure. Several folds of importance are found in this county, the general courses of which are in a northeast-southwest direction.

The principal folds named in order as they occur across the county, from the northwest corner to the southeast corner, are as follows: The Forum syncline; the Enterprise anticline, which forks in the eastern part of T. 9 N., R. 19 E.; the Vian anticline; the Kanima
anticline, which bears to the south of Stigler and passes through Kanima, Gans, Muldrow, Rowland, and east to the Arkansas River; the Cowlington syncline, which extends entirely across the county, dividing it into almost equal parts; the Kinta anticline, which comes in at the west side of the county, passes through Kinta and extends northeastward for a distance of 18 miles and is lost near Ironbridge; the Siloam syncline along the south side of Sansbois Creek in the central part of the county; the Milton anticline begins near Lequire and extends past McCurtain, through LeFlore County into Sequoyah County at or near Milton, Redland, Cottonwood, and ends 4 miles southeast of Ft. Smith (SE. cor. 36, T. 11 N., R. 26 E.) to the Arkansas River; and the Sansbois syncline through the southeastern corner in Sansbois Mountain. The axis of the Brazilian anticline passes parallel to the other lines of structure just to the southeast of the corner of the county. (See map No. XXXVII, in pocket.)

Development

Many wells have been drilled in Haskell County, with important production only in the southwestern part.

The east end of the Quinton gas field is in Haskell County, between Quinton and Kinta. The Kinta gas field extends from southwest to northeast of Kinta.

The Quinton Spelter Company of Quinton owns all the production in those fields. They furnish gas for their zinc smelter at Quinton, and for the cities of Quinton, Kinta, Whitefield, and Stigler in Haskell County, and for Featherston, Blocker, and McAlester in Pittsburg County.

Two wells drilled in sec. 4, T. 9 N., R. 18 E., near Brooken, were dry.

A well drilled in SE. ¼ sec. 15, T. 8 N., R. 18 W., was dry.

A well drilled in sec. 4, T. 9 N., R. 20 E., northeast of Whitefield was dry.

A dry hole was drilled in sec. 35, T. 10 N., R. 22 E.

In 1920 a well was drilled in the NW. ¼ SW. ¼ sec. 8, T. 8 N., R. 17 E.

KINTA FIELD

In 1927 an 880,000 cubic foot gasser was drilled in SW. ¼ NE. ¼ SE. ¼ sec. 23, T. 8 N., R. 20 E., at 904 feet. The rock pressure was 260 pounds.

A well drilled in 1927 in NE. ¼ NE. ¼ sec. 24, T. 8 N., R. 20 E., had an initial flow of 304,320 cubic feet of gas at 880 feet. The rock pressure was 265 pounds. The same year a well drilled in NE. ¼ NE. ¼ NW. ¼ sec. 28, T. 8 N., R. 20 E., had an initial flow of 550,000 cubic feet of dry gas at 899 feet, and a rock pressure of 260 pounds.

Two wells, each with an initial capacity of 1,040,000 cubic feet, were drilled in sec. 32, T. 8 N., R. 20 E., in 1926. The rock pressure was 295 pounds. The largest well in the Kinta field was the Quinton Spelter Company's No. 1 Aldridge, in SE. ¼ SW. ¼ sec. 6, T. 7 N., R. 19 E. Its initial flow was 8,922,000 cubic feet of dry gas, at 1,460 feet. The well was completed in August, 1919.

In the Quinton and Kinta gas fields the sand becomes thicker, the production greater, and the rock pressure higher, from east to west. The average rock pressure in the Kinta field is 250 pounds. In the Quinton field, near the Pittsburg-Haskell county line the rock pressure is 530 pounds. Farther west in the Quinton field in Pittsburg County it is 596 pounds.

The Quinton Spelter Company's No. 1 Curry, in sec. 9, T. 7 N., R. 18 W., was estimated at 50,000,000 cubic feet of wet gas. The sand 12 miles west of the Curry well, near Blocker is 325 feet thick. The same company, which owns all the production in the Quinton and Kinta fields, has several producers in the area of the Curry well of 33,000,000 to 40,000,000 cubic feet capacity.

The depth of the gas sand ranges from 771 feet in sec. 32, T. 8 N., R. 20 E., to around 1,740 feet along the Pittsburg-Haskell county line, and to 3,200 feet near Blocker in Pittsburg County.

Summary

Haskell County can be considered as lying entirely in probable gas territory. The general geology and structural conditions are favorable for the finding of gas, with some possibilities for oil.

Several anticlinal folds of importance occur in the county, and many smaller favorable structures may be found by detailed work. It is highly probable that the less prominent structures may prove most productive in this area. The folding has been very intense and deep-seated in some of the large structures and is perhaps too steeply tilted and too much broken to permit the accumulation of oil. It seems, however, that the county may be considered very favorable for the finding of gas. The miscellaneous drilling which has been done in the county has not necessarily condemned the territory for further prospecting and conditions warrant further investigation.

LATIMER COUNTY

Structure

CHOCTAW FAULT

The greatly folded belt of the south half of the county is limited abruptly on the north by a very extensive fault zone. This great displacement is called the Choctaw fault and separates the more gently
folded northwestward-dipping rocks on the northwest side from the overthrust southeastward-dipping older rocks of the southeast side. Instead of this being called a distinct fault it will be better to term the immediate locality of displacement of rocks as a fault zone in which the line of displacement known as the Choctaw fault is the principal line in breaking. There are many minor faults closely associated with the principal displacement. This zone enters the county near the center of the east side and bears west and southwest entirely across the county. The amount of displacement is very great, and in the folded regions on both sides of the main fault line the rocks are steeply folded and contain many minor faults, many of which have no doubt been concealed by intense folding and overthrust faulting. In practically all cases the overthrust is to the north and northwest.

STRUCTURE NORTH OF THE CHOCTAW FAULT

The northern half of the county is much folded and faulted. Most of the stream valleys are anticlinal, and the rough, mountainous regions of massive sandstones comprise the synclinal areas. The dip of the rocks is in most cases steep, and most of the folds are asymmetrical, and in many cases have been broken by overthrust faulting. In addition to being sharply folded and faulted the formations are badly broken throughout the entire region.

The numerous occurrences of asphalt indicate that oil was present at some time in these formations, but this is also proof that the lighter oils have escaped, leaving behind the asphal tic base. It is probable that, on account of the great thicknesses of shales, some of the oil may have been sealed in. However, the chances for successful development are very slight.

The axis of the Cavanal syncline extends from about Panola in the center of the county, eastward north of Red Oak, Denman, and Barton, to the county line. From this point the axis extends in an almost direct northeast direction entirely through LeFlore County. The broad trough of the syncline is marked by a line of abrupt hills and mountains.

The Brazil anticline is a low fold, the axis of which is from 2 to 4 miles to the north of the axis of Cavanal syncline. The same structure extends into LeFlore County, where the axes of the anticline and syncline grow farther apart. From the county line the anticline continues in a northeastward direction until it merges with the Backbone fault and anticline. The entire course of Brazil Creek is approximately on the axis of the structure.

The LeFlore County Oil and Gas Company has some gas production on this anticline, about 4 miles north of Red Oak. The presence of the gas found and the character of the structure indicate that the area along the axis is favorable for prospecting.

HASKELL, LATIMER, LEFLORE, AND SEQUOYAH COUNTIES

The McAlester anticline extends from Pittsburg County into Latimer County for a distance of about 5 miles, where it forks—one branch extending northeast for a distance of about 3 miles—the other branch extending a little south of east for a distance of about 4 miles, where it dies out or enters the Choctaw fault zone about 2 or 3 miles southwest of Wilburton. The fold is not symmetrical, the north slope being much steeper than that on the south. In fact, in places the rocks on the north side are almost vertical.

The Sansbois syncline crosses the northwestern part of the county. It enters the west side of the county in sec. 27, T. 6 N., R. 17 E., and the axis extends in a direct line to the northeast, crossing the county line in sec. 3 T. 7 N., R. 21 E., running a distance of about 25 miles across the county. The syncline is broad and the area embraced in the structure is occupied by the Sansbois Mountains.

Development

The first production in the county was from the Gladys-Belle Oil and Gas Company's well in sec. 10, T. 6 N., R. 21 E., north of Red Oak in 1912. This well furnished gas to Red Oak until 1913 when it caved in and was abandoned. The offset to that well, the Latimer County Oil and Gas Company's Gallagher well, was drilled in 1913, with a good showing of gas. The hole was lost by caving, but gas from the well is still used for heating and lighting the farm house on the property. A second offset to the Gladys-Belle well was drilled later, but the hole was lost because of caving. No casing was used in these three wells.

The P. & F. Petroleum Company drilled a well on the C. R. Hunt farm in SE 1/4 NW 1/4 sec. 7, T. 5 N., R. 18 E., the C. R. Hunt No. 1. It had a showing of oil and gas at 325-328 feet, at 1,160-1,178 feet, and at 1,360-1,315 feet. It also had gas showings of 1,860-2,128 feet, at 2,335-2,800 feet, and at 2,800-3,002 feet. The test was abandoned at 3,600 feet, and the rig moved about 1½ miles southeast, where a dry hole was drilled. If they had moved east along the trend of the anticline there would have been a better chance for production.

There is a gas spring about one-half mile north of the Hunt well which has been known since the early days. It has been used for heat in cooking by soldiers and campers since Civil War days.

A well near Wilburton in sec. 8, T. 5 N., R. 18 E., was drilled below 1,800 feet. It was a dry hole.

Summary

A part of Latimer County is probable oil and gas territory. The rocks of those of the Pennsylvanian area south of the Arkansas River in the northern part of the county. The Ouachita Mountain region
cannot be considered as probable oil and gas territory, although it is possible that some deposits of small extent may be found. The northern part of the county is in the probable oil and gas area. The rocks are the Pennsylvanian shales and sandstones, and the structure is favorable for the accumulation in some localities.

All the structural features in the county are very prominent and the geological formations are readily differentiated. All locations for tests may readily be located from a geological and structural standpoint, and future prospecting in this county should produce some good results.

LEFLORE COUNTY

Structure and Stratigraphy

The structure in this section of the State is more complex than in any other portion. The folding and faulting is more intense south of the Choctaw fault than to the north, due to the large amount of thrusting in the Ouachita uplift. The almost prominent structural features are discussed under separate headings.

Snider's in his report on the geology of east-central Oklahoma has discussed the various structures, and a part of his information is incorporated in the following pages, along with additional data dealing with the structural features of LeFlore County.

CHOCTAW FAULT

The Choctaw fault enters LeFlore County about a mile north-west of the town of LeFlore and extends in an east-southeast direction to Hodgens, paralleling Fourche Maline Creek and Poteau River. From Hodgens it extends northeastward to the Arkansas line. Prospecting for oil and gas in the near vicinity of the Choctaw fault has brought only failures.

The Poteau syncline extends from west of Heavener eastward to the State line and for a considerable distance into Arkansas. West of the end of the mountains the axis of the syncline crosses Kansas City Southern Railway between Heavener and Petros Switch and soon turns a little to the north of west and continues across the southern part of T. 5 N., R. 25 E., and T. 5 N., R. 24 E. The syncline ends in a basin-shaped structure near the west line of the latter township. The chances for the occurrence of oil or gas in the area of this syncline are not very favorable.

The Heavener anticline lies to the north of the western portion of the Poteau syncline. The axis extends eastward along Fourche Maline. From this point eastward the fold rises very rapidly for a distance of about 4 miles and then plunges just as rapidly to a point about 2 miles west of Heavener. The Hartshorne sandstone and coal outcrop around the north side and east end of the anticline and make a pronounced loop to the westward on the south side. The rocks exposed in the anticline belong to the Atoka formation. Measurements across the upturned edges of the rocks indicate that a thickness of 6,000 to 7,000 feet of this formation have been removed from above the axis of the anticline and the bottom of the formation is not yet exposed. The dips from the axis of the Heavener anticline are quite steep. The general dip to the south is about 30° and to the north and east is from 20° to 40°. The steepest dip observed is about 80° mile directly south of Glendale post-office, where there is a dip of about 65° almost directly south. This is very near the axis of the anticline since one-fourth mile to the north there is a dip of 40° to the north. The rocks exposed in the axis of this anticline are the lowest in the entire area under consideration.

More detailed work in the vicinity of Howe and Poteau has changed the structural mapping first done by Taff. It is now known that the Poteau anticline, the structure of the Poteau gas field, is a distinct structure separated from the Hartford anticline running south of Sugarloaf Mountain. The Hartford and Howe structures are really one continuous fold, beginning just east of Howe, and running northeast into Arkansas. The Poteau axis, instead of turning south to join the Howe structure, has a distinct northward curve on both the east and west ends, so that it has the shape of an arc of a circle.

The Hartford anticline has been described by Collier and by Smith and the northward branch by Smith as the Poteau anticline. These names are used in this report and the name Howe will be discontinued for the portion of the Hartford anticline between Howe and Monroe.

As has been said, the east branch of the Howe anticline is known as the Hartford anticline from Hart ford, Arkansas. The Hartford occupies the eroded valley in the McAlester shales so that it is difficult to locate the axis accurately, but it is almost coincident in Oklahoma with the course of Sugarloaf Creek. Farther east, in Arkansas, the Atoka formation is exposed near the axis of this anticline and gas has been produced from sands in the Atoka near Mansfield. A dry hole the Am. Ind. O. & G. Co. No. 6, SW1/4 sec. 19, T. 6 N., R. 27 E., was drilled in 1918 to a depth of 2,916 feet.

The Poteau anticline, referred to above, is found mostly in the south-central part of T. 7 N., R. 26 E., extending only to the center of sec. 19, T. 7 N., R. 27 E. The rocks exposed in the Poteau anti-


cline are those of the McAlester shale. The dip of the rocks away from the axis of the Poteau anticline is not very steep; the dip to the northwest being 3° to 5° and less to the southeast. The highest part of the fold is found just south of the center of sec. 26, T. 7 N., R. 26 E. Gas in considerable quantities has been found in the Hartshorne sandstone on this structure.

The Sugarloaf syncline lies between the Hartford and Poteau anticlines and is named from Sugarloaf Mountain which forms a very conspicuous topographic feature southeast of Poteau. The mountain is composed of the Savanna formation, topped by the Boggy shale. The dip of the rocks into the syncline is low, not exceeding 5° and usually considerably less than that. The strata in the mountains near the axis are practically level. The syncline extends from near the junction of the Hartford and Poteau anticlines northeastward across the State line and for several miles into Arkansas.

The Cavanal syncline is a broad trough which extends from the vicinity of Red Oak eastward and northeastward across the State line and for many miles into Arkansas. Potato Peaks and Cavanal Mountain lie in this syncline.

The Brazil anticline enters LeFlore County from Latimer County, about a mile west of Walls and extends in a northeast direction to about a mile southeast of Bordeaux. The McAlester shale is the lowest formation exposed. There is a dip from 5° to 8° on the southeastern limb of the anticline and from 12° to 18° on the northwestern limb.

The Backbone anticline extends eastward from a point about two miles south of Bokoshe, past Panama and north of east as far as Greenwood, Arkansas. The anticline is faulted for a considerable portion of its length, the beds on the south side of the fault being thrust over younger beds to the north. The Atoka formation is brought to the surface in the axial portion of the anticline, and the Hartshorne sandstone and coal outcrop around it. The dips in both directions from the axis of this anticline (or the fault) are rather steep, ranging from 12° to 20° or even more.

The Bokoshe syncline extends north of east from Bokoshe to Spiro. From Spiro eastward and northeastward to Arkansas River the country is sand-covered and the axis of the syncline cannot be definitely located.

The Lequire anticline, differentiated from Taff's western end of the Milton anticline, begins near the southwest corner of T. 8 N., R. 21 E., runs east just north of Lequire, almost parallel to the range line until it reaches the west line of R. 22 E., from where it trends northeast almost to the town of McCurtain. It ends in an area where the strata is distinctly flat thus forming a saddle between this structure and the Milton anticline. In this flat area the rocks are considerably disturbed and there are several local faults which are shown by the displacement of the coal in the mines, but which are seldom noticeable on the surface.

From McCurtain to Milton the railroad is approximately one-half mile south of the axis of the Milton anticline. At Milton the axis swings somewhat to the north and passes nearly midway between the old and new towns of Bokoshe, and extends northeastward about one-half mile west of the Redbank Creek to the confluence of that stream with Cache Creek, and to the Arkansas.

The Cowlington syncline cuts through the extreme northwestern corner of the county, north of Cowlington, entering from Haskell County and extending into Sequoyah County from LeFlore County. The features of this syncline are discussed in more detail under the heading of "Structure" of Haskell County.

Development

POTEAU-GILMORE FIELD

The Poteau-Gilmore gas field is located about 4 miles east of Poteau in LeFlore County. The field so far developed includes an area of about 15 square miles, secs. 19-36 inclusive, (excepting sec. 31, 32, and 33) T. 7 N., R. 26 E., (Poteau) and secs. 19 and 30, T. 7 N., R. 27 E. (Gilmore).

The surface rocks are the McAlester shale, which varies in thickness throughout the area on account of erosion having removed some of the upper part of the formation. All of the gas wells in the Poteau field are located on or near the axis of the Poteau anticline.

The first well in the Poteau field was finished in August, 1910. The initial flow was 4,500,000 cubic feet of dry gas, with rock pressure of 365 pounds. The well has flowed continually since 1912, and made an average of 469,750 cubic feet per day during 1927. The rock pressure on September 1, 1927 was 88 pounds. The initial capacities of the wells in the Poteau field ranged from 250,000 cubic feet to 8,000,000 cubic feet. The initial rock pressure ranged from 118 to 365 pounds. The main production is from the Hartshorne sandstone in both the upper and lower part. However, wells that produce from the lower sands find little or no gas in the upper part of the formation and vice versa. There is little production from the Atoka formation which is very short lived.

The average daily production of the Poteau field in June, 1929, was 3,431,000 cubic feet from 34 wells. The rock pressure ranged from 52 to 80 pounds, average about 65 pounds. The open flow volume from these wells is estimated at 22,341,000 cubic feet.
The LeFlore County Gas & Electric Company started a deep test in the Poteau field, which was abandoned at 5,000 feet in the Atoka formation, because of losing tools in the hole.

Many industries, such as glass plants, garment factories, and a handle factory have located in Poteau because of the nearby supply of gas piped in from the Poteau, Gilmore, Cameron, and Rock Island fields. Some gas from these fields is piped to Fort Smith, Arkansas. The Poteau gas field is now very well defined, all development for the future being within the proven area. (See fig. 91.)

There are about 25 wells now producing in the Gilmore area. The average daily production of the field in June, 1929, was 931,000 cubic feet from 19 wells. The first producing well in the field was finished in June, 1924, for 2,071,000 cubic feet of dry gas, at 200 pounds rock pressure. It averaged 1,368,985 cubic feet per day during 1927, with rock pressure of 113 pounds. The initial rock pressure ranged from 135 to 293 pounds. The rock pressure in June, 1929, ranged from 83 to 206 pounds.

**Cameron**

The Cameron field occupies secs. 3 and 4, T. 7 N., R. 26 E., and secs. 33, 34, 35, and 36, T. 8 N., R. 26 E. There are now 10 wells producing in this field. The daily average of 10 wells for June, 1929 was 433,000 cubic feet. The first producing well in the field was finished in March, 1923, at a depth of 1,505 feet, with an initial production of 1,243,000 cubic feet, and rock pressure of 355 pounds. Seven producing wells were drilled in this field in 1923 and three in 1924.

**Rock Island**

The Rock Island field occupies sec. 18, T. 8 N., R. 27 E. There are now only three wells producing. In June, 1929, the production of three wells averaged 86,500 cubic feet per day, with an average rock pressure of 115 pounds and an estimated open flow volume of 647,000 cubic feet. The initial rock pressures ranged from 200 pounds to 250 pounds.

The first well in the field was drilled in 1917, to 2,030 feet. The initial flow was 68,000 cubic feet, and rock pressure was 250 pounds.

**Cedars**

The Cedars field is located in sec. 9, T. 9 N., R. 27 E. The first well of this field was finished in 1924, and produces from two horizons. The total depth was 3,419, being the deepest well drilled in LeFlore County up to 1928. The upper sand had an initial flow of 936,000 cubic feet and rock pressure of 240 pounds. The lower
sand had an initial flow of 1,108,000 cubic feet, and rock pressure of 225 pounds.

The other well in NW. 3/4 NW. 1/4 SE. 1/4 sec. 9, T. 9 N., R. 27 E., was finished in April, 1925, for 1,360,000 cubic feet and initial rock pressure of 200 pounds. It was also a deep well, having a total depth of 3,350 feet.

**SPIRO**

The Spiro field is in sec. 8, T. 9 N., R. 25 E. It has four or five producing gas wells making very little gas at the present time. A well drilled in NE. 1/4 NE. 1/4 NE. 1/4 sec. 24, T. 9 N., R. 25 E., in the Bokoshe syncline northeast of Spiro, finished in October, 1926, was dry after several oil and gas showings.

**MISCELLANEOUS DEVELOPMENT**

A well near Bokoshe in sec. 5, T. 8 N., R. 24 E., showed gas but no oil. It was located about one-half mile south of the axis of the Milton anticline.

Near Panama a well was drilled. A show of gas was found, but the well was off structure, being north of the Backbone anticline and fault.

In the southwestern part of the county, south of the Choctaw fault, in the region of Talihina, three wells have been drilled. One well was drilled in the middle of sec. 16, T. 3 N., R. 22 E., 3 miles southeast of Talihina, in 1925. It had an initial flow of 1,250,000 cubic feet of wet gas, with rock pressure of 57 pounds, at 1,180 feet. The gas tested 28 gasoline per 1,000 cubic feet of gas. The hole caved at 1,480 feet and was lost.

A dry hole was drilled one mile west of Talihina near the county line.

C. B. Shaffer drilled a well in sec. 15, T. 5 N., R. 24 E. A show of gas and oil was found in a 90 foot sand at 2,520 to 2,610 feet. The total depth was 3,200 feet. This well was south of the axis of the Heavener anticline.

In 1928, W. G. Twyman drilled a well on the Hartford anticline which was a dry hole, SW. 1/4 NW. 1/4 sec. 21, T. 6 N., 26 E.

In Massard Prairie, 5 miles southeast of Ft. Smith, Arkansas, the gas wells range in depth from 1,312 to 2,845 feet, but not all were productive. The most productive sands are between 1,000 and 2,100 feet. The well varies in capacity from 140,000 to 4,250,000 cubic feet of gas, and show rock pressure from 145 to 280 pounds to the square inch. All of the wells start in or near the Hartshorne sandstone, and the gas is obtained from the Atoka formation.

It is impossible, however, to draw even an approximate conclusion as to possibilities for oil from the dip. In case any wells are drilled for oil, it will be necessary to drill deeper in order to reach the proper horizon, since the rocks dip away from the axis of the anticline 260 to 300 feet to the mile. It will probably be best under such circumstances to drill just a short distance down the dip from the farthermost producing gas well, as it is easily possible where rocks have such a high angle of dip, to begin too near the syncline.

**Summary**

The northern half of LeFlore County, the area north of the Choctaw fault, is considered probable territory for oil and gas. The production so far has been gas, and only a few showings of oil have been reported from the wells drilled in this county. It is thought that many locations along the Heavener, Howe, Poteau, Hartford, Milton, and Backbore anticlines might produce gas. However, the Backbone anticline has been faulted, and the resultant fracturing of the strata may have furnished a means of escape for the gas.

In the region to the south of the Choctaw fault, little is known concerning the prospects for the occurrence of oil and gas in commercial quantities. From the available data at hand the area does not appear to be favorable, because of the severe folding and faulting. The oil and gas, if present in the rocks, would have escaped. The presence of known asphalt deposits in the area indicates that some of the petroleum has escaped. Whether or not it is all gone is a fact which cannot be determined.

**SEQUOYAH COUNTY**

**Structure**

In general, the Pennsylvanian strata lie in a rather low northeasterly dipping monocline. Locally there are variations in this general northwesterly dip. The axis of an anticline extends from a point near the center of sec. 34, T. 12 N., R. 23 E., almost due east of the E. 1/4 cor. sec. 36, T. 12 N., R. 23 E., a distance of 2½ miles. The strata on the south limb of this anticline dip at angles from 10° to 15°. The strata on the north limb of this anticline dip at angles from 8° to 10°.

The axis of an anticline extends from the center of the NE. 1/4 sec. 33, T. 12 N., R. 24 E., northeast to the center of sec. 27, T. 12 N., R. 24 E., where it swings to almost due east and extends to the center of the NE. 1/4 sec. 29, T. 12 N., R. 25 E. The linear extent of the axis of this anticline is approximately 5 miles. The strata on the south limb of this anticline dip at angles from 8° to 10°; those on the north limb from 3° to 5°.
There is a small anticline in T. 11 N., R. 25 E., whose axis extends from a point near the center of the SE. \(\frac{1}{4}\) section 32, northeast to a point near the center of section 27, a distance of 2 miles.

The axis of an anticline extends from a point near the W. \(\frac{3}{4}\) cor. sec. 26, T. 11 N., R. 25 E., northeast to a point about one-fourth mile north of the NE. cor. sec. 20, T. 11 N., R. 26 E., a distance of 4 miles. The strata on the south limb of this anticline dip from 7° to 20°; those on the north limb from 5° to 12°.

It is noteworthy that in all the above anticlines the steeper dips are found on the south limb of the anticline in each case. There may be other anticlinal folds, but the short time given for field work in Sequoyah permitted the mapping of only those noted above.

A fault enters Sequoyah County from Cherokee County at the NE. cor. T. 13 N., R. 23 E., and extends southwest to a point near the center of T. 12 N., R. 22 E., a distance of approximately 15 miles. This fault has brought Silurian, Devonian, and Mississippian strata in contact with Pennsylvanian.

Development

There are a number of locations made, and a wildcat well, Hunt et al., No. 1, SE. cor. NW. \(\frac{1}{4}\) SW. \(\frac{1}{4}\) sec. 12, T. 12 N., R. 23 E., is now (July, 1929) drilling at 900 feet.

Gas was found many years ago in the Vian anticline, a branch of the Enterprise anticline southwest of Vian. The well was the Nigger Creek Oil and Gas Company's No. 1, drilled to a depth of 1,000 feet.

A well was drilled in SW. \(\frac{1}{4}\) SE. \(\frac{1}{4}\) NE. \(\frac{1}{4}\) sec. 5, T. 11 N., R. 24 E., near Sallisaw, which was a dry hole. Another well, just west of that one had some gas.

A well drilled in sec. 19, T. 11 N., R. 26 E., near Muldrow, encountered a gas sand at about 1,200 feet, making half a million cubic feet. It was turned over to the owner of the land who put tubing in it and used the gas.

Three gas wells and one dry hole were drilled in sec. 10, T. 11 N., R. 26 E.

A dry hole was drilled in sec. 23, T. 11 N., R. 25 E.

A dry hole was drilled in SE. \(\frac{1}{4}\) sec. 8, T. 10 N., R. 26 E.

A dry hole was drilled in NW. \(\frac{1}{4}\) NW. \(\frac{1}{4}\) sec. 5, T. 10 N., R. 24 E., about 1/2 miles southwest of Brent.

A well drilled in NE. \(\frac{1}{4}\) NW. \(\frac{1}{4}\) sec. 25, T. 10 N., R. 25 E., by the LeFlore Co. Gas & Electric Co., northeast of the town of Redland was dry. This well was drilled on the Milton anticline, and close to the Arkansas River.

Three gas wells and one dry hole were drilled southeast of Gans in sec. 32, T. 11 N., R. 25 E. Another gas well was drilled in SW. \(\frac{1}{4}\) sec. 33, T. 11 N., R. 25 E.

A well drilled in NW. \(\frac{1}{4}\) sec. 30, T. 12 N., R. 21 E., has gas. This well is just south of Upson, and three miles southwest of Vian, on the Vian anticline.

Gas was found in two wells in sec. 17, T. 10 N., R. 26 E., near the Arkansas River. They were on the Milton anticline.

The Citizens Gas Company's No. 1 Johnson, NE. \(\frac{1}{4}\) SW. \(\frac{1}{4}\) NE. \(\frac{1}{4}\) sec. 33, T. 12 N., R. 27 E., near the Arkansas line, made 1,500,000 cubic feet of gas at 1,215-25 feet and was shut in. Another gas well was drilled just south of this well in the same section.

Summary

All the production to date in Sequoyah County has been gas, found in the eastern part of the county. This puts the county in proved gas territory. There are known anticlines in the county, but the fact that there is faulting within the area, and that the Pennsylvanian rocks may be of comparatively small vertical section has caused some hesitancy in drilling otherwise favorable looking structures.

**FIXED CARBON THEORY**

A discussion of David White's Fixed Carbon Ratio Theory, at this time, may throw some light on the possibilities of gas or oil production in the area south of the Choctaw fault.

In regions where progressive devolitization of organic material has passed a certain point, marked by a fixed carbon content of 65 percent in associated coals, no commercial oil pools are present, nor in formations directly underlying them, but gas may occur.7

The quality of oil and the presence or absence of oil is determined by the amount of heat and pressure by which it has been affected. The quality of coals is also affected by heat and pressure. With an increase of heat and pressure gases and impurities are driven from the coal, leaving a larger percentage of pure carbon. With an increase in the heat and pressure the gases and more liquid parts of oil are driven off. It is easy to see that there should be a close relationship between the effects of heat and pressure on oils and on the associated coals.

The fixed carbon ratio of coals increases with the increase of heat and pressure, as does also the gas content of the oils.

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It has been found that where the amount of pure carbon is 50-60 per cent of the associated coals there was both oil and gas. Where the pure carbon content of the associated coals was 60-65 per cent, there was gas, but no oil. The occurrence of 65-70 per cent of pure carbon in the associated coals establishes a deadline for oil and gas in commercial quantities. This is particularly the case in the Appalachian fields and holds without question in the gas fields of southeastern Oklahoma.¹

In southeastern Oklahoma the Choctaw fault is the deadline. South of the fault there should be neither oil nor gas in commercial quantities. North of the Choctaw fault there might be gas, but no oil. Drilling, up to this date, has shown these conditions of the fixed carbon theory to be true.

¹ Hager, Dorsey, Practical oil geology, McGraw-Hill, p. 21, 1926.

OKFUSKEE COUNTY

By

J. Philip Boyle

This report is written for the purpose of giving in a general way the surface and subsurface geology and its relation to the production of oil and gas in Okfuskee County, Oklahoma.

ACKNOWLEDGMENTS

In compiling this report a large amount of the data used has been obtained from the following individuals and bureaus to whom the writer wishes to express his thanks for their assistance:


TOPOGRAPHY

Okfuskee County is located in the east-central part of the State and covers an area included in Tps. 10-13 N., Rs. 7-12 E., making 16 entire townships and parts of three others. The total area is approximately 617 square miles.

The topography of Okfuskee County is made up of sandstone-capped hills and gently sloping valleys. These hills and valleys lie

Figure 92. Index map of Oklahoma showing area covered by Okfuskee County.
(Originally published as Bulletin 40-KK, August, 1929)
in lines parallel to the strike of the outcropping formations. The hills are the topographical expression of the resistant sandstones and limestones, and the valleys are the expression of the soft clays and shales.

The county is drained by two rivers and their tributary creeks. This drainage is separated by a divide which runs approximately from the northwest corner of T. 12 N., R. 8 E., in a southeasterly direction to a point located in the center of the east line of T. 11 N., R. 11 E. North of this approximate line the drainage flows to the north and empties into the Deep Fork of Canadian River, while to the south of this line the water drains into the North Fork of Canadian River.

The average relief between hills and valleys is approximately 60 feet. The highest point above sea-level in the county is located in sec. 25, T. 12 N., R. 9 E.; and the lowest point is at the point North Fork of Canadian River intersects the county line, sec. 25, T. 10 N., R. 12 E.

**SURFACE GEOLOGY**

The formations exposed in Okfuskee County, with the exception of the Recent sediments along the river bottoms, belong to the Pennsylvanian system of rocks, and range from the Thurman sandstone through the Buck Creek formation. The recent sediments consist of faulting, folding, and settling, unconsolidated silts, gravels, clays, and sands and the Pennsylvanian rocks are made up of loosely consolidated clays, shales, sandstones, and one dolomite. The shales predominate in the section, and the sandstones, second in occurrence, form flat-topped hills with east-facing escarpments.

The direction of the regional dip of the surface formations is to the north and west at the rate of fifty to seventy feet per mile. This dip has been disturbed in every township of the county by local

**CALVIN SANDSTONE**

The Calvin sandstone, occurring just below the Wetumka formation, is made up of sandstone ledges, massive in character, which form high escarpments and a long range of hills. The formation is exposed over an area about five miles wide and 12 miles long in the west half of T. 10 N., R. 12 E., and the east third of T. 10 N., R. 11 E. It is also exposed in an area about one-half mile wide and three miles long in secs. 2, 11, and 14, T. 10 N., R. 12 E. The formation is made up of sandstones, shales, and clays. The sandstones form the prominent hills and the shales the undulating valley floors. The formation has an approximate total thickness of 100 feet, and a normal dip of approximately 5° NW.

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<td>Vamoosa Formation</td>
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*Formed during post-Devonian period of erosion and correlated with the Sylamore sandstone.*
OIL AND GAS IN OKLAHOMA

WETUMKA FORMATION

The Wetumka formation consists chiefly of shales with massive sandstone members. It is exposed along a narrow irregular strip approximately one-half mile wide, forming a valley between the outcrops of the Wewoka formation and the Calvin sandstone running through the center of T. 10 N., R. 11 E., and the southwest corner of T. 11 N., R. 11 E. It has an approximate thickness of 170 feet, and dips about 4° NW.

WEWOKA FORMATION

The Wewoka formation is composed chiefly of well-bedded shales with two sandstone members, one being near the middle of the formation and the other near the base. Both are massive light reddish-brown sandstones, having a variable thickness of 4 to 15 feet. These sandstones form escarpments or long hills, and the intervening shales form broad valleys with more level floors. This formation covers approximately Tps. 10, 11, and 12 N., Rs. 10, 11, and 12 E., the west half of T. 10 N., R. 11 E., and the southeast corner of T. 11 N., R. 10 E. The total thickness of the formation is about 200 feet.

HOLDENVILLE FORMATION

The contact of the Holdenville and Seminole formations is usually more or less marked by the abrupt change from hills to valley floors. The Holdenville is composed of two major sandstone members, one being at approximately the top of the formation, the other midway between the top and the base. These sandstone members are from four to ten feet thick, massive in character and of medium hardness. The shales predominate in thickness and are yellow to light blue-green in color. Topographically the Holdenville formation makes an irregular line of hills formed by the two major sandstone members. The total thickness of the formation is approximately 100 feet.

SEMINOLE FORMATION

The Seminole formation is exposed in a narrow strip from one to two miles wide diagonally from the southwest corner of T. 10 N., R. 9 E., to the northeast corner of T. 13 N., R. 10 E. Its exposure is prominently marked by more or less rugged hills and sharp escarpments generally covered with black-jack vegetation. The formation is composed chiefly of sandstones and conglomerates, with some sandy shales. The sandstone beds, interstratified with the conglomerates, are massive and from 4 to 6 feet thick. The conglomerates, composed of chert and quartz pebbles, range in color from light yellow to dark red. The cementing material contains a high per cent of iron. The clays and shales occurring in this formation are well stratified, blue, red, and yellow in color, and are very sandy in character.

OKFUSKEE COUNTY

Coffeyville formation

The major part of this formation is made up of red, yellow, black and blue-green shales with the exception of one limestone member occurring near the base of the formation which is known as the Checkerboard limestone. There are two sandstone members occurring in the Coffeyville, one near the top and the other near the middle. These sandstones range in thickness from two to eight feet, thickening toward the south. The formation forms most of the good agricultural land in the valleys north and south of Okemah. The total thickness of the formation is approximately 190 feet. Its normal dip is 4½° NW.

The Checkerboard limestone, the lowest member of the Coffeyville, is exposed in a narrow strip running north and south near the little town of New Okfuskee. It has a thickness of approximately three feet, is hard, very fossiliferous, grayish brown in color, and contains cavities filled with limonite which gives it a brown speckled appearance. It forms a low escarpment, usually near the valley floor, and weathers much like a hard sandstone.

NELLIE BLY FORMATION

This formation, directly underlying the Vamoosa, has an approximate thickness of 170 feet. The contact with the Vamoosa is characterized by a noticeable change in color. The loosely stratified clays and shales of a reddish cast change into a more highly indurated shale of yellowish to light bluish green in color.

The formation consists of clays, shales, some massive sandstones, and several lenticular, thinly stratified sandstones. Its most characteristic member, the Hogshooter limestone, occurs at the base. This limestone is approximately 4½ feet thick, weathers yellowish-brown on exposure, but is blue-gray in color on a fresh surface. This limestone is exposed in a narrow strip running two miles west from the town of Okfuskee to Okemah.

VAMOOSA FORMATION

The Vamoosa formation is exposed in the county over an area of two entire townships and parts of three others, the area of exposure being in a north-south direction from near the town of Paden east to the east line of R. 8 E. The formation consists predominantly of clays and shales, with massive sandstones and sandy conglomerates. The formation has an approximate thickness of 370 feet. It has three major sandstone horizons, the upper one of which is a massive cross-bedded sandstone, light red in color, with a thickness of six to fifteen feet. The second major sandstone horizon is about one-third of the way down in the formation and consists of about four feet of
massive yellow sandstone. The most noticeable member of this formation occurs near its base and consists of about thirty feet of inter-stratified massive sandstones and conglomerates. This member forms characteristic escarpments which make hills north and south of the town of Boley. The remainder of the formation beneath this member consists of thinly stratified red clays, sandstone lenses, and vari-colored shales.

**BUCK CREEK FORMATION**

The Buck Creek formation is exposed in this county over a long narrow area from the town of Paden west, and from the north to the south line of the county. This formation has an approximate thickness of 140 feet, and is made up of alternating layers of thin bedded sandstones, clays, and shales, and has a dolomitic crystalline limestone at the base. The sandstones range from one to two feet in thickness and vary in color from a white gray to a very light red on exposure. It usually forms blackjack covered hills along its outcrop.

**RECENT**

These sediments are made up of sands, clays, silts, and muds. They occur along the flood plains and valleys of the two major rivers.

**SUBSURFACE FORMATIONS**

Only those subsurface formations that are important as producing horizons or form important datum planes will be discussed under "Subsurface formations." These formations are described, beginning with the oldest, in the following paragraphs.

**ARBUCKLE LIMESTONE (Siliceous lime)**

This limestone, found over wide areas throughout the Mid-Continent field, has a variable thickness in eastern Oklahoma, as it lies unconformably upon the granite. It also has a wide unconformity at the top and lies directly upon the Reagan sandstone below, where the Reagan is present. The writer has seen several wells drilled through the Arbuckle limestone to the granite without encountering the Reagan. This limestone is Cambro-Or dovician in age and the top of the formation is siliceous in character, sometimes producing oil and gas. The writer does not have any record of wells which have penetrated the Arbuckle limestone to a greater depth than 250 feet in the county.

**SIMPSON FORMATION**

**BURGEN LIMESTONE**

This limestone, consisting of a single limestone member, is found all over the county, and has a thickness of 30 to 70 feet. It represents the lowest limestone member of the Simpson formation in this county, and directly overlies the Burgen sand throughout northeastern Oklahoma. Very few wells have penetrated this limestone.
BURGEN SANDSTONE

The Burgen sand directly underlies the Burgen limestone and usually lies unconformably on the "Siliceous" lime. In some cases a shale is found in the unconformity below this sand. The sand is a member of the Simpson formation and has a thickness of 20 to 60 feet.

TYNER SERIES

This formation, a member of the Simpson, is found throughout the county, and, although not always distinguishable from the Wilcox sand by its color, can be easily identified by its texture. It is productive of both oil and gas, and quite often the wells in this sand are known as Wilcox wells. The top of this formation is represented by fine-grained sand usually of a characteristic light green color. This color is probably due to the presence of a small amount of green shale as this sand usually grades into a sandy green shale near the base. It has a thickness of 50 to 150 feet. It directly overlies the Burgen limestone and the total horizon may be identified and measured from the point from which the Wilcox changes its color from brown to white and green to its contact with this limestone.

WILcox SAND

This sand, a member of the Simpson formation, is found over the entire county. It directly underlies the Viola limestone and directly overlies the Tyner shale. It has a thickness of 50 to 100 feet, and is one of the most productive sands of the county.

VIOLA LIMESTONE

This formation, Ordovician in age, is found throughout the county and is one of the principal datums used by geologists for correlating the different formations of Ordovician age. It is white to gray in color, usually hard, and has a thickness of 20 to 60 feet throughout the county. It directly underlies the following formations: Misener sand, Sylvan shale, Hunton formation, and Chattanooga shale. It is an important caving point in the drilling of wells to the Wilcox sand, as it conformably overlies this sand.

MISENER SAND

This formation, composed of wind blown sand, occurs in scattered areas in the northern and eastern parts of the county. It is usually white in color and very pure. Where present, it lies upon the Viola limestone and directly underlies the Chattanooga shale.

The writer has seen two oil pools producing from this sand where the Misener has the appearance of grading into the Viola. The most productive points are found on top of the dunes while the lower sand areas were filled with water. It is structurally conformable with the top of the Viola limestone, though of basal Mississippian age.

SYLVAN SHALE

This formation, Silurian in age, is found all over the country with the exception of small areas where some well logs do not show it...
and, as a result the exact point of contact and the thickness of the interval is difficult to determine. A cross-section from the north to the south side of the county shows very definitely that the Boone formation was subjected to, not only great structural disturbances, but that it underwent a long period of erosion, which thinned the upper Mississippian interval on the structural highs and left a greater thickness in the structural troughs. Well logs do not show that the lower Mississippi limestone was exposed to erosion, but some logs show the absence over almost half of the Boone section. Erosion was greatest in the southern part of the county due to the less resistant nature of Boone shales, while towards the north there remains almost a total thickness of the Mississippian series as found in southern Creek and Okmulgee counties. The irregular topography of Mississippi lime was covered with shales and sands, which resulted in the leveling of the topography up to the horizon of the Morrow limestone and the deposition of the Deaver and Papoose sands. It follows that in drilling wells through the Mississippian series in the northeastern part of the county some wells, after passing through the Morrow will miss the Papoose sand and will encounter the total Boone section. Other wells, drilled farther south and west, will encounter this sand horizon and after passing through the lower Pennsylvanian shales will encounter the partial Boone section represented by shales and occasional thin limes.

**DUTCHER HORIZON**

Lyons-Quinn, Papoose, Cromwell

This horizon, found over the entire county, varies in thickness from 0 to 100 feet. It often lies directly under the Morrow limestone, but in many cases is separated from the Morrow by a shale break. This sand horizon is often split by lenticular limestones and shales. It is the most productive sand of the county, producing everywhere proper structural conditions are found. It usually conforms to the Morrow limestones where the interval of the Morrow has not been split by shale breaks. Lying below this horizon unconformably upon the Mississippian occurs an irregular interval of lenticular sands, limes and shales. In this interval occur small producing areas and such sands as the Ingram gas sand and others of local nomenclature. These lower sands cannot be correlated accurately with other horizons.

**MORROW FORMATION**

In the northeastern half of the county this formation occurs as a massive limestone, but towards the west and south it separates into thin limestones and is entirely absent in some wells. It is a cap-rock found by the drillers over the Papoose-Cromwell sand, and is the important datum for subsurface geological work on these horizons. This limestone varies from 20 to 140 feet in thickness throughout the county.
The Dutcher is the principal producing sand of the Lyons-Quinn and the Papoose pools. Figure 96 is a contour map showing the structure of this sand in the Papoose field, located in the southern part of the county.

**KINGWOOD SAND (LIME)**

This horizon, just below the Deaner horizon, is usually a limestone, but in areas, like the Deaner pool, the lime becomes sandy. It is a producer of oil and gas though its productive areas throughout the county are very limited. (See fig. 94). This horizon lies directly upon the Fiskin limestone.

**DEANER HORIZON**

This horizon consisting of sands, shales, and limestone occurs just above the Kingwood sand or lime, and varies from 0 to 60 feet in thickness. Its productive areas are found in the northern and eastern parts of the county. The Deaner horizon produces where the sand and structural conditions are conducive to the accumulation of oil and gas. The Deaner pool of T. 11 N., R. 11 E., (see fig. 94) produces from this horizon. In this area almost the entire thickness of this horizon is sand.

**BOOCH SAND (HARTSHORNE)**

This sand is a light producer of both oil and gas throughout the county. It varies from 10 to 60 feet in thickness.

**CHEROKEE FORMATION**

The Cherokee formation directly underlies the Boggy formation, and does not outcrop in the county. The entire formation consists of shales, sandstones, and limestones, which lie unconformably upon the Boone formation. Its variable thickness in the southwestern part of the county is due to the Boone topography, which underwent greater erosion in the southern part of the county. This formation contains several members which are most important from the standpoint of oil and gas production.

**GLENN SAND (Bartlesville)**

The Glenn or Bartlesville sand varies in thickness from 10 to 150 feet throughout the county, sometimes occurring as a sandy shale. It produces oil and gas in scattered areas over the county.

**STRUCTURE**

In Okfuskee County practically every type of surface structure is found, including almost all the gradations of structures from an anticlinal dome to a very slight nose. These structures are, in many instances, oil or gas bearing. The predominant producing type varies from a slight plunging nose to a flat terraced nose, very often carrying one to two closures. There is very little production occurring in the county that is not directly related to surface faulting or folding.

It is often the case that the accumulation of oil on these structures is associated with faulting. The fault closing the terrace or nose is on the northeast side, from which the formations again rise and assume their normal regional dip. Production sometimes occurs between two faults. The faults may be divided into three major zones, both in direction of strike and occurrence; namely, those occurring along the escarpments of the Buck Creek, the Vamoosa, and the Holdenville formations. The strikes of the fault range from N. 20° W. to N. 40° W. Many of the faults grade into folds with depth. The effect of these faults upon oil accumulation is not the same as found in other districts as their strike almost parallels the normal dip of the formations. In Okfuskee County the operator must usually look to the normal side for production.

**DEVELOPMENT**

One of the most important factors controlling the accumulation of oil in the lower Pennsylvanian is the lenticular conditions of the sands, due to both horizontal variation and thickening and thinning. Both the Dutcher (Papoose) and Deaner sands often change to limes and shales in a few feet, resulting in spotted producing areas over the structure. It is typical of the entire county that the high escarpments are mainly synclinal and that the structural highs lie mostly in the valleys.

The following data on the oil and gas development of Okfuskee County was taken largely from Bulletin 40-Q of the Oklahoma Geological Survey.
BEARDEN

COUNTY: Okfuskee.
LOCATION: T. 10 N., R. 9 E.
SURFACE ELEVATION: 750 to 900 feet.
SURFACE FORMATION: Francis formation.
AGE OF SURFACE ROCKS: Pennsylvanian.
STRUCTURE: Surface anticlinal folding.

PRODUCING HORIZONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Thickness</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glenn</td>
<td>3875</td>
<td>5.35 M. cu. ft.</td>
</tr>
<tr>
<td>Souch</td>
<td>2850</td>
<td>gas</td>
</tr>
<tr>
<td>Gilease</td>
<td>3825</td>
<td>gas</td>
</tr>
<tr>
<td>Pappoose</td>
<td>3230</td>
<td>70</td>
</tr>
</tbody>
</table>

CHARACTER OF OIL: Gravity.
CHARACTER OF GAS: Dry. Rock pressure 1,250 lbs.
DATE OF OPENING: 1924.
REMARKS: The Bearden pool is essentially a gas field, although recent deep drilling has made some shows of oil.

CARY POOL

COUNTY: Okfuskee.
LOCATION: NW. cor. E. 1/4 SE. 3/4 sec. 29, T. 12 N., R. 10 E.
SURFACE ELEVATION: 787 feet.
SURFACE FORMATION: Coffeyville.
AGE OF SURFACE ROCKS: Pennsylvanian.
STRUCTURE: Subsurface folds.

PRODUCING HORIZONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Thickness</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gilease</td>
<td>to 2943</td>
<td>13</td>
</tr>
</tbody>
</table>

CHARACTER OF OIL: 37° B.
CHARACTER OF GAS:
DATE OF OPENING: October 1st, 1928.
REMARKS: This pool occurs on a slightly perceptible surface nose, covering about five hundred acres. There are, to date, ten producing wells and four drilling wells.

DEANER—CLEARVIEW

COUNTY: Okfuskee.
LOCATION: T. 11 N., R. 11 E.
SURFACE ELEVATION: 750 to 900 feet.
SURFACE FORMATION: Wewoka formation.
AGE OF SURFACE ROCKS: Pennsylvanian.
STRUCTURE: Anticlinal dome, lenticular sands.

PRODUCING HORIZONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Thickness</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaneer</td>
<td>8735</td>
<td>80</td>
</tr>
<tr>
<td>Lyons</td>
<td>3980</td>
<td>80</td>
</tr>
<tr>
<td>Sylvan</td>
<td>3425</td>
<td>40</td>
</tr>
<tr>
<td>Wilcox</td>
<td>8500-3600</td>
<td>25-190 bbls.</td>
</tr>
</tbody>
</table>

CHARACTER OF OIL: Gravity, 40.9° B.
CHARACTER OF GAS: Wet.
DATE OF OPENING: 1923 (?)
OIL AND GAS IN OKLAHOMA

OKFUSKEE COUNTY

COUNTY: Okfuskee.
LOCATION: T. 11 N., R. 10 E.
SURFACE ELEVATION: 850 feet.
SURFACE FORMATION: Holdenville formation.
AGE OF SURFACE ROCKS: Pennsylvanian.
STRUCTURE: Local folds.

PRODUCING HORIZONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Thickness</th>
<th>Production</th>
<th>Initial Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glenn</td>
<td>2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Booch</td>
<td>2060</td>
<td>50</td>
<td>oil gas 20 bbls.</td>
</tr>
<tr>
<td>Deane</td>
<td>3230</td>
<td>70</td>
<td>oil gas 10-12 M. cu. ft.</td>
</tr>
<tr>
<td>Lyons</td>
<td>3230</td>
<td>70</td>
<td>oil gas 10-33 M. cu. ft.</td>
</tr>
<tr>
<td>Mississippi</td>
<td>3285</td>
<td>show oil</td>
<td></td>
</tr>
<tr>
<td>Chattanooga</td>
<td>3700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hunton</td>
<td>3226</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sylvan</td>
<td>4235</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viola</td>
<td>4335</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilcox</td>
<td>4305</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CHARACTER OF OIL: Gravity.
CHARACTER OF GAS: Dry.
DATE OF OPENING: 1921.

Remarks:

NORTH BALTIMORE

COUNTY: Okfuskee.
LOCATION: T. 12 N., R. 11 E.
SURFACE ELEVATION: 750 to 950 feet.
SURFACE FORMATION: Wewoka formation.
AGE OF SURFACE ROCKS: Pennsylvanian.
STRUCTURE: Subsurface folds and faults.

PRODUCING HORIZONS

<table>
<thead>
<tr>
<th>Depth</th>
<th>Thickness</th>
<th>Production</th>
<th>Initial Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booch</td>
<td>2402</td>
<td>20</td>
<td>gas 1-6 M. cu. ft.</td>
</tr>
<tr>
<td>Deane</td>
<td>2470</td>
<td>40</td>
<td>oil gas 4-11 M. cu. ft.</td>
</tr>
<tr>
<td>Lyons</td>
<td>2610</td>
<td>20</td>
<td>oil 10-300 bbls.</td>
</tr>
<tr>
<td>Hunton</td>
<td>3395</td>
<td>30</td>
<td>oil 50-600 bbls.</td>
</tr>
<tr>
<td>Sylvan</td>
<td>3425</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Viola</td>
<td>3435</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilcox</td>
<td>3480</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CHARACTER OF OIL: Gravity, 37-38.9° B.
CHARACTER OF GAS: Dry.
DATE OF OPENING: 1920.

Remarks: The North Baltimore pool was discovered December, 1920, by the North Baltimore Oil & Gas Association. The well in sec. 13, T. 12 N., R. 11 E., was drilled through several good
gas shows and at a depth of 2,740 feet there was a show of oil but water filled the hole. In May, 1922, the Anglo-Texas Oil Company and the North Baltimore Oil and Gas Association drilled another well in section 13 to the depth of 2,692 feet with an initial production of 200 barrels of oil per day. This well started the development in the eastern part of Okfuskee County.

**OKFUSKEE COUNTY**

**COUNTY:** Okfuskee.

**LOCATION:** T. 13 N., R. 10 E.

**SURFACE ELEVATION:** 700 to 900 feet.

**SURFACE FORMATION:** Coffeyville formation.

**AGE OF SURFACE ROCKS:** Pennsylvanian.

**STRUCTURE:** Noses.

**PRODUCING HORIZONS**

<table>
<thead>
<tr>
<th>HORIZONS</th>
<th>DEPTH</th>
<th>THICKNESS</th>
<th>PRODUCTION</th>
<th>INITIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glenn</td>
<td>2600</td>
<td>175</td>
<td>gas</td>
<td>1-3 M. cu. ft.</td>
</tr>
<tr>
<td>Dutcher</td>
<td>2800</td>
<td>50</td>
<td>oil</td>
<td>50-300 bbls.</td>
</tr>
<tr>
<td>Wilcox</td>
<td>3300</td>
<td></td>
<td></td>
<td>show gas</td>
</tr>
</tbody>
</table>

**CHARACTER OF OIL:** Gravity, 34-39.4° B.

**CHARACTER OF GAS:**

**DATE OF OPENING:** 1917.

**REMARKS:** Development in the Okfuskee area followed the discovery of production in the Youngstown and other adjacent Okmulgee County pools.

**OKFUSKEE**

**COUNTY:** Okfuskee.

**LOCATION:** T. 13 N., R. 10 E.

**SURFACE ELEVATION:** 700 to 900 feet.

**SURFACE FORMATION:** Coffeyville formation.

**AGE OF SURFACE ROCKS:** Pennsylvanian.

**STRUCTURE:** Noses.

**PRODUCING HORIZONS**

<table>
<thead>
<tr>
<th>HORIZONS</th>
<th>DEPTH</th>
<th>THICKNESS</th>
<th>PRODUCTION</th>
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<td>175</td>
<td>gas</td>
<td>1-3 M. cu. ft.</td>
</tr>
<tr>
<td>Dutcher</td>
<td>2800</td>
<td>50</td>
<td>oil</td>
<td>50-300 bbls.</td>
</tr>
<tr>
<td>Wilcox</td>
<td>3300</td>
<td></td>
<td></td>
<td>show gas</td>
</tr>
</tbody>
</table>

**CHARACTER OF OIL:** Gravity, 34-39.4° B.

**CHARACTER OF GAS:**

**DATE OF OPENING:** 1917.

**REMARKS:** Development in the Okfuskee area followed the discovery of production in the Youngstown and other adjacent Okmulgee County pools.

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FUTURE DEVELOPMENT

Although Okfuskee County has seen some very intensive oil and gas development over a period of several years, this development has been confined mostly to the eastern and southern parts of the county. Many small surface structures still exist that have not been thoroughly tested which may prove productive.

The Mississippian horizons such as the Papoose and Cromwell sands in the eastern half of the county are well tested, but as development moves west the horizons of the Pennsylvanian sands, such as the Cromwell series, and the Simpson offer a large area for future development.

Very little Wilcox drilling has been done except along the east county line. When more wells have been drilled in the west half of the county subsurface work will no doubt reveal many Wilcox structures which at present cannot be found by surface indications. All of Okfuskee County is attractive oil and gas territory as has been proved by oil saturation of sands in every township.

JOHNSON AND MURRAY COUNTIES

By

F. A. Melton

Introduction

Johnston and Murray counties largely cover the area of the exposed Arbuckle Mountains, a folded and faulted mountain system in the second cycle of erosion. Due to its location near an important line of north-south travel, the splendid geological sections that are available in the Arbuckle Mountain system have been studied by many investigators. This report, prepared in one month’s time, is therefore largely a compilation of the facts presented elsewhere by other men. In certain areas, however, additional field work was done when occasion demanded.

FORMATIONS AND GEOLOGIC HISTORY

Pre-Cambrian

The pre-Cambrian rocks of the Arbuckle Mountains have been described by Taft and Taylor in considerable detail. They are chiefly granites, basaltic and gabbroic dikes, and rhyolite. Two granites, the Tishomingo and the Troy, have been described, and a third may be revealed by additional work. The Tishomingo is a coarse-grained pink porphyritic granite, the phenocrysts of which are in places two or more

Figure 97. Index map of Oklahoma showing location of Johnston and Murray counties.


(Originally published as Bulletin 40-11, January, 1930).
inches long. At the large quarry southeast of Troy the phenocrysts are very numerous and are more closely packed than in some other localities. The granite used in the construction of the State Capitol Building was taken from this quarry. The Troy granite is likewise pink and fairly coarse-grained but it differs strikingly from the coarser phases of the Tishomingo granite in the absence of large phenocrysts of feldspar. Phenocrysts are in general inconspicuous in this granite. It contains biotite.

A large number of basic dikes cut both of these granites. Their width ranges from less than one inch to 50 feet and more. Many are so fine-grained that they are properly called basalts, while others are slightly coarser and appear to be gabbros in composition. Additional dikes of aplite and porphyritic rhyolite are also found. In the large area of pre-Cambrian rock north and east of Tishomingo a few rhyolite dikes appear to be the latest intrusive rocks present. Two other areas are known, however, where the porphyritic rhyolite is well exposed. These are the East Timbered Hills and West Timbered Hills in the western part of the Arbuckle Mountains. Here the oldest Cambrian formation overlies the rhyolite with a large unconformity. No other igneous rock is present to show the field relations of the rhyolite, but it is a fair supposition that the age is the same as that of the rhyolite dikes in the Tishomingo and Troy granites—that is, late pre-Cambrian.

The oldest overlying sedimentary formation is the Reagan sandstone which, on the basis of fossils, is believed to be upper Cambrian in age. The possibilities cannot then be definitely excluded that the rhyolite and perhaps the basic dikes are early Cambrian in age. But analogy with other areas of pre-clastic-Cambrian rocks points definitely toward a pre-Cambrian age for all the igneous rocks just discussed.

**Cambrian**

**REAGAN SANDSTONE**

The pre-Cambrian igneous rocks of the Arbuckle area were exposed to erosion for a long period of time during which they were reduced to a surface of small relief. The highest hills were probably no more than a few hundreds of feet high. Because of the absence of land plants, which lessened the amount of chemical disintegration, the lower places were probably covered with arkosic material. During upper Cambrian time epicontinental seas invaded the area depositing a basal conglomerate of arkosic and granitic material followed by sandstone. This is the oldest Paleozoic sedimentary formation known in Oklahoma and is called the Reagan sandstone from the village of Reagan ten miles north of Tishomingo, Johnston County, Oklahoma, which has long been considered the type locality. The outcrops here, however, are similar to the other outcrops only in color and quartz content. The Reagan sandstone, due to its glauconitic content, which, in certain beds reaches as much as sixty per cent, is characterized by a green color. A heavy coating of iron oxide on the sand grains gives the sandstone a brown color if the glauconite is not very abundant. The formation is variable both as to the nature of its material and as to thickness, which ranges from a few feet to more than 500 feet. The average is about 300 feet. It outcrops in three separate areas shown by the colored geologic map of Oklahoma published by the U. S. Geological Survey.

The following is a section of the Reagan sandstone exposed in the SW 1/4 sec. 35, T. 1 S., R. 1 E.*

**Section of Reagan sandstone, sec 35, T. 1 S., R. 1 E.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Prismatic sandstones containing lenses of calcarceous material</td>
<td>171.0</td>
</tr>
<tr>
<td>2. Quartzite, very hard resistant rock, pink in color, composed of quartz and feldspar grains</td>
<td>6.0</td>
</tr>
<tr>
<td>3. Coarse conglomerate; this member is made up of rounded and angular boulders of the underlying Colbert Porphyry which range from 12 to 17 inches in diameter with finer quartz, glauconite, etc., filling the interstices. The conglomerate becomes finer toward the top.</td>
<td>2.5-11.2</td>
</tr>
</tbody>
</table>

**Cambro-Ordovician**

The sea which invaded this area late in Cambrian time continued to spread and deepen through the early Ordovician, changing the conditions to such an extent that a great thickness of calcareous and dolomitic beds was deposited.

**ARBUCKLE LIMESTONE**

This great mass of limestone and dolomite rests conformably on the Reagan sandstone and grades from it. The area of its outcrop is a large part of the Arbuckle Mountains, from which it receives its name. In consequence of its thickness and resistance it is the chief formation to support the Arbuckle Mountain penneplane. It was first

thought to be a very consistent limestone 4,000-6,000 feet in thickness but later work has shown it to be largely dolomite in the lower part and almost 8,000 feet thick. Fossils indicate that the lower part is upper Cambrian and the upper part is lower Ordovician (Beekmantown) in age.

Following is a generalized section along U. S. Highway No. 77, between Davis and Springer. 4

**Section of Arbuckle limestone along U. S. Highway north of Springer.**

7. Medium bedded sandy and shaly limestone. This member contains seven thin conglomerates and breccia, algal beds, mud-cracks, worm trails. The uppermost 445 feet contain a large percentage of sand showing shallow water conditions. It contains five relatively thin beds of strongly dolomitic limestones .................................. 3,121

6. Sand, interstratified with limestone. This member contains silicified fossils and a few beds of siliceousoolites .......................................................... 690

5. Massive bedded limestone. There is a large amount of siliceous oolites in this member, also some massive chert nodules. .......................................................... 657

4. Dolomitic limestone. Heavy bedded limestone with sandy dolomite, containing a few beds of sandy dolomite, and numerous fossils. .......................................................... 519

3. Limestone. Numerous thin beds of limestone, interbedded with more massive beds. .......................................................... 639

2. Dolomite and dolomitic limestone. The upper 286 feet of this member is composed of alternating beds of fine-grained dolomite and coarser-grained dolomite, the latter having the appearance of marble, although no evidence of recrystallization is shown. The remainder of the member is composed of thick beds of pure dolomite with thinner beds of dolomitic limestone. About 73 per cent of this member is composed of pure dolomite. .......................................................... 2,258

1. Thin bedded gray to light chocolate limestone. This member rests conformably upon the calcareous portion of the Reagan sandstone. .......................................................... 98

**SIMPSON FORMATION**

The long period of relatively quiet sedimentation, during which the Reagan sandstone and the Arbuckle limestones were deposited, was ended by general warping of the entire region. The greater part of the Arbuckle Mountains was brought above water for a short time. During this short space of time the upper surface of the limestone was locally eroded. This unconformity is evidenced by a small band of oxidized material between the Arbuckle and the Simpson, and the irregular distribution of the basal sandstone. This sandstone is probably

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Johnston and Murray Counties

a beach or near shore deposit made in the valleys of the Arbuckle which were first filled by the invading sea.

Taff 5 gives the following generalized section, which is usually characteristic of the formation in this area:

**Section of Simpson formation on south side of Arbuckle uplift, west of Washita River.**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.</td>
<td>Thin limestone with green shales interstratified. In the lower part the limestone is sub-crystalline, resembling beds lower in the formation, while higher it becomes fine-grained and argillaceous, resembling that of the succeeding Viola formation.</td>
</tr>
<tr>
<td>10.</td>
<td>Sandstone</td>
</tr>
<tr>
<td>9.</td>
<td>Limestones and shales interbedded. Some of the limestones are highly fossiliferous: Orthis tricenaria, O. deflecta, Monticulporoid Bryozoa, highly ornamented cystid plates, and species of Ctenocysta.</td>
</tr>
<tr>
<td>8.</td>
<td>Sandstone</td>
</tr>
<tr>
<td>7.</td>
<td>Shaly limestone. The lower 50 feet are highly fossiliferous, containing Ostracoda with numerous Bryozoa and bases of crinoid column, making a fauna sufficiently peculiar to be easily distinguished.</td>
</tr>
<tr>
<td>6.</td>
<td>Sandstone</td>
</tr>
<tr>
<td>5.</td>
<td>Thin bedded limestone and shale interstratified. Contains fossils in great abundance, chiefly Ostracoda; large and small species and numerous brachiopods, gastropods, pelecypods, and trilobites.</td>
</tr>
<tr>
<td>4.</td>
<td>Greenish shales with a few thin limestone layers and thin sandstone.</td>
</tr>
<tr>
<td>3.</td>
<td>Granular crystalline limestone in thin beds. Contains an abundance of Ostracoda (Leperditia chiefly) and other fossils.</td>
</tr>
<tr>
<td>2.</td>
<td>Thin limestone and shales interstratified with occasional thin sandstone.</td>
</tr>
<tr>
<td>1.</td>
<td>White to light brown sandstone, occurring locally.</td>
</tr>
</tbody>
</table>

The Simpson is correlated with the Black River, Upper Stones River, and Chazy formations of Ordovician age. It is exposed around the edge of the Arbuckle limestone. On the south side of the mountains the thickness varies from 2,000-2,400 feet. On the north side it is much thinner, averaging about 1,250 feet.

**VIOLA LIMESTONE**

The Viola limestone is 500-700 feet in thickness. As it is more resistant to weathering than either the preceding or the succeeding formations it outcrops usually in long narrow ridges or rounded hills. The limestone appears massive in fresh exposures, but upon weathering the beds are seldom more than one foot in thickness. No dolomite has been found. A division into three members has been made on the
basis of the fossil content. There is a gradual transition from the upper part of the Simpson up into the basal portion of the formation. The lowest member never exceeds 100 feet in thickness and in places is much less. It consists of light colored, coarse-textured, and usually roughly bedded limestone containing some nodular chert. The fossil content correlates this division with the latest Black River and earliest Trenton.

The middle member has a thickness of approximately 300 feet. It is composed of a white to light-blue, thin-bedded limestone. There are two zones near the base that contain an abundance of graptolites, and a third zone near the top that contains numerous trilobites belonging to the genus *Trinucleus*. These fossils indicate that the middle member beds were deposited during the last half of Trenton time.

The highest member resembles the lowest in physical characteristics. The limestone at the top is more crystalline and usually lighter in color, being light gray and occasionally pink. This member is approximately 300 feet in thickness, but only in the upper 25 feet is it abundantly fossiliferous. It contains the same fauna that occurs in the Fernvale formation farther north and east.

Slurian

**SYLVAN SHALE**

This formation is found in narrow timbered valleys between the Viola and Chimneyhill limestones. The shale varies in thickness from 60-300 feet. It is thinner in the eastern than in the western part of the mountains. The basal portion of the formation is a greenish-gray to nearly black, calcareous, bituminous shale, which weathers on exposure to blocks and fissile plates. It contains an abundance of graptolites and shells which are upper Ordovician in age. The middle and upper portions are composed of soft, greenish, fissile shales, which weather easily to a fine soft earth.

**Section of Chimneyhill limestone.**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Min.</th>
<th>Max.</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Oolitic member; limestone which for the most part is composed of calcareous oolites. In a few places where bands and stringers of chert appear, the oolites are siliceous.</td>
<td>0</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>2.</td>
<td>Glauconitic member; white to gray, granular to crystalline, limestone containing disseminated grains of green glauconite.</td>
<td>0</td>
<td>26</td>
<td>15</td>
</tr>
<tr>
<td>3.</td>
<td>Pink Crinoidal member; thin-bedded, compact, earthy to crystalline limestone with numerous crinoidal fragments, which are stained pink by infiltrated iron.</td>
<td>9</td>
<td>39</td>
<td>15</td>
</tr>
<tr>
<td>4.</td>
<td>Blue to gray limestone</td>
<td>25</td>
<td>44</td>
<td>30</td>
</tr>
<tr>
<td>5.</td>
<td>Shale and shaly limestone</td>
<td>10</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>6.</td>
<td>Limestone</td>
<td>10</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>7.</td>
<td>Shale</td>
<td>15</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>8.</td>
<td>Limestone</td>
<td>12</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>9.</td>
<td>Shale</td>
<td>7</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>10.</td>
<td>Limestone</td>
<td>4</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>11.</td>
<td>Shale</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>12.</td>
<td>Limestone</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

This formation is thought to be of Niagara age on the basis of the contained fossils.

**Devonian**

**HARAGAN SHALE**

The Haragan shale is composed of alternating bluish and gray shales and thin-bedded earthy limestones topped by a 0-18-foot bed of

hard, fine-grained limestone containing a few chert nodules. The beds weather to a yellowish color on long exposure. The formation varies in thickness from 0.166 feet, but on the average is near 100 feet thick. The fossils indicate a lower Devonian age (Helderbergian).

BOIS D'ARC LIMESTONE

The Bois d'Arc limestone is the upper part of the Hunton formation, defined by Taff in 1902. It varies in thickness from 0.90 feet and averages 60 feet. It is composed of thin-bedded, bluish to white, crystalline limestones. In the Cool Creek and Goose Creek regions a 6-foot bed of yellowish shale occurs near the middle. In places the limestone is overlain by several feet of cherty limestone which weathers into angular boulders. The age is Oriskany.

WOODFORD CHERT

This formation has been commonly considered upper Devonian in age but it may eventually be called early Mississippian. The Woodford chert has an average thickness of 250-450 feet in the Arbuckle Mountains. It seems to thin to the north, as Morgan did not find outcrops in the Stonewall quadrangle with a greater thickness than 350 feet. It varies somewhat in lithologic character. In places massive chert beds rest directly on the Bois d'Arc, while in others a brownish black shale is found. As a whole it is composed of this strata of dark chert, cherty shale, and black bituminous shale; the chert being more abundant in the lower and middle portions. In the western part of the region bluish shales are interstratified with the black shales near the base. At places, especially in the chert beds, numerous small round, marble-like, calcareous concretions are found. Occasionally, however, they occur as elongate bodies as much as a foot in diameter. Marine fossils are present but rather scarce.

The Woodford outcrops in the southern part of the region in irregular valleys between ridges of Bois d'Arc and Sycamore limestone. Where the Sycamore is absent it occurs as rough, woodland slopes bordering the ridge of Bois d'Arc.

It correlates approximately with the Chattanooga shale of doubtful Devonian-Mississippian age farther east.

MISSISSIPPIAN

SYCAMORE LIMESTONE

The Sycamore formation is a lenticular or wedge-shaped mass of siliceous limestone occurring above the Woodford chert and below the Caney shale. It varies in thickness from 100 feet in the western part of the region to less than five feet in the Stonewall quadrangle, pinching out entirely farther east. The limestone varies in color from slate-blue to bluish-brown when fresh; on weathering it changes to a brownish-yellow color due to inclusions of small amounts of iron. It is a dense, even textured, tough limestone which often breaks with a conchoidal fracture. The bedding of the formation causes the rock to separate into layers six inches to two feet in thickness. Often there is a distinct shale break six to twenty feet in thickness almost in the center of the limestone. The age, which is doubtful, is probably lower Mississippian (Kinderhook).

CANEY SHALE

The Caney shale" rests unconformably upon the Sycamore limestone and the Woodford chert. The Caney, as defined, includes about 2,000 feet of black, bituminous, fissile shales containing ferruginous, calcareous, and phosphatic concretions. The upper part of the formation is generally lighter in color, being composed of bluish shales. Fossils are fairly numerous in the lower 200-500 feet of the formation, where they are believed to be of late Mississippian age. The upper part may be Pennsylvanian. The Caney outcrops in fertile lowland belts of cultivated fields and grassy pastures at the south foot of the Arbuckle Mountains in Johnston County and at the east end of the Arbuckle Mountains in eastern Johnston County.

Section of Springer formation.

<table>
<thead>
<tr>
<th>Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Primrose member, calcareous, hard, semi-crystalline, thin-bedded sandstone with numerous shale partings 150-250</td>
</tr>
<tr>
<td>6. Shale. ........................................ 250-500</td>
</tr>
<tr>
<td>5. Lake Ardmore sandstone ................................... 15-30</td>
</tr>
<tr>
<td>4. Lake Ardmore sandstone ................................... 500</td>
</tr>
<tr>
<td>3. Overbrook sandstone. Medium fine grained white and massive, asphaltic sandstone, practically free from shale partings ............... 45-100</td>
</tr>
<tr>
<td>2. Shale ............................................... 1,000</td>
</tr>
<tr>
<td>1. Rod Club member. Sandy zone containing four or more lodges of sandstone 2.25 feet in thickness, greenish to buff in color, and fine-to medium-grained in texture. .......................... 250-400</td>
</tr>
</tbody>
</table>

CANEY SHALE

The Pennsylvanian of the Ardmore Basin

SPRINGER FORMATION

The Springer" is composed of 3,000 to 3,500 feet of black shales, very similar to the Caney, except for the presence of several persistent

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sandstone members. Diagnostic fossils are scarce, but a small collection made from a sandstone near the middle of the formation indicates early Pennsylvanian (Morrow) age. This formation is the lowest subdivision of the Glenn formation as defined by Taff in 1903. It is further subdivided as shown in the table on page 459.

**Dornick Hills Formation**

The Dornick Hills formation is composed of a series of bluish, tan, and rarer, reddish and brown shales, with limestones, limestone conglomerates, and sandstones, 1,500-4,000 feet in thickness. It is subdivided as follows:

**Section of Dornick Hills formation.**

<table>
<thead>
<tr>
<th></th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pumpkin Creek Member</strong></td>
<td></td>
</tr>
<tr>
<td>9. Coarsely granular, cross-bedded, sandy gray limestone interbedded locally with shale.</td>
<td>70</td>
</tr>
<tr>
<td>8. Shale containing interbedded fissile limestone</td>
<td>1,000</td>
</tr>
<tr>
<td><strong>Lester Limestone Member</strong></td>
<td></td>
</tr>
<tr>
<td>7. White, coarsely crystalline, fissile limestone.</td>
<td>20</td>
</tr>
<tr>
<td>6. Shale.</td>
<td>400-1,000</td>
</tr>
<tr>
<td><strong>Bostwick Member</strong></td>
<td></td>
</tr>
<tr>
<td>5. Massive limestone conglomerate, with associated limestone and sandstone. May correlate with the conglomerate mapped as Franks in Mill Creek.</td>
<td>0-300</td>
</tr>
<tr>
<td>4. Shale.</td>
<td>750</td>
</tr>
<tr>
<td><strong>Ontelville Limestone</strong></td>
<td></td>
</tr>
<tr>
<td>3. Ledge of ferruginous, oolitic, locally conglomeratic limestone.</td>
<td>25</td>
</tr>
<tr>
<td>2. Shale.</td>
<td>300-4,000</td>
</tr>
<tr>
<td><strong>Jolliett</strong></td>
<td></td>
</tr>
<tr>
<td>1. Tan, fissile limestone, locally associated with a little conglomerate at the base.</td>
<td>4-15</td>
</tr>
</tbody>
</table>

**Deese Formation**

The Deese formation northwest of Ardmore is composed of about 6,000 feet of sandstone beds and chert conglomerate separated by blue, tan, and red shales with a few limestone members. About 800 feet above the base is the Devil's Kitchen member some 500 feet thick and composed of two massive buff sandstones separated by a shale interval containing approximately ten feet of fissile limestone and impure calcareous shale. The Arnold member near the middle of the Deese formation contains a bed of fissile limestone and a massive buff sandstone, each about fifty feet thick and separated by about 50 feet of shale. The sandstones are locally saturated with asphalt.

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**HOXBAR FORMATION**

The Hoxbar formation comprises about 4,000 feet of shales interbedded with limestone and sandstones. At the top it is overlain with a profound unconformity by the Pontotoc formation and by the Trinity sandstone. It has been subdivided into several members which are not of great importance in the discussion of Murray and Johnston counties.

**Pennsylvanian East and North of the Mountains**

**Wapanucka Limestone**

The Wapanucka formation outcrops near the town of Wapanucka in northeastern Johnston County. Because of its more resistant character it forms long narrow ridges between the shale valleys on either side. In the type locality it conformably overlaps the Caney shale, although evidences of unconformities have been found elsewhere. The formation consists of one or more beds of massive white to light brown limestone, which is oolitic in places, together with chert, sandstone, and shale strata. The formation varies in thickness from 100-800 feet with an average thickness of 300 feet. In this area, however, the thickness is seldom more than 100 feet. It is early Pennsylvanian in age.

**Section in sec. 22, T. 2 S., R. 8 E.**

<table>
<thead>
<tr>
<th></th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Oolite</td>
<td>5</td>
</tr>
<tr>
<td>6. Massive, light brown limestone</td>
<td>25</td>
</tr>
<tr>
<td>5. Ferruginous sandstone</td>
<td>10</td>
</tr>
<tr>
<td>4. Fissile limestone</td>
<td>10</td>
</tr>
<tr>
<td>3. Brown sandstone</td>
<td>5</td>
</tr>
<tr>
<td>2. Hard limestone</td>
<td>7</td>
</tr>
<tr>
<td>1. Shale to base</td>
<td>1</td>
</tr>
</tbody>
</table>

**ATOKA FORMATION**

The shale member of the basal Atoka succeeds abruptly the limestone of the Wapanucka at the eastern side of the Arbuckle Mountains. The formation as a whole has an estimated thickness of 3,000 feet, but is much thinner in Johnston County. The Atoka is composed of very thick shale members which outcrop as broad valleys and which are separated by the narrow, prominent ridges of sandstone. The sandstone which occurs as lentils is ferruginous, massive, and in places conglomeratic. The shales are dark blue to black clays weathering to shades of blue and yellow. The Atoka is early Pennsylvanian (Pottsville) in age.

**Pennsylvanian-Permian**

**Pontotoc Formation**

This formation is far above the Atoka formation, just considered,
in stratigraphic position. The intermediate beds of Pennsylvanian age, however, are not exposed in the area covered by this report.

By late Pennsylvanian time the strata of this region had been folded into approximately their present attitudes and marked relative uplift had occurred stimulating erosion. As a result of this uplift and rapid erosion the beds of the Pontotoc formation were deposited around the mountains. They rest with a profound unconformity on all older strata found in the main mass of the Arbuckle Mountains down to and including the Reagan sandstone of middle Cambrian age. The Pontotoc is subdivided into the following units in Pontotoc County near the north end of the mountains. Elsewhere the Pontotoc has not yet been satisfactorily subdivided.

**Vanoss Formation**

The Vanoss formation is composed of alternating sandstones, conglomerates, shales, and a few thin limestones. It is characterized by its arkosic nature, some of the sandstones being so much so that they resemble granite. The shales are usually green or gray, although occasionally red ones are found. A bed of conglomerate resembling that found in the Vanoss on the north side of the Arbuckle Mountains has been traced around the western extension of the mountains to the south side where it is covered by younger formations. The thickness on the north side of the mountains (in the Stonewall quadrangle) varies from 250-650 feet, the formation thinning to the north. On slight fossil evidence the Vanoss is thought to be uppermost Pennsylvanian in age.

**Stratford Formation**

The Stratford formation may be divided into two members. The basal one, named the Hart limestone, consists of grayish white, chalky to hard, possibly reworked limestone, interbedded with and grading into red shales and gray arkosic sandstones. Where the limestone is in contact with the shale it has a cellular structure which is probably due to a chemical precipitate in the veins of the shale from percolating calcareous waters.

The upper part of the formation consists predominantly of red shales with a few beds of brown to gray arkosic material, limestone nodules, and beds of limestone. The Hart limestone has been traced entirely around the western end of the Arbuckle Mountains, but the shale has been overlapped in places by the succeeding formation. The exposed thickness in the Stonewall quadrangle is about 400 feet.

**Konawa Formation**

The Konawa formation consists of typically red shales and sandstones with no limestones. This formation may be a northern grade-

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**Comanchean**

The Comanchean rocks of Johnston County lie unconformably upon the pre-Cambrian igneous and the Paleozoic sedimentary rocks. After the formation of the Arbuckle Mountains in Pennsylvanian time and after the deposition of the Permian strata on its flanks, erosion continued uninteruptedly during most of Triassic and Jurassic time. The erosion was so great that this entire area, and in fact most of eastern North America, was reduced to a peneplane. In the Arbuckle Mountains the maximum relief was probably no more than a few tens of feet. Toward the end of the Jurassic period this peneplane was slightly tilted. The Comanchean sea advanced over the land from the southeast and deposited sediments in a nearly horizontal position on the upturned and eroded edges of the older rocks. They have remained in their nearly horizontal position to this time, having been only slightly tilted. These beds dip gently to the southeast. Their uniform slope is interrupted by only a few minor folds in the area covered by this report.

**Trinity Sandstone**

The Trinity sand is the beach or near shore deposit of the Comanchean sea which encroached upon the land from the southeast. The lower part of the formation, from the vicinity of Ravia eastward to the border of the county where it rests upon the granite, is composed of sand which has been produced from the granite. Westward from Ravia, where the lower part approaches the limestone formations of the Arbuckle Mountains, it is composed of a very coarse limestone conglomerate. Above the basal conglomerate is 300-400 feet of fine, white to yellow pack sand with lenses of clay. The clays are variable in thickness from a few inches to 30 feet and vary widely in color. Occasionally a few thin beds of oyster shells are found though parts of the formation contain silicified and carbonized wood.

The Trinity sand outcrops in southern Johnston County as gentle, forest-covered slopes.
GOODLAND LIMESTONE

The Goodland limestone lies conformably above the Trinity sandstone. It is a white, semi-crystalline limestone about 25 feet in thickness. The beds at the base where they are in contact with the Trinity sand are somewhat siliceous. In the middle the limestone is massive. At the top it is thinner bedded and passes by transition into the overlying clay shales. Marine shells are rather abundant in the limestone. The shell substance, however, has been very largely replaced by crystalline lime.

The Goodland limestone outcrops as a bluff or escarpment projecting above the friable, underlying Trinity sand which is easily eroded. Soft shales follow above, which are also easily eroded, leaving exposed broad flat tablelands of the limestone. The limestone weathers by solution into irregular boulders or slabs.

KIAMICHI FORMATION

Upon the Goodland limestone are platy layers of siliceous limestone interbedded with thin layers of shaly marl. These transition beds are only a few feet in thickness and are not usually well exposed in the flat lands above the resistant Goodland limestone. About 30 feet of blue marl succeeds the basal shaly strata. The top of the formation is marked by two or three thin ledges of yellowish limestones made up principally of oyster shells.

The Kiamichi outcrops on the slopes above the Goodland escarpment, or on the sides of hills capped by the lower Duck Creek limestone. Since the Kiamichi lies between two escarpment-forming limestones, its outcrop is narrow and tortuous.

DUCK CREEK FORMATION

The Duck Creek formation consists of approximately 100 feet of limestone and gray to bluish-gray shale. In the lower 30 to 40 feet of the formation the limestone and the shaly clay layers alternate. The limestone ranges from a yellowish marly limestone to a hard white limestone. The latter is similar to the Goodland in unweathered appearance. The shales are very calcareous, and bluish gray colors predominate. In the white limestone bed very large shells and ammonites are found. In the upper 50 to 60 feet of the formation the limestones are thin, separated by thick layers of shale. This upper portion is practically barren of fossils.

FORT WORTH LIMESTONE

The Fort Worth limestone may be divided into three parts. The lower division consists of 10-15 feet of alternating beds of a yellowish white limestone and a gray to blue shaly clay. The middle division is about the same thickness and is chiefly shale. The upper division is predominantly limestone separated by thin layers of shaly clay. The limestone is hard and cream colored very similar to the more massive beds of the lower Duck Creek. These harder limestones at the top project as ledges and in some places as bluffs.

The Arbuckle Orogeny

The diastrophism which constituted the formation of the Arbuckle Mountains was a combination of faulting and folding. There is evidence for believing that it started somewhat to the southeast of the exposed Arbuckle Mountains and slowly appeared farther and farther toward the northwest. It is possible that the earliest phases of the orogeny were manifested at the surface a hundred or more miles south of cast from Johnston County in late Mississippian time, thus furnishing the chief source of the clastic sediments of the thick Stanley and Jackfork formations of southeastern Oklahoma and southwestern Arkansas. The orogenic disturbance appeared in the area of the presently exposed Arbuckle Mountains by early Pennsylvanian time and after intermittent movements of greater or less importance, it ceased near the early part of Permian time. All additional movements up to the present have been insignificant from the orogenic standpoint in comparison with the earlier movements. Contemporaneously with the faulting and folding of the Paleozoic rocks now exposed in the Arbuckle Mountains proper, deformation was also taking place to the south in the so-called Ardmore Basin and the Criner Hills. It is noteworthy that at no time until the end of the Pennsylvanian period did the mountains rise very high above sea level. This was especially true in the southern part of the mountains around Ardmore, where, in spite of recurrent movements, the sea was not eliminated.

As a generalization it may be stated that faulting has been the chief mode of deformation of strata in the Arbuckle Mountains. Furthermore there is a strong suggestion that the main exposed axis of the mountains—the Arbuckle anticline of Murray and southern Johnston counties—is a fault block which has been tilted upward at the north edge in spite of, or in addition to, the folding which has taken place. This could explain the greater abundance and coarseness of the conglomerates on that side as opposed to those south of the Arbuckle anticline. The abrupt slopes on the north side of this main Arbuckle axis constitute a “fault-line-scarp”. The conglomerates are likewise very abundant, and a similar but higher scarp is also present farther west on the north side of the Wichita Mountains. This suggests that the main granite area of the Wichita Mountains, too, may have been a block mountain in Pennsylvanian or earliest Permian time. The “fault-line-scarp” there is very prominent. The block-mountain nature of this diastrophism, the author believes, has been too little considered.
PRESENT PHYSIOGRAPHIC DEVELOPMENT

Good evidence is at hand that the Jurassic peneplane in the Arbuckle Mountains was an exceptionally perfect one. An occasional monadnock rises a few tens of feet above the even surface at the edge of the overlying Trinity sandstone. But the irregularities of surface, it is noteworthy, are not valleys. The East and West Timbered Hills rise between 25 and 50 feet above the projected upland surface of the Arbuckle Mountains today, and it is believed that they were monadnocks of similar height in late Jurassic time.

In early Comanchean time this entire peneplaned area in the western Gulf Coastal Plain was gradually tilted and warped, allowing the Comanchean sea to invade a large area in western Oklahoma and surrounding states. Additional slight tilting, sea invasion, and deposition of sediments kept the Arbuckle Mountains covered, it is believed, until near the end of the Cretaceous period. At this time the mountains and surrounding regions were elevated vertically a considerable distance above sea level, partaking of the elevation which was so general in eastern and southern North America. Stream erosion then began to remove those clastic and other beds so lately deposited. There has been a renewal of folding or uplift along the axis of the Arbuckle anticline at some time since the Jurassic period. This movement was slight but of sufficient magnitude easily to be detected. It caused a reversal of slope in the peneplaned surface of the mountains amounting to about 100 feet. This revival of the old movements probably took place at the end of the Cretaceous period also, though this is not a certainty. It rests on analogy with other areas of similar history in North America.

Through most of the Tertiary era the mountains and surrounding regions underwent erosion, and by late Tertiary time a new peneplane had been developed on the soft, unmetamorphosed strata of the surrounding plains. The older Paleozoic rocks of the mountains are in general more resistant than the Pennsylvanian, Permian, and Comanchean rocks which surround them. Hence, this mountainous area was left standing above the "Tertiary" peneplane as a broad and complicated monadnock. The great thickness of the Arbuckle limestone is the chief cause of the greater resistance of these beds.

Oil and Gas Possibilities

There is only one locality in Johnston and Murray counties in which the possibility that oil exists is not remote. This is in the northeastern end of Murray County, north of Sulphur and Davis and south of Wynnewood. Several wells have been drilled into the red beds of the Pontotoc series and some have gone through them into older Paleozoic strata without more than an occasional showing of oil or asphalt. It seems unlikely that the sandstones and conglomerates of this formation will ever yield oil in paying quantities within the area under consideration. The uniform dip away from the mountains and the high porosity of some of these layers should allow quick dissipation of any oil in these strata. The unconformity at the base of this series of red beds is to be considered less favorable than other porous horizons, unless a pronounced buried hill should furnish a local reversal of the surface and hence a local trap. If such a feature can be located by geophysical or other means several miles distant from the edge of the Pontotoc strata, further exploration should be attempted.

Most of the showings of oil, which have been reported in wells already drilled in this area, have come from such a depth and from such beds that the source is believed to be the various sandstone horizons of the Simpson formation. The well on Scott's (Vine's) Dome in the SW¼ of sec. 34, T. 1 S., R. 2 E., has produced asphalt since its completion in 1919. The horizon is a sandstone about 430 feet below the top of the Simpson formation, and it seems to be approximately equivalent of the uppermost sandstone in this formation as exposed on the main highway crossing the mountains south of Davis. From this well and from showings in several other wells northwest of the mountains, it is concluded that the sandstones of the Simpson formation here are potential oil horizons. In the opinion of the writer they are the most favorable strata for exploration.

It may not be claimed, however, that prospects are good for commercial production of a high quality of oil from the Simpson formation. The difficulty of locating a suitable anticline or fault structure where the beds are sufficiently deep to be free from the probability that the more volatile constituents have evaporated, is quite formidable. The pronounced angular unconformity at the base of the Pontotoc red beds and the concealment of the mountainous structure by this series of strata introduce obstacles that it will be very difficult to surmount. It is not unlikely that oil in commercial quantities is present along the buried northwestern extension of some of the long faults to be seen on the colored geologic map of Oklahoma. But so far as known exploratory work could be accomplished only by random drilling.

The following logs are of interest in connection with the oil possibilities in the area of the Pontotoc outcrop northwest of the exposed mountains:

*Choate Oil Corporation's No. 2 Mat Wolf, sec. 16, T. 1 N., R. 2 E.*

Drilling commenced, Jan. 1922; completed, April, 1924.

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Scott's Dome Oil Company's No. 1 Ellis Price, sec. 34 T., 1 S., R. 2 E.

Drilling Commenced, Mar. 17, 1929; completed, Nov. 16, 1929.
Styvesant Oil Company's No. 1 Ashton, sec. 7, T. 1 N., R. 3 E.
Drilling commenced, May 12, 1920; completed, Jan. 15, 1921.

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<td>Sand water</td>
<td>2228 2290</td>
</tr>
<tr>
<td>Shale</td>
<td>2290 2300</td>
</tr>
<tr>
<td>Sand</td>
<td>2390 2540</td>
</tr>
</tbody>
</table>

INTRODUCTION

Considerable drilling of a scattered nature has been done in these counties for oil and gas but nothing of good commercial value has been encountered. The possibilities for gas have been proved and wells put down which had short-lived production at Mazie. Other wells drilled within the Pennsylvanian outcrop area and along the western side of Mayes county have possibilities.

The writer did not attempt to revise the earlier map made by L. C. Spindler in 1915. New information is constantly being gathered which will make a revised map possible in the near future. With only a few modifications, the map as printed is the same as the earlier one. The map is based on the Pryor, Siloam Springs, Venita, and Wyandotte quadrangles of the U. S. Geological Survey.

Acknowledgments

The writer is particularly indebted to Dr. S. Weidman of the University of Oklahoma for valuable aid in the field and for many valuable and helpful suggestions. Most of Ottawa County was worked out with his company and the writer has used items mentioned in his report of the lead and zinc district.

Figure 98.—Index map of Oklahoma showing location of Mayes, Delaware, and Ottawa counties.

(Originally published as Bulletin 40-NN, January, 1930).
Location and Accessibility

Mayes, Delaware, and Ottawa counties are located in the extreme northeastern corner of the State. Ottawa County borders on Kansas and Missouri, and Delaware County borders on Missouri and Arkansas. The following table gives interesting data:

<table>
<thead>
<tr>
<th>COUNTY</th>
<th>AREA</th>
<th>POPULATION</th>
<th>PERSONS PER SQUARE MILE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ottawa</td>
<td>477</td>
<td>41,108</td>
<td>86.2</td>
</tr>
<tr>
<td>Delaware</td>
<td>704</td>
<td>13,868</td>
<td>17.5</td>
</tr>
<tr>
<td>Mayes</td>
<td>676</td>
<td>16,829</td>
<td>24.9</td>
</tr>
</tbody>
</table>

Pryor is the county seat of Mayes County with Choteau, Adair, Spavinaw, and Locust Grove being the larger towns. This county is chiefly agricultural with timber industry in the eastern part. Spavinaw Lake, formed by damming Spavinaw Creek, is water storage for the Tulsa water supply. The main line of the Missouri, Kansas, and Texas Railroad, and the Missouri, Oklahoma, and Gulf Railroad serve the county. Nearly all of the main state highways are graveled, other roads are graded, or dirt.

Jay is the county seat of Delaware County. This region is characterized by very broken topography, steep, deeply cut valleys with level prairie-like country on the divides. Most of the county is timbered and supports a very scanty population. Bernice and Grove are the largest towns. The Missouri, Oklahoma, and Gulf Railroad cuts the northwestern corner of the county and a branch line of the Frisco Railroad terminates at Grove, entering from northwestern Arkansas. Most of the main roads are graveled and the Boone chert forms a natural hard surface for many of the secondary roads.

Miami is the county seat of Ottawa County and one of the larger towns of the state. Afton, Fairland, and Wyandotte are fair sized smaller towns. Ficher and Commerce are large towns due to their location in the lead and zinc district. The main line and a branch line of the St. Louis and San Francisco Railroad and the main line of the Missouri, Oklahoma, and Gulf Railroad serve the county. All of the highways are graveled or paved and most of the county section lines are graveled with the chat tailings of the mine dumps. The chief occupations in this county are mining, and business. As shown by the population the county is prosperous.

Drainage and Topography

The Grand River (Neosho) is the major stream, with tributaries entering from the east and the west. It is formed by the junction of the Neosho and Spring rivers near Wyandotte. All of the western tributaries contain muddy waters due to flowing over Pennsylvanian clastic sediments. The principal creeks are Horse Creek, Cabin Creek, Pryor Creek, and Choteau Creek. The eastern tributaries are clear since they flow out of the Ozark Mountains over limestone and flint. These eastern streams are perennial spring fed streams, but the western streams are frequently dry during the summer. The main eastern branches are Lost Creek, Elk River, Honey, Spavinaw, Salina, and Spring Creeks. It is significant that Grand River flows along the western outcrop of the resistant Boone chert. Another large stream, Flint Creek, cuts the southeast corner of Delaware County.

The eastern portions of the three counties have been uplifted and since these portions are underlaid by the resistant Boone chert the uplands are more or less flat with deeply incised valleys giving a mature topography. West of Grand River the topography is a prairie underlaid by less resistant rock with outstanding buttes capped by harder rock. Along the western side of Mayes county is a scarp and highland marking the outcrop of the Bluejacket sandstone which is the surface outcrop of the lower part of the Bartlesville sand series.

The highest points of the area, about 1,200 feet, are in the southeastern part of Delaware County. The topography slopes to the north to about 800 feet and to the west to about 600 feet in western Mayes County.

GEOLoGY

The rocks of this area range from Ordovician to Pennsylvanian, the Mississippian covering the larger part. The table on page 8 shows the stratigraphic column of exposed rocks.

Spavinaw Granite

An outcrop of granite occurs about one-half mile west of the Tulsa water supply dam across Spavinaw creek in sec. 15, T. 22 N., R. 21 E., Mayes County. The strike is N. 40° E. at the northern end and N. 30° E. at the southern end of the outcrop. The granite appears in five localities as follows (see fig. 99):

1. The granite rises out of the stream bed and extends northward to the road for a distance of about 300 feet and a width of 75 feet.

2. Another outcrop is 150 feet from the first, being 75 feet wide at the southern end and 50 feet wide at the northern end and about 125 feet long.
Surface formations in Mayes, Delaware, and Ottawa Counties.

<table>
<thead>
<tr>
<th>AGE</th>
<th>FORMATION</th>
<th>CORRELATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>PENNSYLVANIAN</td>
<td>Cherokee shale</td>
<td>Allegheny</td>
</tr>
<tr>
<td></td>
<td>Morrow formation (southern part)</td>
<td>Pottsville</td>
</tr>
<tr>
<td>MISSISSIPPIAN</td>
<td>Fayetteville formation</td>
<td>Chester</td>
</tr>
<tr>
<td></td>
<td>Mayes limestone</td>
<td>Osage</td>
</tr>
<tr>
<td></td>
<td>Boone chert and limestone (St. Joe limestone member)</td>
<td>Kinderhook</td>
</tr>
<tr>
<td>ORDOVICIAN</td>
<td>Tyner shale</td>
<td>Chazy</td>
</tr>
<tr>
<td></td>
<td>Burgen sandstone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Un-named limestone and dolomite (Arbuckle?)</td>
<td>Beekmantown</td>
</tr>
<tr>
<td>PRE-CAMBRIAN?</td>
<td>Granite</td>
<td></td>
</tr>
</tbody>
</table>

3. The third exposure, about 450 feet from the second, is 200 feet long and 300 feet wide. At this location there is an old abandoned quarry, with many good blocks of granite still in place. Transportation costs have prohibited development and the quarry is abandoned.

4. An exposure occurs 200 feet north of number 3, and is about 175 feet long and 100 feet wide.

5. The last outcrop, about 5 by 10 feet, is due west from outcrop number 3. Adjacent is a mineralized zone similar to the zone adjacent to the larger masses.

The total distance of the outcrop is about 1,600 feet. Copper stains of varying amounts occur in several places. A zone of intense...
silicification extends on either side of the mass, decreasing away from the granite. A well drilled on the east flank near the south end struck granite at a depth of 50 feet, 100 feet away from the outcrop. Near the north end on the same side, roten granite was struck at 74 feet, and 200 yards east granite was not found at 95 feet. A well a few hundred feet to the west of the granite outcrop failed to reach it at 112 feet. These wells were drilled by W. E. Kay of Spavinaw. These wells tend to show that the granite is very narrow or ridge-like in its occurrence. Immediately west of exposure number 2, a shaft 87 feet deep was sunk by the government to a nine foot deposit of pyrite to use in manufacturing sulphuric acid for use in war supplies. The shaft is now full of water and the only evidence of the shaft having encountered granite is a few weathered fragments on the dump. There are numerous pits and prospect holes dug on all sides of the granite, all of which show no commercial ore. Pyrite, dolomite, and quartz crystals are common in cavities and in veins adjacent to the igneous body.

Joints observed on outcrops Nos. 1 and 2 show very interesting features. Viewed from the end, the joints radiate fan-like. Viewed from the side they are also fan-like and perpendicular to the surface of the rock mass. When observed from the top the joints are essentially parallel with the strike of the outcrop.

The rock itself is a red, coarse-grained granite. The feldspar grains are the chief color giving constituent and are chiefly orthoclase. The grains are up to ten centimeters in diameter. Black flakes of magnetite and hornblende are scattered throughout. The quartz is not apparent to the naked eye and a megascopic examination would cause one to call the rock syenite. Examined under the microscope the rock is a distinct granite as will be described later. Some portions of the rock are green in character, especially near exposure No. 3.

The writer quotes verbatim the original microscopic description made by Dr. N. E. Drake.

Feldspars, quartz, chlorite, and magnetite are the principal minerals of the rock, while hornblende and epidote occur sparingly. A holocrystalline texture is shown throughout the rock. The most striking and general microscopic feature is its granophyric and micropegmatitic structure. Through most of the feldspar crystals, quartz is intergrown in a most intimate manner, so that each feldspar shows radiating or alternating quartz and feldspar in each crystal, the included quartz plates or prisms show the same orientation. Quartz occurs sparingly isolated in the larger crystals, but very rarely shows its outline. Feldspars are the predominating minerals. They are principally orthoclase, but plagioclase crystals are rather common. The feldspars have a fine granular appearance and a reddish color. Phenocrysts of feldspar are quite common but they do not show crystal faces. Magnetite occurs in small opaque masses many of which show crystal outlines. They show a slight grouping through the rock and in places give a blended appearance to the crystals. The hornblende is the greenish variety and of rather uncommon occurrence. The chlorite is common and occurs in greenish bands, spicular aggregates, and minute particles. Epidote is of rather common appearance.

**Chemical Analysis of Spavinaw Granite.**

<table>
<thead>
<tr>
<th>Chemical Analysis</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO₂)</td>
<td>71.10</td>
</tr>
<tr>
<td>Ferric Oxide and</td>
<td></td>
</tr>
<tr>
<td>alumina (Fe₂O₃)</td>
<td>20.60</td>
</tr>
<tr>
<td>Calcium oxide (CaO)</td>
<td>2.53</td>
</tr>
<tr>
<td>Magnesium oxide (MgO)</td>
<td>.99</td>
</tr>
<tr>
<td>Sodium and Potassium oxides (Na₂O, K₂O)</td>
<td>3.76</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td>100.09</td>
</tr>
</tbody>
</table>

The following is a petrographic analysis made by Mr. Robert Roth* of the Indian Territory Illuminating Oil Co.

The analysis of this rock shows it to be intermediate between an "alkali granite" and a syenite; it is in fact, much closer to a syenite than to a granite. The hand specimen shows no quartz, but a chemical analysis shows 71.10 per cent of SiO₂. In a thin section it will be noted that the quartz is present in great extent and thus accounts for the large percentage of silica. The feldspars are largely of the soda type and are very well altered to kaolinite-like material. The ferro-magnesian silicates are largely hornblende, probably of the arfvedsonite variety, giving blue and green tones, also augite. These femic are quite well altered. The texture of the rock is hypidiomorphic, which is very characteristic of the deep-seated consolidated rocks. These characters may be found throughout and show no change in any direction. The basic secretions separating out from this "acid syenite" are composed largely of hornblende and some augite. There is no muscovite or biotite in this rock. There is some sericite present along the twinning planes of the feldspar.

Conglomerate and breccia of quartzite and chert cemented by silica is found on a wooded knoll and near a prospect hole 200 yards northeast of the last exposure of the granite. The knoll is undoubtedly a bulge with granite close beneath. Sandstone of quartzitic nature occurs in a gully on the south side of Spavinaw Creek just east of the bridge and 200 yards west of the granite. The quartzite in the conglomerate is much more indurated than the above due to silicifying solutions. In many places cavities in the silicified zone show well developed quartz, dolomite, and pyrite crystals, as well as pseudomorphs after pyrite. Jasperoid is also quite common.

The layers overlying the granite are Ordovician dolomite and limestone somewhat sandy in places. These layers are highly silicified near

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*Personal communication.
the granite and less so at a distance. The formations over the granite are seen on the south side of the creek inclining away from the crest at five to ten degree angles, the dip being the steeper on the west side. At the crest of the granite there is a definite topographic bulge which is apparently associated with the structure of the granite exposure. Other strata over the granite are the Chattanooga shale and the Boone chert.

There are two opinions as to the age of the granite. One is that the mass is a dike intruded in post-Ordovician and the other that it is a pre-Cambrian ridge.

D. D. Owens' first mentioned the outcrop in 1860 calling it a granite axis, but he never visited the outcrop himself.

N. F. Drake described it in detail in 1898, calling it a dike intruded into dolomite. This was the first article published by one who studied the exposure and no one has written a better description. However, he now expresses himself as differing from his original opinion. He says: * Before I knew that there was any controversy as to whether this granite was a dike or pre-Cambrian peak, I had suspected it to be the latter. I believe that the evidence is in favor of classing it as a pre-Cambrian peak.

In 1901, G. I. Adams described the granite as a post-Carboniferous dike, dating the intrusion as contemporary with the folding and faulting of the Ozark uplift.

L. H. Hutchison and R. R. Severin studied the outcrop and called it a dike occurring after the Pennsylvanian. The inference was made from the fact that the Mississippian rocks overlying were affected and that this region was in movement during late Mississippian and early Pennsylvanian and the dike was contemporaneous.

In 1907, C. E. Ciebenthal refers to the granite mass as a dike.

L. C. Snider in his report on northeastern Oklahoma in 1915 calls the rock a dike and gives verbatim Drake's description since the original is not easily obtained.

F. L. Aurin, G. C. Clark, and E. A. Trager did not agree with the statement of earlier men and stated that the granite was a pre-Cambrian peak or ridge, but they did not present in their paper any evidence for the statement.

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"Initial Dips Peripheral to Resurrected Hills". These dips are not reflected in the overlying Mississippian and are soon dissipated in the older rocks, as those at Sapinaw dam are practically flat lying. Furthermore, there are conglomerates and quartates adjacent to this alkali syenite (granite) which are not metamorphosed. If the igneous rock were a dike or a pegmatite one must find some of the following conditions or else it cannot be classed as such: If it were a pegmatite the adjoining limestone, dolomite, and granite would be intensely altered, due to the pneumatolytic action of the hydrothermal gases emanating from this igneous mass. Nothing like this is found, but we do find a great amount of grahamite, maresite, and pyrite adjacent to the mass which with the temperature naturally formed by the dike would not exist in this proximity. The alkali syenite shows definitely no contact phases such as a change in texture from the central portion toward the contact which is always found adjacent to dikes and pegmatite. This point is probably the best evidence, proving that this mass is but an exposed remnant of a much larger mass. Furthermore the crystalline texture of that portion which is weathered is identical with any other portion of the ridge.

C. W. Honess\(^{14}\) has visited the outcrop several times and studied thin sections. He states:

To my mind after studying the outcrop, the granite must be a dike as originally interpreted, by N. F. Drake, and I give the following reasons:
1. The granite is unusual. It is a pegmatite.
2. The chert at the contact is shattercd vertically to bits as if by heat.
3. There is an absence of a basal conglomerate and all other evidence of erosion at the top of the granite.
4. The cherty dolomites dip away from the granite at the rate of about five degrees dipping southeast on the southeast side and northward on the northwest side so that the granite is at the crest of an antcline.

Dr. S. Wiedman of the University of Oklahoma believes the granite to be a dike. The evidence upon which he interprets the intrusive character of the Sapinaw granite is as follows:\(^{15}\)

1. The texture of the Sapinaw granite is not that of a normal granite but is distinctly pegmatitic, the granophyric and micropegmatitic character being the most striking feature of the rock. Pegmatites are characteristic dike rocks.
2. The extensive alteration of minerals within the granite such as the metasomatic replacement of the feldspar by epidote and sericite and the replacement of hornblende by chlorite are characteristic hydrothermal alterations and indicate a type of alteration commonly associated with contact metamorphism.
3. The Ordovician limestone along the contact with the granite is altered to chert or jasperoid, the limestone being completely silified within a zone of 25 to 30 feet from the contact, beyond which to about 100 feet or more silification as well as dolomitization and the formation of pyrite has taken place. The chert along the contact is considered a metasomatic replacement of the limestone, and with the associated dolomitization and pyritization is interpreted as evidence of contact metamorphism developed at slight or moderate depths and under thermal conditions of moderate rather than high temperatures.
4. Parallel to and along the contact there is fissuring and brecciation of the jasperoid, and there is also a distinct arching of the overlying strata above the granite and there are common structural features associated with upthrusting by igneous intrusion.
5. There is no evidence of conglomerate or other distinctly clastic sediments derived from the granite along the contact and thus the character of the sedimentary rock at the contact supports the view that the granite is intrusive rather than basal to the surrounding rock.
6. The Spavinaw granite is similar in its pegmatite texture to the intrusive pegmatic granite in the Rose Dome\(^{16}\) of Woodson County, Kansas and the development of chert and other phases of metamorphic rocks along the contact with the granite in both these localities is very much alike.

In the judgment of many geologists the evidence of contact metamorphism is not sufficient to be conclusive that the granite was intruded. There are no minerals such as wollastonite, vesuvianite, garnet, serpentine, or staurolite found in the contact zone with the Ordovician dolomites. Alteration has taken place in the granite but such may have occurred previously. Quartz, pyrite, and dolomite crystals may be formed in a number of ways besides that of contact metamorphism. There is no doubt that considerable mineralization has taken place adjacent to the granite but the mineralization has not exhibited the expected high temperature contact metamorphic minerals. In some way the presence of the granite has affected the zone and pressure has taken place it was different form the usual type. The granite as a solid may have been pushed up into the sediments by the vertical component stress resulting from lateral pressure. Such would give the fracturing and folding described, allowing the circulation of water which deposited minerals in the existing cavities and fissures.

The Spavinaw exposure is another of the many igneous outcrops occurring in the Mississippi valley. The Rose Dome intrusion in eastern Kansas, the peridotite at Manhattan, Kansas, the pegmatites and diorite sills of southeastern Oklahoma may be given to show that intrusions have occurred. In Camden county in central Missouri, there is a pegmatite dike described by Winslow\(^{17}\) and by Adams.\(^{18}\) The age given is post-Ordovician and perhaps post-Carboniferous.

**Ordovician**

The Ordovician rocks outcrop in several places within this area. About 10 to 15 feet of limestone is exposed beneath the Chattanooga shale two miles north of the mouth of Elk River in T. 23 N., R. 24 E.

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\(^{14}\) Personal communication.
\(^{15}\) Wiedman. S. For read before the Oklahoma Academy of Sciences, Oklahoma City, November 29, 1929.
The outcrop is terminated to the west by Grand River and the Seneca fault. The rock is composed of fine-grained, thin-beded limestone with flint nodules near the river level. Near and at the contact with the shale above, the formation is dark and dirty colored with flinty portions and many pits and irregularities. The rock weathers to nearly the same color of the soil. The limestone is very dolomitic.

At Spavinaw the formation rises from stream level at the Spavinaw dam to about 200 feet above the granite mass and then dips rapidly at 5 to 10 degree angles. The whole exposure is about a mile long and is well silicified in some portions, especially over the granite. The strata here are composed of well-beded layers of dolomite, sandy or siliceous limestone with occasional thin beds of sandstone, nearly quartzitic in texture. Flint layers and nodules weather into rounded forms. The formation also rises toward the north and at the north end of the Spavinaw dam it is 25 feet above stream level. The following is a description by Robert Roth of a section made on the apex of the granitic axis:

There is about 30 feet of sandy dolomite, some interbedded green shale, and many quartz and calcite vugs. These vugs are largely filled with grahamite or allied substances. There are very few fossils in this section. The next 30 feet contains considerable white angular and frosted sand interbedded with fine dolomite. This also contains considerable grahamite. Below this, there appears to be another unconformity as there is crumpled chert conglomerate and a great abundance of grahamite. Below this there is about 40 feet of light and dark fine-grained dolomite, quite platy in places, containing drusey vugs of quartz and chaledony. Most of the finely powdered material shows evidence of sun-cracks.

Fossils of lower Ordovician age have been found in the formation at Spavinaw and identified by R. D. Mesler of the U. S. Geological Survey at the request of Sidney Powers.

*Turritoma milaniiformis*
*Orospira bignanoa*
*Linospira sp.*

These belong to the “Swan Creek” zone of the Cotter formation in Missouri and Yellville in Arkansas. Another group of fossils collected by Sidney Powers were identified by H. N. Coryell of Columbia University as being equivalent to Beekmantown and Chazy.

*Linospira*
*Echinomaria*
*Eoclysmophalus*
*Archaeosella*
*Macurites*

It is reported that there is an outcrop of Tyner shale about one to two miles above the eastern end of Spavinaw lake, which would put it in about sec. 15, T. 22 N., R. 22 E. The writer has not seen the exposure and therefore can not verify the report.

**Ordovician occurs along Spring Creek near the border of Mayes County in sec. 12, T. 19 N., R. 20 E.** It does not show on the south bank of the stream but rises to the northward where about 15 feet of it is found. The layers beneath the black shale are limestone interbedded with thin shale layers. This is probably an exposure of the Tyner. Farther to the south the Burgen sandstone and the Tyner shale appear at the surface and the Chattanooga shale lies over shale where in the northern exposures it overlies limestone. An outcrop just three miles out of Oklahoma into Missouri up Buffalo Creek shows limestone at the contact with four inches of sandstone, probably representing the Sylamo, between it and the Chattanooga shale.

The exposures of dolomite and limestone correlate with the Jefferson City dolomite of Missouri, the Yellville of Arkansas, and the Arbuckle limestone.

L. C. Snider reports the sandstone found at the base of the Chattanooga at Flint on Flint Creek, Delaware County, to be Sylamo. The author considers the sandstone to be the Burgen. The sandstone at the base of the Chattanooga at Eagle Bluff 15 miles southeast of Flint is reddish, hard, dense, ferruginous. The sandstone herein called Burgen is a white, medium to fine-grained sandstone with streaks of iron oxide weathered brown. The sand grains are clear quartz and well rounded, with some oblong, and some etched and ground character-istic of Ordovician sands. Fucoids are abundant in the upper layers, some beds being entirely composed of them. The sandstone rises rapidly out of the creek bed beginning one-half mile above the bridge at the town of Flint. The strata dip away from there to the south disappearing beneath the creek bed a mile or so from the bridge. The maximum thickness shown is 20 feet near the bridge with the base not shown. It forms a bench in the valley with the Chattanooga shale above it. The sandstone rises to the west from the creek and in a half mile is 80 feet above the stream level. Luther White also designates this outcrop as Burgen. It has never been mapped as such.

A well drilled five miles south of Mayes County in SW.1/4 NE.1/4 NW.1/4 sec. 36, T. 19 N., R. 21 E., Cherokee County, gives a very fine section of Ordovician. The well starts in the Chattanooga shale and gives a section of dark limestone, reddish in the lower part, with eight shale beds 10 to 100 feet thick between layers of limestone 30 to 340 feet thick. At about the center of the section, 1,500 feet from the top, is 180 feet of grey sandstone. The whole section is 2,857 feet thick with 80 feet of Chattanooga sand and surface gravel, 2,210 feet of limestone, 377 feet of shale, and 190 feet of sandstone. In another well five miles south of Delaware County in sec. 32, T. 19 N., R. 25 E.,

19. Personal communication.
Adair County, there is 289 feet of Boone chert, 75 feet of Chattanooga shale, 1,066 feet of Ordovician limestone, some shale, and sand with granite at the base.

**Chattanooga Shale**

The Chattanooga shale is a thin-beded, black, bituminous and carbonaceous shale. It weathers along joints into rectangular blocks, but on continued weathering these split into thin paper shale. The beds are uniform in composition and contain few fossils. Siderite concretions of various sizes and cone-in-cone structures occur in some localities. Fossils are found within some of the concretions. The shale is found throughout these countries at the surface and in wells. The thickness is variable up to a maximum of 85 feet. In some localities a sandstone at the base called the Sylamore occurs. Springs are very common at the top of the shale due to its impervious character, and are often an aid in locating the contact.

The exposures in Mayes County are along Spring and Spavinaw creeks. The outcrop in the southeast corner on Spring Creek extends up the stream for 12 miles, but only 2 miles of it is in Mayes County. The shale is characteristic and about 40 feet thick and underlain by Ordovician rock, described previously. The Oklahoma geologic map shows 6 miles of Chattanooga shale along Little Spring Creek, but such is an error for no outcrops occur.

The shale is exposed in Spavinaw Creek for about 20 miles with the greater part in Delaware County. Part of it is covered by the water of Spavinaw Lake, but a complete section can be observed at the dam. The shale here measures 85 feet and rises until over the granite mass and then dips rapidly westward until it disappears 2 miles downstream. Near the highway bridge there is 50 feet of shale.

*Depths and thickness of Chattanooga shale in Mayes County.*

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>DEPTH TO TOP</th>
<th>THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sec. 26, T. 19 N., R. 18 E</td>
<td>402</td>
<td>40</td>
</tr>
<tr>
<td>Sec. 23, T. 19 N., R. 18 E</td>
<td>475</td>
<td>52</td>
</tr>
<tr>
<td>Sec. 2, T. 20 N., R. 18 E</td>
<td>410</td>
<td>46</td>
</tr>
<tr>
<td>Sec. 8, T. 20 N., R. 19 E</td>
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</tr>
<tr>
<td>Sec. 17, T. 21 N., R. 18 E</td>
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<td>53</td>
</tr>
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<td>65</td>
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<td>54</td>
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<td>Sec. 9, T. 22 N., R. 18 E</td>
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<td>37</td>
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<tr>
<td>Sec. 31, T. 22 N., R. 20 E</td>
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<td>82</td>
</tr>
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<td>Sec. 2, T. 23 N., R. 21 E</td>
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<td>84</td>
</tr>
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<td>55</td>
</tr>
<tr>
<td>Sec. 2, T. 23 N., R. 21 E</td>
<td>120</td>
<td>40</td>
</tr>
</tbody>
</table>

In the southeast corner of Delaware County the shale is exposed for 5 miles along Flint Creek. The outcrop extends to the juncture of Illinois River and Flint Creek and into Cherokee County nearly to Tahlequah. The base of the shale is shown at Flint and is about 50 feet thick with 20 feet of Burgen sandstone exposed beneath. The shale is also along Spavinaw Creek in Delaware County. Two small outcrops occur on Drowning Creek a mile from its juncture with Grand River. At Armstrong Ferry in Sec. 24, T. 24 N., R. 22 E., the south member of the Seneca fault brings up a small exposure of about 10 feet of Chattanooga shale. One other exposure occurs in Delaware County, on the south side of Grand River below the mouth of Honey Creek near the center of T. 24 N., R. 23 E. Here the shale is 80 feet thick with the base not exposed.

Only one outcrop of the shale occurs in Ottawa County. It is about a mile north of the county line in the southwest corner of T. 26 N., R. 24 E. Here it is 25 feet thick and shows the base above 15 feet of Ordovician limestone.

The thicknesses in closely localities not in the counties of this report are as follows: 20 feet on Buffalo Creek three miles in Missouri, with Ordovician below; 150 feet at Southwest City, Arkansas; 60 feet southeast of Tahlequah; 40 feet on Clear Creek five miles south of Mayes County line; 40 feet on Cabin Creek one mile north of the Mayes County line.

All of these exposures are inliers. The broad uplift of the Ozark region has bowed the rocks up in Mayes and Delaware counties. The shale is near the surface in all major stream valleys and shows in some of them as outlined above. It would not require much cutting to reach the shale in other localities. In northern Ottawa County the wells show the shale to be 450 to 500 feet down and from 0 to 30 feet thick. (See the table of wells of Ottawa County).

The Chattanooga shale is found in nearly every well that is drilled to its horizon in eastern and northeastern Oklahoma. It is found near Tulsa, Okmulgee, Seminole, Oklahoma City, and thence to where it outcrops again in the Arbuckle Mountains. Much discussion has occurred as to whether the shale is Mississippian or upper Devonian and there still will be. But it is generally accepted now in most places as being lower Mississippian, rather than Devonian. This puts it just below the Kinderhook shale of the Mississippian type section. The shale may be correlated with the Woodford chert of the Arbuckle Mountains, the Noël shale of Arkansas, the Chattanooga shale of other places in the Mississippi Valley, and the upper part of the Ohio shale.

The fauna includes some linguloid brachiopods, many conodonts, shell fragments, and an occasional form of pelecypod or other form in the interior of small concretions. Remains of Dinichthys are sometimes
found. A plant spore, *Sporangites huronensis* is a good marker of the Chattanooga.

**Kinderhook Shale**

In nearly all places where the top of the Chattanooga shale was observed there was a foot or so of greenish-black soft shale between the black shale and the overlying St. Joe limestone member of the Boone chert. This layer is thicker to the south in Cherokee County and to the west in western Mayes County. This shale is the representative of the Kinderhook which overlies the Chattanooga in the type section.

**Boone Chert**

The Boone chert is typically a formation of alternating limestone and flint layers. Practically the eastern half of this area is underlaid by the chert, forming hills, incised valleys, and bluffs along streams giving a rugged topography everywhere characteristic of the Ozark Mountains. The chert weathers into sharp angular fragments which, mixed with soil, forms a thick covering. These fragments make it difficult to walk when on slopes. The type locality is in Boone County, Arkansas.

The Boone is separated from the Chattanooga shale by the soft green layer mentioned previously and several feet of thin uneven-bedded soft limestone with no flint and which weathers whitish. This limestone is called the St. Joe limestone and designated as a member of the Boone. Its type location is at St. Joe, Arkansas, and it correlates with the Fern Glen of Missouri. In southern Ottawa County the limestone is 15 feet thick with a shale parting of three or four inches of soft blue shale 5 feet above the base. At Spavinaw an excellent outcrop 20 feet thick occurs on the hillside a few hundred feet below the dam:

**Section of St. Joe limestone near Spavinaw Lake dam.**

<table>
<thead>
<tr>
<th>Layer Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin to medium bedded dense grey limestone</td>
<td>9</td>
</tr>
<tr>
<td>Shaly layer with 6 inches of soft blue shale</td>
<td>1</td>
</tr>
<tr>
<td>Finely uneven thin beded limestone</td>
<td>10</td>
</tr>
</tbody>
</table>

Along Spring Creek the St. Joe is 11 feet thick and resembles that of elsewhere. At Flint the limestone is 15 feet thick on the east side of the creek. A mile west of Flint the bed is 8 feet with the transitional shale below not typically greenish. A half mile east of Eucha on Spavinaw Creek at a spring there is 18 feet of St. Joe as follows:

In well records there is often shown a stratum of soft non-flinty layer at the base of the Boone which is probably St. Joe.

The lower part of the Boone contains light colored flint and more limestone than the upper part. The chert layers are generally persistent as a stratum and uniform in thickness giving a well bedded appearance. The cherts are more porous and darker in color, weathering frequently with considerable iron oxide stains. In northern Ottawa County about 110 feet from the top is a “green limestone” layer more or less persistent and just below it a brown lime oolite layer called the Short Creek member, which are very useful in correlation in wells. Because of the similarity of the successive layers of chert and limestone it is difficult to locate one place in the Boone section, and these above mentioned layers are valuable. The Boone is more or less pervious to water and many springs are found at the base of the formation where ground water flows out upon the impervious Chattanooga shale.

The thickness is uniform in northern Ottawa County, being 320 to 390 feet in wells. (See table of wells in Ottawa County.) The thickness diminishes to the west away from the border of the Ozark uplift. In the northeast corner of Mayes County the Boone is 101 feet as shown by a well. A well on sec. 17, T. 21 N., R. 18 E., the western border of the same county, shows the Boone 64 feet thick. In the same well occurs 8 feet of St. Joe and 9 feet of green shale known as Grass Creek shale which is the same as the few inches of green shale overlying the Chattanooga shale in various places.

Due to the Ozark uplift there was considerable fracturing and a certain amount of faulting. Later these fractures were cemented together by silica and formed widespread areas of breccia composed of flint fragments. This is especially true in the lead and zinc area of northern Ottawa County. Also, one happens upon a fissure now and then which has a breccia silicified together in it. An example is the one at Armstrong Ferry at the west landing.

The Boone chert is Osage age including the Fern Glen, Burlington, Keokuk, and lower Warsaw. It represents the lower part of the “Mississippi lime” of the driller.

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Chester Series

The Chester formations of northeastern Oklahoma are the Pitkin limestone, the Fayetteville shale, and the Mayes limestone. The formations are very variable in thickness and lithology, lensing out and thinning to the north. The Pitkin limestone is not found in these counties but is found not far from the southern border of Mayes County. The Mayes and the Fayetteville will be discussed together as they are closely related and the contacts are indistinguishable in most places.

The name Mayes was given by L. C. Snider because of the best development of the limestone in Mayes County. The Fayetteville shale takes its name from the type locality at Fayetteville, Arkansas. The Mayes formation is considered as the limestone immediately overlying the Boone chert and beneath the black shale and limestone of the Fayetteville. In the southern part of Mayes County, sec. 15, T. 19 N., R. 19 E., the Mayes is 50 feet thick with about 50 feet of Fayetteville capped by the Morrow formation. A very fine exposure of the Mayes, 97 feet thick, occurs two miles northwest of the above location on the west bluff of Grand River. The section consists of thin-and heavy-bedded fossiliferous limestone interbedded with black shale and capped by the Morrow. North of this point, about the vicinity of Pryor, the Mayes is about 100 feet thick. It thins to 30 or 40 feet at the northern boundary of the county. The limestone near Pryor is a granular, crystalline, crinoidal or coquinal dark colored limestone. It forms a flat prairie with a few feet of soil cover with occasional broad places where the soil has been washed away. East of Pryor are a number of hills of Boone chert projecting through the Mayes limestone and farther east in the area of the Boone outcrops. One of these hills is one-half mile east of Pryor and several others are to be found 6 miles east along the main highway. These have been explained as islands of Boone around which the Mayes was deposited, since the Mayes is unconformable on the Boone. Even though they are of small extent, several hundred yards to one-half mile in length, it is possible that they are results of uplift. There is no evidence of strand formations around the base of the hills so it is thought that they may be results of subsurface movement. The one near Pryor is fractured with Mayes on the west side apparently faulted with a small fault against the Boone. All of the beds are tilted at this point.

A fine section of the Mayes may be seen in a stream along the highway to Locust Grove from Choteau, about two miles east of the bridge over Grand River. Here the Mayes is in contact with the Boone and shows a thin platy limestone, shaly at the base, with heavy limestone above. Above this is limestone and shale followed by the thin white-weathering limestone of the Fayetteville. All of the lime-

stone east of Grand River presents a similar appearance, which may be seen in the railroad cuts and along the major stream valleys.

The Fayetteville in this region and 5 miles to the north is primarily a thin-bedded, two to five inches, drab, dense limestone with some interbedded shale, and weathering into whitish cubical and angular fragments. Above this is a thin black shale about 20 to 40 feet thick. In places where erosion has not removed it, there is an upper limestone. On the outlier in sec. 31, T. 21 N., R. 20 E., the Morrow overlies the shale. Several other buttes southeast of Pryor give excellent exposures on this phase of the limestone of the Fayetteville.

To the north of Pryor, the Fayetteville thins and changes in character. The shale becomes grey rather than black, and above is thin platy earthy limestone very fossiliferous. Below the shale is a thin bedded limestone resembling that farther to the south. This character is especially well shown east and southeast of Adair about four miles.

In southern Ottawa and northern Delaware counties the Fayetteville is similar to the formation in northern Mayes County. The northernmost outcrop is a small conspicuous knoll of earthy and platy limestone a half-mile southeast of Fairland. To the north of this point the formation has been removed by erosion, and the Cherokee formation overlies the Mayes limestone.

Along Rock Creek, secs. 32 and 33, T. 23 N., R. 20 E., the Mayes is well exposed, about 40 feet being present. The lower part is thin platy limestone with a layer of yellowish sandstone above followed by more limestone, all being more or less fossiliferous. Other outcrops in this region are of the same character. In northern Delaware and Ottawa counties, the Mayes is variable, having considerable sandstone interbedded with thin fossiliferous limestone. The lower part is dark crystalline crinoidal or siliceous limestone. These variable beds are most common in the area around Grove and in eastern Ottawa County where outliers of the Mayes occur. Near Bereneice the Mayes is about 20 feet thick. In northern Ottawa County the top of the Mayes is sandstone with shale below and followed by a compact coquina limestone. The top of the Mayes in this region generally has a layer of gravel at the top. The sandstone increases in thickness from south to north. The shale is a lateral grading of an upper part of the formation, but the limestone is rather persistent in character, though not in thickness, from Choteau to the Kansas line.

The sandstone occurs on top of a hill two miles east of Miami where it has abundant bryozoa of the type Archimedes. The sandstone and shale measure 20 feet with 25 feet of crinoidal fossiliferous limestone below. In the western part of sec. 31, T. 29 N., R. 24 E., a sink-hole due to caving of an old lead and zink mine shows Boone
chert at the bottom in contact with the Mayes. There is 24 feet of heavy bedded limestone with soft, buff, fossiliferous sandstone at the top, but no shale is present. Fifty feet into Kansas across the border of sec. 17, T. 29 N., R. 24 E., is another larger sink showing the contact of the Boone with the Mayes, and a section as follows:

**Section of Mayes limestone 50 feet north of sec. 17, T. 29 N., R. 24 E.**

<table>
<thead>
<tr>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
</tr>
<tr>
<td>50</td>
</tr>
</tbody>
</table>

**Boone**

This same sandstone with gravel on top is found on a hill one mile south of Baxter Springs, Kansas. Below it is shale and the coquina limestone of the Mayes. The possibility of the sandstone being Cherokee is discarded because of the presence of the gravel. No similar fossiliferous sandstone is found in the Cherokee formation. A preliminary study of the fossils of the sandstone show them to be Mississippian. Four miles east of Spring River between sec. 2 and 11, T. 28 N., T. 24 E., the same fossiliferous sandstone occurs over the limestone of the Mayes formation.

It is noteworthy that in northern Ottawa County and also in the vicinity of Pensacola, gravel occurs on the hills and in the valleys with the Mayes formation always underlying. The pebbles will average about an inch in diameter and are generally well-rounded or subangular and composed of flint with a brown outside stain. Portions of the Mayes limestone are silicified in the lead and zinc district and flinty pebbles may well have been derived from such localities as well as from the abundant flint layers and nodules of the Boone chert. These pebbles were reworked out of the Mayes and Boone and laid at the base of the Cherokee. The gravel does not occur within the area of Cherokee exposures. Just west of the city limits of Miami the gravel is bound together with asphalt. Above the gravel is the yellowish oxidized shale of the Cherokee and below the thin shale and coquina limestone of the Mayes. East of Miami, along Tar Creek, gravel is embedded in a ferruginous sandstone with coquina limestone and thin platy sandstone above showing that one source of the gravel is the Mayes. Pebbles are also found in the Mayes in northern Mayes County. The gravel has been described as occurring in shafts of lead and zinc mines. Both surface and subsurface occurrences have been described in the Oklahoma Geological Survey bulletin on the lead and zinc district by Weidman.  

Siebenthal noted the gravels and called them Tertiary and allied them with gravel of the Atlantic coast and Mississippian embayment. If Tertiary they would probably be of river or lacustrine deposition and would have about the same elevation. Where the Cherokee contact occurs at the base of the hills there is gravel and as well where the contact occurs on the top of a hill. The gravel may therefore be used to define the top of the Mississippian.

The map by Snider derived from the earlier one by Siebenthal shows the Chester or Mayes formation as terminating in northern Ottawa County. The Mayes is found in contact with the Boone chert north of Baxter Springs, Kansas, and it has been found in sinkholes within the area mapped as all Boone, so that the Chester formations should be extended into Kansas.

The thickness of the Mayes is well known in Ottawa County because of the many prospect holes drilled through it in the lead and zinc district and by wells drilled for water in other areas. The thickness is from 20 to 50 feet with an average of 37 feet.

The Fayetteville shale can be correlated with the Caney shale of southern Oklahoma and with the middle and lower upper Chester of the Mississippi Valley. The Mayes contains Batesville and Moorefield Faunas. The southern part of the formation has a fauna typically that of the Moorefield and it dies out to the north as the Batesville becomes more prominent. As much as the northern part of the Mayes is sandstone and the Batesville fauna increases to the north the correlation with the Batesville sandstone of Arkansas becomes logical.

**Morrow Formation**

The Morrow formation is the lowest of the Pennsylvanian series of rocks. It occurs over the Chester and is found only in the southern part of Mayes County, thinning out to the north. The northernmost outcrop is in the Seneca fault block two miles south and one-half mile east of Pryor, in and along a small creek and the road-side gully. The rock is a thin platy, irregular bedded, fenocid and arenaceous limestone. East of the fault plane and higher than the limestone is a layer of sandstone with the typical limestone of the Fayetteville above. Just where the south member of the fault crosses is not definite, but it probably cuts through between the sandstone and the Fayetteville. Another outcrop is reported within the Seneca fault block in sec. 15, T. 22 N., R. 20 E. This location has much sandstone and cannot be definitely called Morrow. It is also much farther to the north than the last outlier of Morrow eight miles away. This outlier is formed by the Morrow as a cap to the hill and is located in sec. 31, T. 21 N., R. 20 E. The Morrow is 35 feet thick, 20 feet of dark earthy cross-bedded sand-

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Weidman, S. report now in manuscript form.
stone above 15 feet of thin, platy, earthy, and heavy bedded limestone. The Morrow beds overlie the black shale and typical whitish limestone of the Fayetteville. To the southward the Morrow becomes more calcareous losing the sandstone bed and the thin platy character. The thickness of the Morrow just south of Mayes County is about 100 feet. In the well in sec. 17, T. 21 N., R. 18 E., the formation is 120 feet thick.

In sec. 16, T. 19 N., R. 19 E., there is only 5 feet of sandstone with 15 feet of platy crinoidal limestone above, belonging to the Morrow.

**Cherokee Formation**

The Cherokee formation occupies the western two-fifths of Mayes County and the northwestern one-third of Ottawa County. No Cherokee occurs in Delaware County except for small areas within the downthrown block of the Seneca fault. Numerous outliers of the Cherokee occur to the east of the major outcrop, some as much as five miles. These are generally elevations capped by a hard layer of sandstone. A broad level prairie exists where the formation outcrops except for the outliers and the upland underlaid by the Bluejacket sandstone member.

The Cherokee measures 450 to 500 feet at the Kansas line and thickens to the south. Near Pryor it is about 1,000 feet. Only the lower portion is exposed in these counties. The formation is composed primarily of shale, with frequent lenticular and variable beds of sandstone, and occasional limestone layers. The shale is thin bedded, soft, and often clayey, varying in color from blue-grey and brown to black. Thin layers of coal occur, particularly about 20 feet beneath the Bluejacket sandstone. Openings have been made and considerable effort spent but coal of value has not been worked in these counties. In Craig and Wagoner counties the Bluejacket coal is mined. This formation is the chief oil and gas producing horizon of the proven fields in adjacent counties.

The Bluejacket sandstone is an outstanding member of the Cherokee formation. It is the surface outcrop of the Bartlesville oil sand. The sandstone appears as a scarp and as the cap rock on buttes and outliers in the western part of Mayes County. Four miles west of Pryor on the north side of the highway the sandstone is 58 feet thick, 38 feet being a massive bluff.

**Section of lower Cherokee west of Pryor.**

<table>
<thead>
<tr>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEROKEE</td>
</tr>
<tr>
<td>Thin sandstones and shales ........................................... 15</td>
</tr>
<tr>
<td>Dense, dark, bluish, fossiliferous limestone, several beds 2 to 3 inches thick ........................................... 1</td>
</tr>
<tr>
<td>Sandy shale .................................................................. 5</td>
</tr>
<tr>
<td>Frangible, buff, massive, crossbedded sandstone, some iron concretions (Bluejacket sandstone) ....................... 58</td>
</tr>
<tr>
<td>Dark colored shale with thin coal seams ......................... 110</td>
</tr>
</tbody>
</table>

The Burgess sand, an oil sand within the Cherokee occurs about 200 to 325 feet below the Bluejacket. The sand, being soft and friable, erodes easily and surface outcrops rarely are seen. The following is a section of the Cherokee taken from the bottom contact about a mile east of Pryor to the top of the Bluejacket sandstone. The Burgess occurs 196 feet below the Bluejacket in this section.8

**Section of lower Cherokee east of Pryor.**

<table>
<thead>
<tr>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEOKEE</td>
</tr>
<tr>
<td>Sandstone, medium-grained massive ................................ 14</td>
</tr>
<tr>
<td>Sandstone, shaly ....................................................... 8</td>
</tr>
<tr>
<td>Sandstone, massive, medium-grained ................................ 37</td>
</tr>
<tr>
<td>Limestone, argillaceous, fossiliferous ............................. 8</td>
</tr>
<tr>
<td>Shales and sandstone, alternating .................................... 70</td>
</tr>
<tr>
<td>Shale, arenaceous ...................................................... 7</td>
</tr>
<tr>
<td>Sandstone, gray, fine-grained ......................................... 7</td>
</tr>
<tr>
<td>Shale, carbonaceous, capped by 6 inches of ferruginous siliceous limestone ........................................... 3</td>
</tr>
<tr>
<td>Shale, bluish .................................................................. 85</td>
</tr>
<tr>
<td>Lime stone, argillaceous, heavily bedded, fossiliferous ....... 3</td>
</tr>
<tr>
<td>Burgess sandstone ........................................................ 3</td>
</tr>
<tr>
<td>Sandstone, shaly ....................................................... 17</td>
</tr>
<tr>
<td>Sandstone, massive, medium-grained ................................ 17</td>
</tr>
<tr>
<td>Shale with a few interbedded sandstones ......................... 135</td>
</tr>
</tbody>
</table>

The Bluejacket sandstone appears in the extreme northwestern corner of Ottawa County, but does not form a scarp. North of Picher one-half mile into Kansas, sandstone about 25 feet thick occurs on top of a hill known locally as Blue Mound. The sandstone is ferruginous, medium-grained, and contains considerable boggy limonite. This layer is the same as the Bluejacket. It dips three to five degrees to the northwest and is found 25 feet below the surface in the Miami syncline one mile away. At the base of the Cherokee in Ottawa County is a few feet or a few inches of gravel which is very helpful in determining the basal contact, as described previously.

The Cherokee overlies the Morrow formation to about the center of Mayes County, it overlies the Fayetteville in the northern part of Mayes County, and in Ottawa County it overlies the Mayes formation.

**GEOLLOGIC HISTORY**

The geologic history of Mayes, Delaware, and Ottawa counties is bound up in the movements relating to the Ozark Mountains. The sediments were laid down at intervals during times subjected to repeated fluctuations causing alternate land and sea area. The land mass eventually became the Ozark Mountains and the progression to the present status furnished the origin of the sediments around it by the erosion of previously deposited strata.

Not until Ordovician time did the sea advance over the pre-Cambrian land mass designated as Ozarkia. The rocks laid at first were sandstones and dolomitic limestones about 500 to 3,000 feet thick compared to the 8,000 feet of Arbuckle limestone in the Arbuckle Mountains. If similar amounts were deposited considerable erosion has removed the Ozarkian section. It is more probable that the basin was shallow and the source of sediments limited. The white, clean, well-rounded grains of the Burgen sandstone show near shore conditions with the land mass low so that mud and silt were not brought in. After the deposition of the green shale and sandstone of the Tyner formation uplift and erosion occurred in these counties which lasted until Mississippian time. To the south, however, withdrawal did not prevent the deposition of the St. Clair marble of Silurian age, or the sea reinvaded locally. There is no Devonian unless the Sylamore be considered as such.

In Mississippian time the sea again flooded the area and the Chattanooga shale was deposited over the truncated lower Paleozoic beds. This feature is well shown on the map by Luther White.25 The shale was thin but universal over much of eastern United States. At the base the Sylamore sandstone was deposited but it occurs only locally as a basal bed. The black shale derived its carbonaceous matter from vegetation accumulated on a land mass exposed since Ordovician. An unconformity marks the top as well as the bottom of the Chattanooga shale. In some places the shale is entirely eroded but the persistence of the formation over eastern United States, though relatively thin, is remarkable. The advancing sea reworked the Chattanooga and deposited a foot or so of thin greenish shale block in some places and then deposited limestone. The topography was low at the end of Chattanooga time so that the sea had only to rework the few feet of mantle rock and deposit the Kinderhookian, resulting in clear water for the normal deposition of limestone.

The St. Joe Limestone marks the readvance of the sea which lasted throughout the Fern Glen, Burlington, Keokuk, and lower Warsaw, representing the Boone deposition. Uplift caused the removal of the sea with an unconformity representing upper Warsaw, Salem, St. Genevieve, and St. Louis time. The Mayes formation and the Fayetteville indicate the return of marine waters during Chester time with the sediments containing more detritals than previously. These detritus probably due to minor oscillations of the Ozark region preceding the widespread uplifts of the Pennsylvanian. Evidently the shore line of the Chester sea was close to where the outcrops exist today. Such is indicated by the sandy and clastic character of the deposition in northern Delaware and Ottawa counties. The source of the sediments was close of the Mississippian as Chester deposits are chiefly around the border of the Ozarks. The Chester thins to the north and the Mississippian is marked at the top by an unconformity.

The lowest Pennsylvanian, the Morrow formation, is bounded above and below by unconformities. It thins out to the northward and allows the Cherokee to overly the upper Mississippian. The Ozark region was in oscillation throughout the Paleozoic and the movement culminated with a general warping of the rocks in the Pennsylvanian, at which time gentle folds were formed and the Seneca and Locust faults occurred.

**STRUCTURE**

The strata dip away from the core of the Ozark Mountains, the western border of which is in northeastern Oklahoma, so that in the counties discussed the rocks dip northwest, west, and southwest. The dip is very slight about 25 to 50 feet per mile, though it may be much steeper locally. The structure as a whole is a great broad dome-shaped uplift warped locally by minor folds with low angle dips. Major faults and a few minor faults occur.

In the eastern part of these three counties, in the Boone chert area, it is difficult to trace the structures since the Boone lithologically is so similar that definite horizons cannot be defined. Many folds and faults are thus lost to observation. A thorough examination and study of the beds would no doubt yield correlating evidence, but the time necessary for such is prohibitive. Only where the lower beds are exposed is it possible to define the structure.

A large fold occurs in southern Mayes County dipping west rapidly into the basin containing the Mid-Continent oil fields. It is interrupted east of Grand River by the Locust fault which brings Boone chert to the same level as Cherokee shale. To the east of the fault another anticline or a continuation of the above one rises along Spring Creek, with the crest unknown but probably about five miles to the northeast. Outcrops of the Chattanooga shale and the Ordovician below are found on the southern limb.

A well defined structure occurs along Spavinaw Creek with the crest of the northwest-southeast axis over the granite. The strata rise to the northwest at an angle of about three degrees and then dips away from the granite at about ten degrees to the northwest. The structure also rises to the north at a similar rate, the crest being a few miles away with the Chattanooga shale outcrops on Drowning Creek on the north limb. The disappearance and reappearance of the Chattanooga shale near Eucha shows a second large anticline on Spavinaw Creek to the east of Eucha. The fold extends for about eight miles, as shown on the map.

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The folds on Spavinaw and Spring creeks bring up Ordovician rocks but the anticline along which Salina Creek flows does not show the Ordovician nor even the Chattanooga shale. All three of these folds are not noticeable west of Grand River and the strata dip uniformly westward as the Prairie Plains monocline.

Flint Creek is crossed by a fold but the direction of the axis is hard to determine. From near the stream level the Burgen sandstone rises to the west for one-half mile and then dips and disappears some distance on. On the other axis the sandstone rises out of Flint Creek about one-half mile north of the town of Flint and dips under the stream again about three-fourth mile south of town. The highest part of the structure is at the town of Flint.

The Horse Creek anticline and the Seneca fault are the most outstanding structures of the area. The anticline begins near where Cabin Creek enters Mayes County and trends northeast across northwestern Delaware County near Berenice. Near the mouth of Elk City the trend changes to almost east and continues on into Missouri. The anticline is an asymmetrical fold with the steeper side on the south. Debris has been washed down obliterating good exposures but dips of five degrees were obtained east of Tiff City. West of Berenice the dip is 15 degrees to the southeast. These agree approximately with Siebenthal's description though the writer did not visit the gap cut by Horse Creek where Siebenthal measured a dip of five degrees. The dip to the north is less than five degrees dipping gently toward Afton and Fairland. An exposure of Chattanooga shale and Ordovician limestone is brought up along Grand River as the core of the anticline but it is faulted out on the west side of the river by the Seneca fault. The Grand River cuts across the anticline along the Seneca fault.

The syncline to the south of the Horse Creek fold is just as pronounced as the anticline, especially at Berenice. (see the cross-section.) Elk River flows along the axis of the syncline and is therefore designated as the Elk River syncline. The strata rise again to the south as the north limb of the Spavinaw anticline.

A small synclinal fold called the Miami syncline with a north-northeast trend occurs about a mile west of Commerce, Cardin, and Picher.

The Seneca fault originates near Spurgen, Missouri, passes through Seneca, Missouri, and thence across southeastern Ottawa County, northwestern Delaware County, and diagonally across Mayes County. It apparently ends three miles south of Pryor since the soft sandstone and shale of the Cherokee formation do not give evidence of the fault trace but the trend of the fault may be continued until in northern Wagoner County near the Verdigris River the offset of the

Bluejack sandstone for a mile or so indicates the fault. The greater part of the fault is double, letting down a graben, but south of Pryor Creek and along the rest of the fault there is only a single displacement. For thirty miles from where the fault enters Oklahoma, the Chester formations are let down into the Boone chert. South of this point the Cherokee shale lies within the block except for four miles of Chester near Strang. Judging from this vicinity and from the region near the southeast corner of T. 22 N., R. 19 E., the throw of the fault is about 100 to 200 feet. The fault intersects the meanders of Grand River fifteen times and many good exposures may be seen along the bluffs.

Siebenthal says:

The width of the down dropped block ranges from 200 to more than 1,500 feet, but the fault ranges in character from a simple pair of opposed breaks with the downdropped block between them, and with the strata of the wall rock on either side dipping more or less steeply toward the faulted block, to a sort of faulted syncline, the limbs of which are made up of distributive faults with the accumulated downthrow toward the axis of the syncline. The best view of this is shown on the west bluff of Grand River opposite the mouth of Elk River. Here the south limb dips from two to five degrees north increasing toward the axis, and shows four distinct dislocations, one being opposed to the other three, but leaving a resultant throw of 14 feet to the north. On the north side there is a faulted zone 55 feet wide in which there is an upthrow of 18 feet. But this is more than counter-balanced by three small faults, and by one with a throw of 22 feet to the south, and by the southerly dip of eleven degrees near the fault and two degrees some distance away.

At Armstrong's Ferry in sec. 24, T. 24 N., R. 22 E., Chattanooga shale is exposed at river level on the upthrow side of the southern fault plane. The fault may be seen in the bluffs. A hundred yards to the south a fissure may be seen across the road down to the ferry which has breccia cemented by silica. This probably represents a minor fracture accompanying the fault zone with the fragments cemented later.

Snider reports two minor faults of small extent and displacement, one in the southern part of sec. 16, T. 19 N., R. 19 E., and the other in the eastern part of sec. 6 of the same township.

The Locust fault begins south of Locust Grove and extends southward into Wagoner County. The west side of the fault is the downthrow side, and causes the upper part of the Boone chert on the east side of the fault to be at the same level as the Pennsylvanian formation on the west side of the fault. This gives a displacement of somewhere between 100 to 200 feet. This fault interrupts the fold originating west of the river as described before. The displacement increases along the fault to the south.

MAYES, DELAWARE, AND OTTAWA COUNTIES

The prospects for oil and gas in these counties is slight, except in Mayes County. To the west and to the north in Rogers and Craig counties oil and gas are recovered from shallow depths of 400 to 700 feet. The production is from Pennsylvanian sands, the Bartlesville and the Burgess. These formations outcrop at the surface in western Mayes County and in the extreme northwestern corner of Ottawa County. In Mayes County no production can be obtained from the Bartlesville except in the extreme northwest corner. The sand must dip beneath the overlying rocks in order to have a cover rock and the dip is not rapid enough to give that condition except in the northwest corner. In sec. 4, T. 23 N., R. 18 E., a number of wells were drilled in 1920, one of which produced five barrels of oil. The Bartlesville sand was encountered at depths from 90 to 100 feet and the Burgess sand at depths of 350 to 360 feet with intervals between of 227 to 332 feet. The depth at which the sands would be found would increase to the west. No outcrop of the Burgess was observed, but it should be found one to three miles west of the Missouri, Kansas, and Texas railroad.

Most of the production has been gas, and such is the production in the shallow pools of adjacent counties. Gas wells were drilled near Mazine in southern Mayes County but the supply soon diminished. Production varied from 50,000 to 2,000,000 cubic feet per day. One of the wells had an initial production of 175 barrels of oil. South of Inola in Rogers County there is gas in sufficient quantities to supply adjacent small towns.

Numerous wells have been drilled over Mayes County with frequent good showings of gas and oil but none have been in sufficient quantities for commercial production. Gas seeps occur in the Boone chert and several wells drilled as tests but none have produced to date. Farther to the west equivalents of the Boone have good producing horizons.

It may be said therefore, that the presence of so much oil and gas showings should indicate the presence of larger accumulations. However, the presence of such is only the prophecy of the greater accumulations to the west. One cannot expect to find large amounts of oil but small paying quantities are present which may yield returns if it is not necessary to drill too deep.

East of Grand River within the area occupied by the Boone chert a series of good reservoir sands in the Ordovician occur below the Chattanooga. However, these sandstones always contain water and any oil present has been flushed out. This applies for all three counties. The water wells of a number of the towns are drilled to the Ordovician sand generally a part of the St. Peters or Burgen. The above eliminates eastern Mayes, all of Delaware, and eastern Ottawa counties. Structures are present, reservoirs are present, and the source of oil was probably present but what oil did accumulate is now gone.

The Sylamore sandstone which is found locally beneath the Chattanooga shale is the Misener sand of the oil field. Production is possible from it but since its occurrence is not widespread or defined, the possibilities of encountering it in wells is a gamble.

Some evidence of petroleum is found in Ottawa County. Wells have been drilled 550 to 1,045 feet into the Ordovician in the northern part of the county but the sands produce only water. Asphalt which has accumulated on the floor of lead and zinc mines near Picher is collected. The asphalt drips down from fissures and through core drill holes. These deposits do not occur except where the surface rock is Cherokee shale. The deposits are found in many places, but in only a few spots in any large quantities. In one location the asphalt accumulates at the rate of 35 to 50 barrels per month. This material is utilized by the Picher Roofing Company to make a high grade roofing compound. The collection is due to gravity and seepage and to the fact that the ground water has been drained away by the mine stopes. The origin of the asphalt is from a residue of evaporated and naturally distilled petroleum. Tar Spring on Tar Creek, six miles north of Miami, is so named because of a heavy bitumen which occurs at the base of the Cherokee shale. Deposits are also noted at the base of the shale in the gravel layer just west of the city limits of Miami, and just west of Afton. These bituminous depositions indicate the former presence of petroleum and are prophetic of the productive oil fields farther to the west and south.

The above wells have been drilled in northern Ottawa County for water or to test for lead and zinc deposits. The detailed logs may be found in the bulletin on lead and zinc now in preparation by Wiedman. Many wells occur which are not listed here.

The subsurface section of western Mayes County is well described in a sample determination of a well in NW. 3/4 NE. 3/4 sec. 17, T. 21 N., R. 18 E. by F. A. Bush.*

* F. A. Bush, Personal communication in Oklahoma Geol. Survey Bull. 40-U, pp. 11-12, 1926.
Table showing the thicknesses of formations in wells drilled in northern Ottawa County.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>LEASE</th>
<th>DEPTH</th>
<th>YEAR DRILLED</th>
<th>PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW NE SW 2-19-18</td>
<td>Black and Severson, No. 1</td>
<td>354</td>
<td>1918</td>
<td>Show</td>
</tr>
<tr>
<td>SW SW SE 18-19-18</td>
<td>Claver and Dillenbeck, Warner No. 1</td>
<td>785</td>
<td>1925</td>
<td>50,000' gas</td>
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<tr>
<td>NE NW SW 23-19-18</td>
<td>Green, No. 1</td>
<td>622</td>
<td>1925</td>
<td>175 bbl. oil</td>
</tr>
<tr>
<td>S. NE SW SE 26-19-18</td>
<td>Swih, Housing No. 1</td>
<td>484</td>
<td>1925</td>
<td>1,000,000' gas</td>
</tr>
<tr>
<td>SE SW NE 26-19-18</td>
<td>White and Jefferson, No. 1</td>
<td>485</td>
<td>1920</td>
<td>1,000,000' gas</td>
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<tr>
<td>NW SW NW 26-19-18</td>
<td>Sargent, George, Seger, Boyle No. 2</td>
<td>470</td>
<td>1919</td>
<td>1,760,000' gas</td>
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<tr>
<td>SW NW NW 26-19-18</td>
<td>Campbell and Durio, Boyle No. 2</td>
<td>475</td>
<td>1924</td>
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<td>SW NE NE 27-19-18</td>
<td>Campbell and Durio, Boyle No. 1</td>
<td>523</td>
<td>1925</td>
<td></td>
</tr>
<tr>
<td>NW NE NE 27-19-18</td>
<td>Campbell, Polar No. 1</td>
<td>610</td>
<td>1924</td>
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<tr>
<td>SE NE NE 27-19-18</td>
<td>Campbell, Polar No. 1</td>
<td>591</td>
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<td>Four Star Oil and Gas, Luttrel No. 1</td>
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<td>J. L. Daxson, Drew No. 1</td>
<td>582</td>
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<tr>
<td>NE NE NE 3-20-19</td>
<td>Layne and Farnsworth, Crockett No. 1</td>
<td>583</td>
<td>1927</td>
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<tr>
<td>NW NE NE 17-21-18</td>
<td>J. W. Merritt, Price No. 1</td>
<td>702</td>
<td>1921</td>
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</tr>
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<td>SW SW NW 24-21-18</td>
<td>Mayes Oil-Gas Corp., Major No. 1</td>
<td>615</td>
<td>1928</td>
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<tr>
<td>SW NE NW 30-21-18</td>
<td>Van Nostrand, Swift No. 1</td>
<td>635</td>
<td>1923</td>
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<tr>
<td>NE NE NW 32-21-18</td>
<td>Van Nostrand, Blake No. 1</td>
<td>400</td>
<td>1924</td>
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<td>SW NW 1-2-19</td>
<td>Invader Oil Corp., Suite No. 1</td>
<td>440</td>
<td>1924</td>
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<tr>
<td>NW SW NW 32-21-20</td>
<td>Frank Partain, Sharp No. 1</td>
<td>795</td>
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</tr>
<tr>
<td>SE NE NE 4-2-21-18</td>
<td>A. J. Rose, Pog No. 1</td>
<td>508</td>
<td>1926</td>
<td></td>
</tr>
<tr>
<td>NE NE SW 18-22-18</td>
<td>Rogers Co. Dry Co., Burton No. 1</td>
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<td>363</td>
<td>1930</td>
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<td>369</td>
<td>1920</td>
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<tr>
<td>SE NE SE 4-23-18</td>
<td>Page Oil Co., J. Robinson No. 4</td>
<td>370</td>
<td>1920</td>
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</tr>
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<td>SE NE SE 4-23-18</td>
<td>Page Oil Co., J. Robinson No. 4</td>
<td>373</td>
<td>1920</td>
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Table showing thicknesses of formations, continued.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>LEASE</th>
<th>DEPTH</th>
<th>YEAR DRILLED</th>
<th>PRODUCTION</th>
</tr>
</thead>
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<tr>
<td>NE NE SE 2-23-21</td>
<td>J. T. Haggard, Byrn No. 1</td>
<td>1554</td>
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<td>SW NE 16-26-23</td>
<td>Fairland City</td>
<td>535</td>
<td>1922</td>
<td></td>
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<td>SW SW 12-27-22</td>
<td>Ottawa County Welfare Home</td>
<td>1055</td>
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<td>NE SE 24-28-22</td>
<td>Miami City, Lot 22, Block 7</td>
<td>1257</td>
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<td>NW SW 29-29-22</td>
<td>Bertha McGhee</td>
<td>1046</td>
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<td>SE 25-29-22</td>
<td>Walter Tyding</td>
<td>1500</td>
<td>1914</td>
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<tr>
<td>NE 21-29-22</td>
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<tr>
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<td>Bligham Mine well (Fisher City 1)</td>
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<td>NE 19-29-22</td>
<td>Anna Beaver Mine well</td>
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<td>1924</td>
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<td>Goodesdale Mine well, Hole No. 40</td>
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<td>Lucky Syndicate Mine well</td>
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<tr>
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<td>Pelican Mine well</td>
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<td>1926</td>
<td></td>
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<tr>
<td>SW SE 19-29-23</td>
<td>Beaver Mine well</td>
<td>1080</td>
<td>1926</td>
<td></td>
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<tr>
<td>NE NE 19-29-24</td>
<td>Risto Mine well</td>
<td>1113</td>
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<tr>
<td>SE NE 30-29-23</td>
<td>Blue Goose Mine well</td>
<td>926</td>
<td>1926</td>
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</table>
Lead and zinc ore occurs in great abundance in the Boone and Mayes limestone of northern Ottawa County. The ore is found in cavities, fissures, and interstices of flint breccia. There is a bulletin on the lead and zinc district giving complete details of the region now in preparation by the Oklahoma Geological Survey.

Tripoli occurs in the eastern part of Ottawa County adjacent to the Oklahoma-Missouri line, near Seneca, Missouri. Tripoli is a slight weight porous rock originating from weathered flint. The soluble matter present was leached out leaving the flint granules to form the body of the tripoli. The product occurs in the upper part of the Boone and probably in the Mayes formation as well where flint has occurred. The material is used as filter and when ground into powder is used for a high grade metal polish and abrasive. A good description is found in Mining World, vol. 31, no. 11, p. 552, 1909, also Okla. Geol. Survey, Bull. 28.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>CHEROKEE</th>
<th>MAYES</th>
<th>BOONE</th>
<th>CHATT.</th>
<th>PRE CHATT.</th>
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<td>18-29-24</td>
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<tr>
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<td>370</td>
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<td>100</td>
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<td>MIAMI CITY</td>
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<td>MIAMI FREMOUTH</td>
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</tbody>
</table>
LOVE AND MARSHALL COUNTIES

By

Fred M. Bullard and John S. Redfield

INTRODUCTION

Location

Love and Marshall counties are located in the extreme south-central part of Oklahoma. They are bounded on the south by Red River, on the west by Jefferson County, on the north by Carter and Johnston counties, and on the east by Bryan County. The total area is approximately 965 square miles, Love comprising 523 square miles and Marshall 442.

Literature

For a list of the principal publications relating to the geology of the area discussed in the present report, see pp. 9-10, Bulletin 39, Oklahoma Geological Survey. Bulletins 33 and 39 of the Oklahoma Geological Survey served as the source for practically all of the data and maps used in this report; up-to-date production and development data were added.

Figure 100.—Index map of Oklahoma showing location of Love and Marshall counties.

1. Department of Geology, University of Texas.
2. Fred M. Bullard, 1926.
3. Fred M. Bullard, 1926.

(Originally published as Bulletin 40-00, March, 1930).
Phylography

Love and Marshall counties lie in the Red River Plain, which is the northern border of the larger physiographic province of North America known as the Gulf Coastal Plain. The Gulf Coastal Plain extends almost entirely around the Gulf of Mexico as a broad belt of sands, clays, and limestones having a gentle slope toward the sea.

Drainage and Topography

Red River and its tributaries drain the entire area of Love and Marshall counties. The principal tributaries, from east to west, are Washita River, Duncan Creek, Hickory Creek, Walnut Bayou, and Mud Creek. The drainage which is generally to the south and east, conforms to the normal dip of the surface rocks. As a rule the streams have narrow channels with broad flood plains. Red River has a very slight gradient, averaging less than one foot six inches per mile for its extent along the southern boundary of the area.

The topography of this region is rolling to hilly. In the Criner Hills of northern Love County elevations of 150 to 300 feet above the surrounding country are not uncommon. In the Cretaceous area the maximum relief is less than 150 feet except along Red River where bluffs 200 feet above the water level are found.

The main topographic feature, other than the Criner Hills, is the Goodland limestone escarpment (see Goodland outcrop, map No. XLII). Underlying the massive, hard Goodland limestone is Trinity sand which is a loose, unconsolidated pack sand. The difference in hardness of these two formations gives rise to a pronounced escarpment where they outcrop together, the ridge being continuous and regular, usually from 75 to 100 feet high.

Another noticeable feature is the line of symmetrical hills southeast of Marietta which rise 150 to 200 feet above the valleys at their base, capped by the Main Street limestone.4

The wide, meandering bends which Red River makes are conspicuous physiographic features of the southern parts of Love and Marshall counties.

The Criner Hills of northern Love County are made up essentially of the same formations as are exposed in the Arbuckle Mountains. The limestones as a rule form the hills and the shales the valleys.

General Geologic Features

The surface rocks of Love and Marshall counties are mainly Lower Cretaceous in age, although Upper Cretaceous and Paleozoic rocks are represented in small exposures. Just to the north of this area the old Paleozoic rocks and pre-Paleozoic granites come to the surface in the Arbuckle Mountain uplift. The upper surface of the Paleozoic rocks is believed to have been worn down to a penplain prior to the deposition of the Comanchean sediments upon it, and subsequently tilted seaward. The Comanchean rocks, lapping unconformably upon the Paleozoic rocks and the pre-Paleozoic granites, represent the ancient shore line of the Comanchean sea in which practically all the rocks exposed at the surface in Love and Marshall counties were deposited as a result of the wasting and erosion of the Arbuckle Mountains and other land areas to the north.

Only the basal part of the Upper Cretaceous deposits are represented in this area, and that is in southeastern Marshall County where the Woodbine sand occupies an area of approximately three square miles. No doubt the major part of the Upper Cretaceous section was present in this area at one time since it is well developed in the area adjoining to the east and south, but erosion has removed all except the basal portion of the lowest formation.

In the Criner Hills of Love County there is a considerable area of Pennsylvanian rocks, and near Overbrook a small V-shaped area of Paleozoic rocks older than Pennsylvanian.5 In the western part of the county the Permian underlies the Comanchean but does not extend very far to the east. Well records in the eastern part of Love County show that the Comanchean lies directly upon the Pennsylvanian. If the Permian ever covered the eastern part of the county it evidently was removed by pre-Comanchean erosion.

The Lower Cretaceous rocks consist of sands, shaly clays, marls, and limestones. They form a total thickness averaging about 1,000 feet in this area. Overlying the Comanche series, and separated from it by a probable unconformity, is found the basal part of the Woodbine sand, the oldest of the Upper Cretaceous formations.

Recent alluvium, river sand, and terrace deposits along Red River represent the youngest formations found on the surface in this area.

STRATIGRAPHY

Paleozoic

On the geologic map (No. XLII) the Paleozoic area is outlined as being undifferentiated and completely surrounded by rocks of Trinity age. These regions have subsequently been worked by Dr. C. W. Tomlinson and J. A. Stone (referred to above). Some changes of areal outcrop and nomenclature have been made which will not be discussed in this report since their findings will be presented in future reports of the Oklahoma Geological Survey.

4. The name Main Street Limestone is adopted because of its priority over Bennington limestone.

5. A detailed report on the geology of the Criner Hills is now being prepared by J. A. Stone, former Assistant Geologist of the Oklahoma Geological Survey.
Formations exposed in Love and Marshall counties, Oklahoma*

<table>
<thead>
<tr>
<th>AGE</th>
<th>FORMATION</th>
<th>THICKNESS IN FEET</th>
<th>CHARACTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>GULF SERIES</td>
<td>WOODBINE SAND</td>
<td>50</td>
<td>Soft yellow to brown sandstone with large quantities of ferruginous segregations. Cross-beding is present.</td>
</tr>
<tr>
<td></td>
<td>GRAYSON MARL</td>
<td>30</td>
<td>Yellow to gray calcareous marl; lime nodules present.</td>
</tr>
<tr>
<td>MAIN ST. LIMESTONE</td>
<td>10-20</td>
<td>Massive brown-yellow limestone, massive and fossiliferous.</td>
<td></td>
</tr>
<tr>
<td>PLEISTOCENE</td>
<td>PAWPAW SAND</td>
<td>50</td>
<td>Yellow to gray sandstone with calcareous shales and numerous ferruginous layers.</td>
</tr>
<tr>
<td>WAHITA DIVISION</td>
<td>WENOClay</td>
<td>100</td>
<td>Dark gray shaly clay with thin lenses and layers of soft yellow sand.</td>
</tr>
<tr>
<td></td>
<td>DENTON CLAY</td>
<td>45-60</td>
<td>Brownish yellow clay. Thinly laminated brown sandstone with ripple marks conspicuous.</td>
</tr>
<tr>
<td></td>
<td>FT. WORTH LIMESTONE</td>
<td>40-45</td>
<td>Alternating beds of white limestone and bluish gray shale.</td>
</tr>
<tr>
<td></td>
<td>DUCK CREEK FORMATION</td>
<td>100</td>
<td>Blue-gray calcareous shale, and alternating beds of blue-gray shale and limestone.</td>
</tr>
<tr>
<td></td>
<td>KIAMICHI CLAY</td>
<td>30-40</td>
<td>Greenish yellow clay containing indurated shell breccia composed of Gypsea navia, called “edge rock.”</td>
</tr>
<tr>
<td></td>
<td>GOODLAND LIMESTONE</td>
<td>15-25</td>
<td>Massive white limestone, sometimes nodular.</td>
</tr>
<tr>
<td></td>
<td>TRINITY SAND</td>
<td>400-700</td>
<td>Fine white to yellow pack sand with occasional lenticels of red and blue shale; basal conglomerate of quartz and chert pebbles with some intraformational conglomerates.</td>
</tr>
</tbody>
</table>

PALEOZOIC ROCKS


**Pennsylvanian and Permian (7)**

The Permian-Lower Cretaceous contact is difficult of delineation because the basal member of the Trinity sand contains beds of red shale and sandstone very similar to the Permian red beds. The contact has been mapped on a quartzose conglomerate, supposed at the base of the Comanche series, but there are several conglomerates in the lower part of the Trinity formation. It is extremely difficult to determine whether the particular conglomerate in question is a basal conglomerate or an intraformational conglomerate.

It is probable that in the southwestern portion of Love County, along Red River and Mud Creek, the Pennsylvanian or Permian, or both, are represented. Much of this area is covered by alluvial material from Red River and exposures are very meager. However, investigations on the Texas side, especially at Rock Bluff crossing, indicate that a considerable thickness, 50 to 75 feet, of Pennsylvanian (upper Cisco) sandstones and conglomerates are present between the water level of Red River and the overlying Trinity sand. This establishes the fact, almost without doubt, that a considerable area in southwestern Love County must contain rocks of Pennsylvanian age. However, as above stated, much of this area is covered by alluvium, and for that reason no attempt has been made to draw any contacts.

**Cretaceous COMANCHE SERIES TRINITY DIVISION**

The Trinity sand, which represents the Trinity division in this area, is the beach or near-shore deposit of the Comanchean sea which encroached upon the land from the southeast. Due to a slow transgression of the sea, the Paleozoic rocks which underlie the Comanchean sediments were worn smooth and upon this weathered surface the Trinity sand was deposited in about the same position that it is now found.

The Trinity sand is composed of fine incoherent, white to yellow pack sands, local coarse conglomerates, and occasional lenticels of clay and shale. However, the Trinity sand is extremely variable and it is not unusual to find beds of red or blue shale, or thin calcareous sand-
stones. Silicified (or carbonized?) wood is abundant in this sand. The basal conglomerate has quartz pebbles varying from a size of a pea to three inches in diameter.

The Trinity weathers, forming a flat to gentle rolling plain. Small ravines in the Trinity are characterized by almost perpendicular sides. The Trinity sand is a water horizon, most of the water wells in this region deriving their supply from this formation.

**FREDERICKSBURG DIVISION**

**GOODLAND LIMESTONE**

The Trinity sand is overlain by the Fredericksburg division which is represented in this area by the Goodland limestone. This limestone is pure, semi-crystalline, massive, and white, and is approximately 25 feet in thickness. The Goodland outcrops in a narrow sinusous land, distributed over a large portion of the area. The Preston anticlinal uplift has brought the Goodland limestone and other formations in the lower part of the section to the surface in areas where otherwise they would be deeply buried by later sediments. The outcrop is usually in the form of an escarpment, capped by the Goodland limestone, overlooking the outcrop of the Trinity sand.

**WASHITA DIVISION**

The Washita division, which lies conformably upon the Fredericksburg division, is the highest member of the Comanche series. It is composed of marine shaly clays, marls, sandstones, and subordinate limestones, having a total thickness of approximately 415 feet. The limestone beds, although less in amount than the shaly clays, form several definite horizons that are readily traceable throughout the area, and are valuable key beds in determining the structure.

The Washita division has been mapped and differentiated as follows:

<table>
<thead>
<tr>
<th>Washita Division</th>
<th>Bokchito Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grayson marl</td>
<td></td>
</tr>
<tr>
<td>Main Street limestone</td>
<td></td>
</tr>
<tr>
<td>Pawpaw sand</td>
<td></td>
</tr>
<tr>
<td>Weno clay</td>
<td></td>
</tr>
<tr>
<td>Denton clay</td>
<td></td>
</tr>
<tr>
<td>Fort Worth limestone</td>
<td></td>
</tr>
<tr>
<td>Duck Creek formation</td>
<td></td>
</tr>
<tr>
<td>Kiamichi clay</td>
<td></td>
</tr>
</tbody>
</table>

**KIAMICHI CLAY**

Lying immediately above the Goodland limestone is a zone of about 35 feet of yellowish green clay known as the Kiamichi. The top of the formation is marked by two or three thin ledges of a hard yellowish limestone made up principally of oyster shells, *Gryphaea navia* Hall, and *Gryphaea corrugata* Say, being the most common species. The weathering of the soft clay underlying the hard shell breccia permits it to slump, breaking into large slabs which are found standing at every angle.

**DUCK CREEK FORMATION**

The Duck Creek formation, which is typically exposed on Duck Creek north of Denison, in Grayson County, Texas, consists of approximately 100 feet of limestone and gray to bluish shaly calcareous Worth limestone above. In the lower 30 to 40 feet of the formation the limestone and shaly clay layers alternate in beds averaging from six to twelve inches in thickness in about equal proportion; in the upper 50 to 60 feet of the formation the clay greatly predominate, the limestone layers become thinner and are separated by a greater thickness of clay.

A complete section of the Duck Creek is exposed in an almost vertical cliff along the west bank of Red River in sec. 22, T. 8 S., R. 2 E., Love County. A detailed description of this section is given on page 35, Bulletin 33, Oklahoma Geological Survey.

The lower portion of the Duck Creek contains an abundance of characteristic fossils, the most prominent being a large ammonite, *Desmocteras brazeeni* Co. Shumard, which occurs in a narrow zone about thirty feet above the base of the Duck Creek. This "large ammonite" horizon is a good key bed for structural work.

**FORT WORTH LIMESTONE**

The Fort Worth limestone consists of 40 to 50 feet of alternating beds of white limestone and bluish gray shale. In the lower 10 to 15 feet of the formation beds of yellowish limestone alternate with grayish to bluish shaly clay in about equal proportions. The middle portion of the formation is made up chiefly of shale while the upper part is predominantly of limestone.

The Duck Creek formation and Fort Worth limestone outcrop in two areas in Marshall County, one in the northeastern part of the county near Cumberland, and the other in the southeastern part, near Kingston. Both of these areas are synclinal in structure.

The Duck Creek and the Fort Worth outcrop in Love County in an oblong area surrounding the town of Marietta and lying in the trough of the Marietta syncline.

**BOKCHITO FORMATION**

The Bokchito formation is composed of clay and sandy clay, with beds of friable brown sandstone, siliceous shell limestone, and ferruginous concretions of sand and clay totaling 140 feet in thickness. The
Bokchito formation is the equivalent of the Denton, Weno, and Pawpaw formations of north-central Texas, which attain a total thickness of 210 feet. This rapid thinning of the sediments to the north during Bokchito time marks the beginning of the retreat of the Comanchean sea. It is interesting to note that this thinning did not begin until about the middle of Bokchito time, for the lower 70 feet of the Bokchito, the Denton clay, has the same thickness in this region as farther south.

On a basis of lithology and paleontology, the Bokchito formation is divided as follows, from older to younger: Denton clay, 55 feet thick; Weno clay, 100 feet thick; and Pawpaw sand, 45 feet thick. These are well established formation names in Texas and replace the term Bokchito in Oklahoma.

DENTON CLAY

The Denton is a brownish yellow clay, with thinly laminated layers of brown, ripple-marked sandstone, and sandstone lenses. The top is marked by a hard, brownish-yellow sandy limestone containing an abundance of fossils (Ostrea carinata and Gryphaea wushitaensis especially) and averaging one foot in thickness. Its outcrop in Love County is in a roughly circular area, lying in the trough of the Marietta syncline to the southeast of Marietta. In Marshall County it outcrops in two isolated areas, one extending southeast from Kingston and the other north and west from Aylesworth; both of these areas occupy the troughs of synclines.

WENO CLAY

The Weno is a yellowish-brown clay with thin lenses and layers of soft yellow sand. In mapping, the “Quarry” limestone, very sandy and averaging one to two feet in thickness, was considered the top of the Weno. The Weno is characterized by an abundance of clay ironstone concretions. Because the Weno weathers very easily and forms a rolling upland, it is very poorly exposed and sections suitable for detailed study are difficult to find.

The Weno like the Denton, outcrops in the troughs of the Marietta, Kingston, and Cumberland synclines.

PAWPAW SAND

The Pawpaw sand is restricted to those sediments lying between the “Quarry” limestone (uppermost Weno) at the base and the Main Street limestone at the top. The Pawpaw contains several thin lenses of highly fossiliferous, ferruginous, oxidized, soft sandstones which resemble the beds in the Weno, but the beds in the Pawpaw, while carrying many of the fossils found in the Weno, do not usually contain Turritella, while those in the Weno are composed chiefly of this gastropod. The Pawpaw weathers forming a very sandy, ferruginous soil, the iron concretions often covering the surface.

The Pawpaw outcrops are confined to a small area southeast of Marietta and two areas in Marshall County, one southeast of Kingston and the other near Cumberland—all occupying synclines.

MAIN STREET LIMESTONE

In Love County the Main Street limestone, (formerly called Bennington), brownish white, massive, and containing an abundance of fossils, is represented by two small outliers covering only a few hundred feet, capping the hills southeast of Marietta in secs. 27 and 34, T. 7 S., R. 2 E. The limestone is only a few feet thick, the remainder having been removed by erosion. The Main Street is the uppermost formation of the Comanche series in this county.

The Main Street limestone is well exposed in Marshall County in the area northeast of Woodville, along the road between secs. 7 and 8, 17 and 18, and 19 and 20, T. 7 S., R. 7 E. In the Cumberland area there are only two small outliers, capping the tops of the hills in the W. ½ sec. 6, T. 5 S., R. 6 E. The Main Street outcrops in a narrow band, 10 to 20 feet in thickness, lying directly above the Pawpaw sand and below the Woodbine sand, so that it is frequently covered by debris from the Woodbine and the Main Street is then only exposed where erosion has removed this material.

GRAYSON MARL

The Grayson marl is the uppermost formation of the Comanche series in this region. It consists of light colored, fossiliferous clays or marls with many small lumps of lime and limestone nodules, and has a total thickness of approximately 25 feet in Marshall County.

The Grayson marl is well exposed in the area north of Woodville, at the same locations as given for the Main Street limestone in Marshall County. The Grayson marl outcrops as a narrow bench or gentle slope lying directly above the Main Street limestone and is usually capped by the Woodbine sand.

GULF SERIES

WOODBINE SAND

The Woodbine sand is the basal member of the Gulf series of the Cretaceous in this region. It immediately overlies the Grayson marl and is apparently unconformable on it. The Woodbine sand is cross-bedded and is approximately 300-500 feet thick. In Marshall County only the basal portion of the Woodbine sand is present in one isolated outlier located northeast of Woodville, lying in the trough of the Kingston syncline. It is estimated that the lower 50 feet of the formation
is present capping the tops of the hills, the remainder having been removed by erosion. The Woodbine sand has been correlated with at least a portion of the Dakota formation of the Rocky Mountain region.

**Pliocene (?) Deposits**

**GRAVEL, TERRACE SAND, AND RIVER SAND**

Covering the tops of many of the hills and resting unconformably on all of the Cretaceous sediments alike is a very thin mantle of gravel. This gravel consists chiefly of quartz pebbles, well-rounded, and ranging from small gravel size up to pebbles several inches in diameter. This material has been questionably referred to as "Tertiary gravels". It seems probable that these gravels are related to a former course of some stream.

Terrace sands, gravels, and river sand occur in the valleys of the drainage systems of this area. These deposits are found in thinly scattered remnants resting unconformably upon the eroded surfaces of Paleozoic and Cretaceous rocks.

**STRUCTURE**

The structure of Love and Marshall counties is of two types: pre-Cretaceous, and post-Cretaceous. The pre-Cretaceous or in this case, Paleozoic, structures are those that were developed prior to the deposition of the Cretaceous sediments and are concealed by them. The post-Cretaceous structure is that developed in the Cretaceous sediments after their deposition.

The structure of the surface formations is that of a gently dipping monocline sloping to the south and southeast, toward the Gulf of Mexico, with the rate of dip varying from 30 to 80 feet per mile. This gentle monocline is interrupted in several places by local folds which will be discussed in detail.

There is no marked structural unconformity between the various subdivisions of the Cretaceous in this area; for this reason a fold in the beds at the surface is substantially duplicated in all of the underlying Cretaceous formations, although it may not be present in the underlying Paleozoic rocks. It seems reasonably safe to assume that the major structural features of the Cretaceous, such as the Preston anticline and Marietta syncline, are present in the underlying Paleozoic rocks. It is also likely that the smaller folds have occurred along lines of previous folding in the Paleozoic rocks, since all of these folds are parallel to one another and the lines of folding can be traced in the old rocks where they are exposed in the Crier Hills and along Turkey Creek. (See figure 103, map of the principal folds in Love and Marshall counties, page 520.)
Marietta Syncline

The outstanding structural feature of Love County is the Marietta syncline, asymmetrical in shape, with the steep side to the northeast. The axis of the syncline trends approximately due northwest. The hills southeast of Marietta, the highest of which is capped by the Main Street limestone, lie approximately in the trough of the syncline. The Sherman syncline in Grayson County, Texas, is believed to be a continuation of the Marietta syncline. Figure 101 illustrates the features of the Marietta syncline.

Preliminary work in the vicinity of Horseshoe bend, in the southern-central part of T. 8 S., R. 2 E., shows indications of folding at that point. Good southwest and northeast dips were observed on limestone beds in the lower part of the Duck Creek formation near the edge of the water level in Red River. About five miles south of the above described area, and due east of Thackerville, is another bend, known as Walnut bend. It is thought that detailed work in this area might disclose the presence of a structure similar to the one in Horseshoe bend. Subsurface work, according to Decker, indicates the possibility of an anticline with its axis roughly along the line between the villages of Burreyville and Pike.

"The Overbrook anticline" extends from central Carter County in a southwesterly direction to Red River. Tomlinson says in part that the Overbrook anticline is an overturned fold with a structural height of at least 10,000 feet, which can be traced continuously for 15 miles through the belt of Pennsylvanian rocks which lies between Ardmore and the Criner Hills."

On the geologic map the structure of the surface formations is shown by structural contours, (lines, in this case printed in red, which connect points of equal elevation above sea level on a particular bed), representing the top of the Goodland limestone. From a study of this map some additional structural features are to be found.

Preston Anticline

One of the major structural features of southern Oklahoma and north-central Texas is the Preston anticline. It is a large arch, 30 to 50 miles in length, beginning near Ardmore, Oklahoma, and extending southeastward to a point a few miles east of Denison, Texas. It is a plunging anticline with the crest of the structure near Shady and Enos, Marshall County, where a number of gas wells have been drilled. The Criner Hills are believed to represent a portion of the Preston anticline where the Cretaceous cover has been removed exposing the ancient Paleozoic core.

Oakland Anticline

The Oakland anticline is a long plunging anticlinal nose which occurs mostly in the southwest part of T. 5 S., R. 5 E., Marshall County, Oklahoma. The crest of this anticline is along Glasses Creek valley which is rimmed on both sides by the Goodland limestone forming the sides of the eroded arch.

Madill Anticline

The Madill anticline, so named from the small oil pool on its northwest end, extends in a southeasterly direction from sec. 36, T. 5 S., R. 5 E., passing 1 mile northeast of Cliff and 1 1/2 miles south of Aylesworth. Its extreme southeast end is not outlined on Plate IV but the part shown is 12 miles long. The axis of this fold dips gently to the southeast through its entire length at a rate of 20 to 40 feet to the mile. The dip on the flanks of the anticline amounts to as much as 50 feet to the mile. The trend of the Madill anticline is parallel to that of the Preston anticline from which it is separated by a broad, shallow syncline.

The Madill anticline may be a direct continuation of the Oakland anticline which has been offset by a cross fault in the underlaying rocks. This hypothesis would account for the abrupt southeasterly termination of the Oakland anticline and also for the presence of the very small Madill oil pool, as the cross fault would form an avenue of escape for oil from the petroliferous Paleozoic rocks into the Trinity sand, where it is found.

The Turkey Creek exposure of Paleozoic rocks in northwestern Marshall County is located along the northwestern extension of the Madill anticline. This part of the anticline and its northwestern continuation are frequently referred to as the Mansville-Madill anticline.

The Kingston syncline, a broad, shallow basin, separates the Preston and Madill anticlines. It is represented on the surface by a row of prominent hills which trend in a southeasterly direction extending from Kingston on the north to near Woodville. These hills occupy approximately the trough of the syncline and are composed of the youngest sediments in the area.

The Cumberland syncline lies to the northeast of the Madill anticline and is parallel to it. A row of prominent hills marks the axis of this downfold. Notably in this instance, and that of the Kingston syncline and other basins of southern Oklahoma and north Texas covered by rocks of Cretaceous age, the structural low is represented on the surface by a topographic high. Figure 102 illustrates the structural features of Marshall County.

All of the folds of Love and Marshall counties are aligned in a parallel sequence, in a northwest-southeast direction, conforming in general to the trend of the Arbuckle Mountains and Criner Hills. This fact is illustrated in figure 103, p. 520.

10. Structure contours shown in Plate I of this report were in part derived from Plate IV, U. S. G. S. Bulletin 734.
KEY HORIZONS IN LOVE AND MARSHALL COUNTIES

In working the structure of a region it is necessary to have some bed or horizon which extends over the area, and which can be easily recognized. In the portion of Love and Marshall counties covered by the formations lying above the Trinity sand, there are a number of excellent "key horizons". These key horizons, beginning with the oldest, are described in the following paragraphs.

Goodland limestone.—This is probably the horizon best suited for structural work. It is a most persistent horizon, outcrops over a broad area, maintains a fairly uniform thickness, and forms a sharp, easily recognized contact with the overlying Kiamichi clay. As a rule a flat terrace varying in width up to several hundred feet is found at the top of the Goodland, formed by the removal of the soft clay above.

"Oyster shell conglomerate."—This bed occurs at the top of the Kiamichi clay. It is a very easily recognized bed, but care must be used in working structure on this horizon as it frequently slumps and is found covering the entire slope below.

Duck Creek formation.—There are several horizons in the lower Duck Creek which may be used as key beds, the most prominent being the "large ammonite" horizon occurring about 33 feet above the base of the Duck Creek. It is a zone about 6 to 10 feet in thickness, in which the "large ammonite" Desmoeceras braasense is abundant. A massive white limestone bed about two feet in thickness, occurs in the same zone as the "large ammonite". This bed is the most prominent bed in the lower Duck Creek.

Fort Worth limestone.—There are no easily recognized horizons in the Fort Worth limestone, although the top of the formation, the contact of the Fort Worth with the overlying Denton clay, may be used as a key bed.

Denton clay.—The thinly laminated "ripple-marked" sandstone occurring near the middle of the Denton clay may be used as a key bed. It is easily located, as it frequently forms a distinct beach or terrace, due to the fact that it is harder than the remainder of the formation.

Denton-Weno contact.—The contact of the Denton and Weno is marked by a shell conglomerate composed of countless specimens of Gryphaea washitaensis and Ostrea curvata. This horizon is easily recognized and well suited for structural work.

"Quarry" limestone.—This bed, which marks the top of the Weno, may be used as a key horizon, although care must be taken to prevent confusing it with similar beds in the Pawpaw.

Main Street limestone.—Occurring near the top of the Lower Cretaceous is a yellowish-brown, semi-crystalline limestone which is
practically the only exception to a clay-sand series of several hundred feet. The Main Street (Bennington) is an excellent marker and is well adapted for use as a key horizon.

The intervals between these various horizons having been determined, elevations may of course be taken on any of them and then reduced to a common plane of "Datum".

In that portion of the county covered by the outcrop of the Trinity sand, it has been impossible to do any structural work, as thus far no beds which can be traced or recognized at other localities have been found. The variable character of the Trinity sand and also the cross-bedding and the rapid change in lithologic character tend to make structural work very uncertain.

In these counties all elevations were reduced to the top of the Goodland limestone, which is taken as the "key horizon" for the mapping of the structure.

**OIL AND GAS DEVELOPMENT**

So far as is known, no oil or gas occurs indigenously to the Cretaceous sediments in this general region. Some oil production has been obtained in the basal beds of the Trinity sand in Marshall County but this oil evidently migrated from the underlying Pennsylvanian rocks.

**Love County**

No commercial production has been obtained in Love County although it has been tested rather extensively. The eastern part of the county near the Criner Hills would not be considered favorable territory for the production of oil or gas due to the intense folding that the rocks have undergone. Oil that was present in the Pennsylvanian of this area would have escaped in the form of gas, except the heavier portions which would remain in the form of asphalt. Field investigations tend to bear out this relation, for deposits of asphalt occur in the Trinity sand adjacent to the Criner Hills.

In the Brock structure, which borders the Criner Hills to the north of Love County, oil is found in a faulted anticline. It is probable, however, that the fault sealed the reservoir rocks below and has been the most important factor in the accumulation of oil. Conditions similar to those found at Brock, while unusual, might be expected along the southwest flank of the Criner Hills in north-central Love County.

The presence of the Marietta syncline should not necessarily prevent the production of oil from the underlying Pennsylvanian rocks. The unconformity between these two systems makes it very difficult to tell anything regarding the structure of the Pennsylvanian from the
surface, and it is possible that structures favorable for the accumulation of oil are buried by the Lower Cretaceous sediments.

In the western part of the county the surface is covered by the Trinity sand, and due to the unconsolidated and extremely variable character of this formation it is nearly impossible to tell anything regarding the subsurface structure from surface outcrops. However, it is thought that there are good chances for the discovery of oil and gas in this portion of the county. An extension of the line of folding of the Hewitt, Bayou, and Healdton fields, parallel to the general trend of folding in this part of the state, extends through this western part of Love County. While any prospecting in this area must be considered strictly "wildcat" drilling it is believed that this portion of the county is favorably located with reference to oil and gas production. It is altogether probable that folds similar to the fields to the northwest are buried by the mantle of Cretaceous which covers this portion of the county.

The absence of reliable outcrops in western Love County makes it necessary to rely upon well records for information on this area. So few wells have been drilled in this portion of the county that a definite statement regarding subsurface conditions can not be made.

The collection and identification of samples would be of much value in future exploration.

See map No. XLII, for location of the various tests for oil and gas which have been drilled. These data were obtained from the files of the Well Log Division, Corporation Commission, Oklahoma City, and from the Schermerhorn-Ardmore Oil Company.

Marshall County

Marshall County has been classed as an oil and gas producing county for the past 21 years. The production of oil is chiefly from the area 1½ miles east of Madill, located in secs. 13, 14, 24 and 25, T. 5 S., R. 5 E., and the NW. ¼ of sec. 30, T. 5 S., R. 6 E., usually called the Madill or Bilbo pool, and from the SW. ¼ of sec. 25, T. 5 S., R. 5 E., the old Madill or Arbuckle pool. Although these two areas are about a mile apart, they are no doubt located on the same structure. Figure 104 is a recent oil and gas production map of the Madill (Bilbo) and the old Madill (Arbuckle) pools. The gas production in Marshall County is concentrated chiefly in the south-central part near the store of Enos and is called the Enos gas field. This area is located on the Preston fold.

MADILL POOL

A very good summary of the early development and history of the Madill oil pool and also of the Enos gas field is given in Bulletin 736 of the United States Geological Survey.11 This description is given herewith in full:

The presence of oil seeps in the region near Madill led to prospecting with the drill and finally in March, 1909, to the discovery of a small pool of oil 1½ miles east of town. Oil was discovered by the Mat-Millan Oil Co., on the Arbuckle farm, in the SW. ¼ sec. 25, T. 5 S., R. 5 E., and this pool is sometimes called the Arbuckle pool. Active drilling was begun immediately after the discovery, but the pool has not been extended beyond the limits of the quarter section although showings of oil were found in widely scattered parts of the surrounding area. By April 20, 1909, eight wells had been drilled in this pool, four of which were productive. The largest well in the pool was completed March 25, 1909, and had an estimated initial daily production of 400 barrels. During January, 1916, only one well was producing at the rate of eight barrels a day. One well was drilled through 18 inches of sand at 420 feet and abandoned dry at 460 feet during that month. The Kanok Oil Co. is reported to have completed a five barrel well at 430 feet in the northwest corner of the SW. ¼ SW. ¼ sec. 25, T. 5 S., R. 5 E., in July, 1916.

The wells here start near the top of the Goodland limestone and find the oil sand at a depth of 430 to 460 feet, presumably near the base of the Trinity sand. The oil-bearing sand is lenticular and ranges in thickness from 1½ to 20 feet. It is considered of Trinity age because the rocks above it are soft, and no fragments of shale or sandstone that might be of Pennsylvanian age could be found in the cuttings. In a report of the Oklahoma Geological Survey12, however, it is suggested that the oil-bearing sand (which Oklahoma geologists call the "Arbuckle sand") may be of Pennsylvanian age. Structurally the oil is found to the northeast of the Madill anticline. (See Plate 1). This oil pool is on what, if viewed locally, may be considered a terrace. The oil from the Madill pool is of high grade. It has a specific gravity of 0.7087 (47.5° Baumé) at 60°F and yields 80 per cent of gasoline and kerosene, about 7 per cent of paraffin, and little or no asphalt. It is 18° Baumé lighter than the average Mid-Continent crude oil.

There are approximately forty oil producers in Marshall County, most of which are in the Madill (Bilbo) field. The new wells, found northwest of the older area which is in the SE. ¼ of sec. 24, T. 5 S., R. 5 E., although producing oil of heavier gravity averaging about 40° Baumé, are on property operated and owned by the United Eight Oil Co., Geo. W. Bilbo, Cox-Hamon, Goddard Company, F. W. Merrick, Westheimer & Dauble, and Carter Oil Co. The daily average production during December, 1929, was 540 barrels. In the January 8, 1930 issue of the Kronhol Oil Review, the initial 24-hour production of the completions in the Madill area totaled 2,053 barrels.

A well log which represents average conditions in the Madill pool is given on page 525.

**Log of United Eight Oil Co.'s No. 7 Well on the I. C. Brown lease, SW., SE., SE. Sec. 24, T. 5 S., R. 5 E.**

<table>
<thead>
<tr>
<th>Formation</th>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow clay</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td>lime shale</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>blue shale</td>
<td>22</td>
<td>63</td>
</tr>
<tr>
<td>white shale</td>
<td>63</td>
<td>67</td>
</tr>
<tr>
<td>white lime</td>
<td>67</td>
<td>95</td>
</tr>
<tr>
<td>black shale</td>
<td>95</td>
<td>116</td>
</tr>
<tr>
<td>Duck Creek fm.</td>
<td>116</td>
<td>160</td>
</tr>
<tr>
<td>Kiamichi clay</td>
<td>160</td>
<td>165</td>
</tr>
<tr>
<td>Goodland l.</td>
<td>165</td>
<td>192</td>
</tr>
<tr>
<td>blue shale</td>
<td>192</td>
<td>255</td>
</tr>
<tr>
<td>water sand</td>
<td>255</td>
<td>299</td>
</tr>
<tr>
<td>white shale</td>
<td>299</td>
<td>320</td>
</tr>
<tr>
<td>water sand</td>
<td>320</td>
<td>330</td>
</tr>
<tr>
<td>blue sandy shale</td>
<td>330</td>
<td>365</td>
</tr>
<tr>
<td>water sand</td>
<td>365</td>
<td>375</td>
</tr>
<tr>
<td>blue shale</td>
<td>375</td>
<td>410</td>
</tr>
<tr>
<td>water sand</td>
<td>410</td>
<td>430</td>
</tr>
<tr>
<td>blue shale</td>
<td>430</td>
<td>490</td>
</tr>
<tr>
<td>water sand</td>
<td>490</td>
<td>530</td>
</tr>
<tr>
<td>blue shale</td>
<td>530</td>
<td>555</td>
</tr>
<tr>
<td>Trinity sand</td>
<td>555</td>
<td>581</td>
</tr>
<tr>
<td>red rock</td>
<td>581</td>
<td>584</td>
</tr>
</tbody>
</table>

Initial Production: 15 bbls. per day.

**ENOS GAS FIELD**

The following summary of the Enos Gas field is quoted from the United States Geological Survey Bulletin above referred to:

The Enos gas field is seven miles south of Kingston, Okla., near a store called Enos. Twelve or more wells have been drilled here, and most of them made at least showings of oil and gas. The gas is found more abundantly than the oil. Few of the wells were drilled to a depth of more than 800 feet. In the SW.1/4, NW.1/4 sec. 36, T. 7 S., R. 5 E., a well known as the J. C. Everett well No. 1 of the Wascomb Thorne Oil and Gas Co., was drilled to a reported depth of 600 feet. It encountered gas at a depth of 600 feet and has an estimated volume of 2,500,000 cubic feet of gas a day, but salt water drowned the gas out. The Signal Mountain Petroleum Co.'s Thomas well No. 1, in the SW.1/4 SW.1/4 sec. 36 of the same township, is said to have had a flow of 2,000,000 cubic feet of gas a day, with a show of oil at a depth of 475 feet. The Smith-Coleman well No. 1, in the southwest corner of the NW.1/4 SE.1/4 sec. 35, is reported to have had an original capacity of 5,000,000 cubic feet of gas a day, from a depth of 493 feet. It is now the only producing well in the field. A salt water sand is found directly below the oil sand, and all the wells, with the exception of this one, were drilled too deep into it. Smith-Coleman well No. 2, sometimes called the Greer well, was drilled in the SW.1/4 NE.1/4 SW.1/4 sec. 35, T. 7 S., R. 5 E., to a depth of 1,625 feet. It is reported to have encountered gas at 520 feet and showings of oil at 800, 1,000, and 1,480 feet. The log is given below.

Driller's log of Smith-Coleman well No. 2, Kingston, Okla., in the SW 1/4 sec. 35, T. 7 S., R. 5 E.

<table>
<thead>
<tr>
<th>Formation</th>
<th>Thickness Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay, red and blue</td>
<td>10</td>
</tr>
<tr>
<td>Lime</td>
<td>4</td>
</tr>
<tr>
<td>Sand, gray</td>
<td>5</td>
</tr>
<tr>
<td>Lime and boulders</td>
<td>11</td>
</tr>
<tr>
<td>Sand, yellow</td>
<td>40</td>
</tr>
<tr>
<td>Sand, blue</td>
<td>6</td>
</tr>
<tr>
<td>Sand and soapstone</td>
<td>34</td>
</tr>
<tr>
<td>Rock, hard sand</td>
<td>5</td>
</tr>
<tr>
<td>Sand, water</td>
<td>4</td>
</tr>
<tr>
<td>Lime boulders</td>
<td>1</td>
</tr>
<tr>
<td>Gas sand</td>
<td>18</td>
</tr>
<tr>
<td>Gumbo</td>
<td>19</td>
</tr>
<tr>
<td>Rock, hard</td>
<td>2</td>
</tr>
<tr>
<td>Shale, blue</td>
<td>29</td>
</tr>
<tr>
<td>Lime, shell rock</td>
<td>4</td>
</tr>
<tr>
<td>Shale, blue</td>
<td>4</td>
</tr>
<tr>
<td>Gumbo, red</td>
<td>20</td>
</tr>
<tr>
<td>Gumbo, blue; set 10-in. casing</td>
<td>5</td>
</tr>
<tr>
<td>Gumbo, blue</td>
<td>3</td>
</tr>
<tr>
<td>Gas sand No. 2</td>
<td>12</td>
</tr>
<tr>
<td>Oil sand</td>
<td>2</td>
</tr>
<tr>
<td>Gas sand</td>
<td>4</td>
</tr>
<tr>
<td>Oil sand</td>
<td>9</td>
</tr>
<tr>
<td>Oil sand</td>
<td>3</td>
</tr>
<tr>
<td>Shale, blue</td>
<td>5</td>
</tr>
<tr>
<td>Rock, hard sand</td>
<td>7</td>
</tr>
<tr>
<td>Oil sand</td>
<td>10</td>
</tr>
<tr>
<td>Sand, water</td>
<td>10</td>
</tr>
<tr>
<td>Shale, blue</td>
<td>73</td>
</tr>
<tr>
<td>Sand, hard</td>
<td>3</td>
</tr>
<tr>
<td>Rock, hard</td>
<td>1</td>
</tr>
<tr>
<td>Shale, blue</td>
<td>29</td>
</tr>
<tr>
<td>Gumbo, blue</td>
<td>51</td>
</tr>
<tr>
<td>Rock, shale</td>
<td>10</td>
</tr>
<tr>
<td>Gumbo</td>
<td>2</td>
</tr>
<tr>
<td>Rock, hard</td>
<td>14</td>
</tr>
<tr>
<td>Gumbo, white</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Formation</th>
<th>Thickness Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand, hard</td>
<td>5</td>
</tr>
<tr>
<td>Lime, hard</td>
<td>2</td>
</tr>
<tr>
<td>Gas sand</td>
<td>35</td>
</tr>
<tr>
<td>Gumbo, blue</td>
<td>32</td>
</tr>
<tr>
<td>Oil sand</td>
<td>4</td>
</tr>
<tr>
<td>Gas sand; biggest oil</td>
<td>19</td>
</tr>
<tr>
<td>Gumbo</td>
<td>10</td>
</tr>
<tr>
<td>Gas rock; bailed at 332 feet; got dry gas</td>
<td>4</td>
</tr>
<tr>
<td>Red beds</td>
<td>7</td>
</tr>
<tr>
<td>Oil sand</td>
<td>26</td>
</tr>
<tr>
<td>Rock, hard</td>
<td>3</td>
</tr>
<tr>
<td>Oil sand; good show</td>
<td>20</td>
</tr>
<tr>
<td>Red beds</td>
<td>4</td>
</tr>
<tr>
<td>Oil sand</td>
<td>15</td>
</tr>
<tr>
<td>Red beds</td>
<td>6</td>
</tr>
<tr>
<td>Oil sands</td>
<td>12</td>
</tr>
<tr>
<td>Oil sand; brown shales</td>
<td>35</td>
</tr>
<tr>
<td>Sand, hard, sandrock</td>
<td>49</td>
</tr>
<tr>
<td>Shale, hard, brown</td>
<td>3</td>
</tr>
<tr>
<td>Rock, hard</td>
<td>2</td>
</tr>
<tr>
<td>Shale, black slate</td>
<td>3</td>
</tr>
<tr>
<td>Shale, black</td>
<td>278</td>
</tr>
<tr>
<td>Sand, hard</td>
<td>10</td>
</tr>
<tr>
<td>Oil sand, dark</td>
<td>3</td>
</tr>
<tr>
<td>Rock, hard sand</td>
<td>19</td>
</tr>
<tr>
<td>Shale, sandrock</td>
<td>506</td>
</tr>
<tr>
<td>Rock, hard sand</td>
<td>3</td>
</tr>
<tr>
<td>Shale, blue</td>
<td>36</td>
</tr>
<tr>
<td>Lime shales</td>
<td>1</td>
</tr>
<tr>
<td>Rock, hard</td>
<td>2</td>
</tr>
<tr>
<td>Sand, fine black; show of gas</td>
<td>17</td>
</tr>
<tr>
<td>Shale, brown</td>
<td>3</td>
</tr>
<tr>
<td>Sand, hard</td>
<td>2</td>
</tr>
<tr>
<td>Shale, blue, sandy</td>
<td>2</td>
</tr>
<tr>
<td>Sand, black</td>
<td>23</td>
</tr>
</tbody>
</table>

The Tobe Greer well, in the SE 1/4 NW 1/4 SW 1/4 sec. 35 of the same township, was drilled to a depth of 915 feet and is reported to have yielded showings of oil at 220 and 420 feet and a volume of gas estimated at 1,500,000 cubic feet. In the southwest corner of SW 1/4 SW 1/4 sec. 25 the Roy Miliken well was drilled to a depth of 760 feet and reported a showing of about 1,000,000 cubic feet of gas and a trace of oil. In the northeast corner of the NE 1/4 sec. 2, T. 8 S., R. 5 E., the Deere well was drilled to a reported depth of 620 feet. Gas was found below 500 feet with an estimated volume of 4,000,000 cubic feet. Another well was drilled by Wascomb Thorne Oil & Gas Co. on the J. A. L. Wolff farm, in the northwest corner of SE 1/4 sec. 1, T. 8 S., R. 5 E., to a depth of 550 feet. A volume of gas estimated at 4,000,000 cubic feet was found at 500 feet, but the gas was drowned by water. In the northwest corner of the SW 1/4, sec. 6, T. 8 S., R. 5 E., two wells were drilled by the Whitewright Oil Co. The western well was drilled to a depth of 620 feet and at 540 feet encountered 18 feet of sand that made a strong showing of high-grade oil. The other well was abandoned at a depth of 360 feet.

A well 150 feet deep drilled in the northeast corner of sec. 27, T. 7 S., R. 5 E., was reported to have yielded only salt water. Favorable showings of oil were found in the Waite well, in the southeast corner of the SW 1/4 sec. 53, in the same township, which had reached a depth of 1,800 feet in January, 1918. In September, 1918, it was reported that a 100 barrel well had been completed in sec. 23 at a depth of 410 feet. In October of the same year it was reported that the Kingston Dome Oil Co.'s well No. 3, on the Anotubby farm, also in sec. 23, would make three barrels of oil a day from a sand at 431 to 432 feet, and later that the hole was lost at 1,600 feet.

The gas and best oil showing in this pool are found near the crest of the Preston anticline, (See PI. 1), at its northwest end, which is its highest part. The gas wells obtain their gas from sandy lenses in the lower part of the Trinity sand. The largest gas wells have been drilled in secs. 25, 35, and 36, T. 7 S., R. 5 E. Oil has been found in sand lenses near the base of the Trinity and also in sandy beds in black shales of the Casey (C) formation. The best oil showings have been found in sec. 23, T. 7 S., R. 5 E., in the Trinity sand.

At the present time no gas from this area is being utilized. Some gas was used for fuel in a nearby cotton gin last fall. Recent development of the gas on the Massenberg lease in sec. 26, T. 7 S., R. 5 E., by Westheimer & Daube of Ardmore will probably lead to commercial production since some of the wells are large enough to justify the laying of a line for serving fuel to Madill and Kingston; but the gas producers are now shut in.

MISCELLANEOUS WELLS

A detailed summary of oil and gas prospecting in Marshall County was published in Bulletin 39 of the Oklahoma Geological Survey, to which reference should be made by interested parties. Since 1926, when that report was published, about the only development has been in the Bihlo district and the results of this are shown by Figure 5. Map No. XI, J1 shows the location of all wells where the exact location is known. It is a general fact that either oil or gas, or both, are found several times as showings in nearly every prospect well drilled on the Madill and Preston anticlines.

FUTURE POSSIBILITIES

In regard to the oil and gas possibilities of Marshall County, Messrs. Hopkins, Powers, and Robinson have summarized the subject in a very satisfactory manner. The following is quoted from their report:

The Trinity sand underlies the entire area under consideration and, as far as known, is structurally conformable with all the overlying Cretaceous formations. This being the case, a fold that shows in the surface beds in this area must also be present in the Trinity sand. As oil and gas most commonly occur in anticlines, the folds here outlined from the study of surface formations present favorable structural conditions for oil and gas accumulation in the Trinity sand. Structure is, however, only one of the factors governing the occurrence of oil; there must be a source of oil, favorable sand conditions to permit its migration, and an imperious cap to prevent its dissipation.

The high grade of oil now found in the Trinity, the absence of organic matter in the formation, and the distribution of the oil in it prove fairly conclusively that oil has migrated into the Trinity from underlying Paleozoic formations, either from the Caney shale or from the Glenn formation, both of which are believed to underlie this area. Thus, wherever the Trinity is in contact with either of these formations an adequate source of oil is probably available. But they are in contact with the Trinity only under abnormal structural conditions where they have been folded or faulted and deeply eroded before the Trinity was deposited. Such a condition is not likely to exist in this area except near the crests of major anticlines like the Preston, Madill, and Oklahoma folds. Accordingly, it is unlikely that oil will be found in paying quantities in the Trinity anywhere in this area except on these folds, a conclusion that is corroborated in a measure by the drilling that has been done.

The Trinity has yielded prominent showings of oil and gas in this area only on these anticlines. Because of the intensity of the pre-Cretaceous folding and the depth to which these folds were eroded before the deposition of the Trinity, it is rather unlikely that much oil will be found in that formation except in favorable structural conditions. Over a broad area in Texas the Trinity constitutes an enormous reservoir of fresh, potable water; in the area here considered the Trinity contains a large supply of water, but the water is more or less salty, dubious owing to its stagnant character.

The Trinity sand contains many pervious sand beds through which the oil is free to migrate to localities where conditions favor its accumulation. In the area of the Preston, Oklahoma, and Madill anticlines, however, the Trinity is exposed at the surface and in places deeply eroded offering a mesa of escape of the oil to the surface. Surface seeps of oil are found on the Bill Easton place, 1 1/2 miles south of Rock Bluff on Red River, in the Enos gas pool, and near Madill. The exposure near Enos gas pool of more than six feet of typical oil sand, from which dark yellow oil of paraffin base may be extracted. That the Trinity has sufficiently thick clay beds at many places to prevent the escape and dissipation of all the oil and gas it contains, is indicated by the presence of these substances in the Enos gas pool and the Madill oil pool and in a broader area where favorable showings have been found. Under the existing conditions, however, only small wells may be expected.

The Paleozoic rocks are entirely concealed in Marshall County, except the small exposure which occurs in Turkey Creek, along the northern boundary of the county, previously described. Information regarding these rocks is obtained chiefly by study of the well records which have penetrated them and from a study of their exposures in the region north and west of Madill where they unconformably underlie the Trinity sand. In regard to the oil and gas possibilities of the Paleozoic rocks, Messrs. Hopkins, Powers, and Robinson are quoted as follows:

None of these formations have been definitely recognized in well borings in the Madill-DeSoto area, as no fossils have been obtained from them on the basis of lithologic similarity, however, it is possible to recognize, with more or less certainty, the Glenn and Caney formations. The nearest exposure of the Glenn is two miles northeast of Eufaula, or 11 miles northwest of Madill. There it consists of red to pale yellow shales and sandstones that strike northwest and dip 20°-30° SW. Similar rocks are found in the Dula Askew well, in sec. 8, T. 7 S., R. 4 E., Okla.; in the C. V. Westover well, in the northwest corner of Grayson County, Tex.; in the Indian Chief well, in sec. 10, T. 7 S., R. 4 E., Okla. It is probable that the Owens well, in the syncline between the Preston and Madill anticlines, encountered the Glenn formation, and that Musser well, north of DeSoto and south of the Preston anticline, passed through the basal part of that formation and entered the underlying Caney shale.

The Caney shale, characterized by its black color in fresh cuttings and dark gray color in weathered cuttings, was probably found in the Mattie Sacra wells, in sec. 17, T. 8 S., R. 5 E., Okla.; in the Dundee Petroleum Co.’s well, in sec. 9, T. 5 S., R. 6 E., Okla.; in the Bæt in well in sec. 23, T. 7 S., R. 5 E., Oklahoma; and in the Musser and Campbell wells in Gray County, Texas. The Caney well, which encountered below the Glenn formation more than 1,000 feet of black shale, probably the Caney, is less than 4 miles from the Indian Chief well, which encountered below the Glenn only red and brown shale and sandstone, probably belonging to the Glenn formation, to a depth of 2,540 feet. As the Caney is below the Glenn, the Caney must be more than 1,000 feet lower at the Indian Chief well than at the Waite well, whereas the dip of the Cretaceous between the two places amounts to only about 100 feet. The conclusion seems to be justified that along the Madill, Oklahoma, and Preston anticlines the dark shales, probably the Caney shale, were folded or faulted up and the overlying formations eroded before the Cretaceous was laid down, and subsequent folding along the old line of uplift has gently arched the Cretaceous formations. The wide area over which the black shale is found and the steep dip determined from well logs and from the exposures in the area to the northwest suggest that the old rocks may be more or less completely folded and faulted so that there is a repetition of the beds below the gentle arch in the Cretaceous. The structure of the underlying rocks may thus be too complicated to favor commercial accumulation of oil in them.

Indications of petroleum in the Caney shale are rare. There is a seep of light green oil, which is reported to make 3 or 2 barrels of oil daily, on Oil Creek, northeast of Berwyn, at the outcrop of vertical Caney shale and the Sylvan limestone. The
oil found in the Caney (1) in the Mattie Saerz well is in part 66° and in part 72° Baume' gravity and is an abnormal oil resulting from natural filtration or distillation. The oil in the Waite wells is also of high gravity. No normal oil has been found in the Caney shale.

Petroleum is known to occur in the Glenn formation in the Ardmore region, and asphalt has been extensively quarried in it east of the Criner Hills. It has been thought that the oil and gas of southern Oklahoma is derived from beds of Glenn age and that the oil in north Texas is derived from the Cisco formation. More recently it has been suggested that on account of the steep tilting of the Glenn formation in the Criner Hills and of the almost horizontal Pennsylvanian sands in the similar buried Healdton Hills, the producing sands at Healdton and elsewhere may be in a formation that lies unconformably above the Glenn, which is cut off by progressive overlap around the Arbuckle Mountains and Criner Hills. Such a formation as the one here suggested may or may not underlie the Cretaceous beds in the Madill-Denison area.

What underlies the black shale tentatively referred to the Caney formation is in doubt. The Pennsylvanian rests on Ordovician beds in the Healdton, Loco, and Petrolia fields, whereas farther south, between Port Worth and Weatherford, the Pennsylvanian overlies pre-Cambrian rocks. In the Petrolia Field and near St. Jo, in Montague County, Texas, the Ordovician is underlain by pre-Cambrian rocks. It is possible that the Madill-Denison area the Pennsylvanian will be found to rest on the pre-Cambrian.

The carbon ratios of the Pennsylvanian coals of north Texas indicate, according to Fuller, the absence of commercial accumulations of oil in the Pennsylvanian and underlying rocks of this area. Determinations of the carbon ratios are available for the Madill-Denison area, but the increase of the carbon ratio to the east probably justifies this conclusion, which is also suggested by the high gravity of the oil found here.

Oil in commercial quantities is not expected in the Caney shale, which is believed to underlie the Trinity along the high parts of the anticlines in this area, because of the absence of suitable reservoirs, the highly folded character of the rocks, and the intense metamorphism which they have undergone as inferred from the carbon ratios of the Pennsylvanian coals in the area to the west. The Glenn formation, which probably occurs below the Caney on the anticlines in this area, does not seem to offer any more favorable source of oil, because of its structural position and the probability that it has been strongly metamorphosed. Attempts to drill deeper than the Caney involved great hazards because of the unknown but probably complex structure of the Paleozoic rocks, because the succession of beds below the Caney is not known, and because of the high degree of metamorphism which the rocks have probably undergone.

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**CHEROKEE AND ADAIR COUNTIES**

By

Ira H. Cram*

**INTRODUCTION**

Although drilling for oil or gas has met with little success in Cherokee and Adair counties, Oklahoma, these counties are of particular interest to the oil fraternity for it is in these counties that one may study at the surface the character and structure of many of the formations that are penetrated by the drill in the oil pools to the west. It is, therefore, the purpose of this paper to compile briefly the important information on the geology of these counties contained in the published accounts, and to add what little information the writer has been able to gather by field studies.

The following published reports deal with the general geology of Cherokee and Adair counties:


Following are important papers dealing with the oil and gas resources or stratigraphy of these counties:


Brotz, Robert, A comparative faunal chart of the Mississippian and Morrow formations of Oklahoma and Arkansas: Oklahoma Geol. Surv. Cir. 18, 1929.

*Geologist, Fure Oil Co., Tulsa, Oklahoma. Published by permission of the Chief Geologist of the Fure Oil Co.

(Originally published as Bulletin 40-QQ, May, 1920)
The physiography of the area has been well described by Taff and Snider. The southern part of the area is in the Boston Mountain plateau; the northern part is in the Springfield plain. Briefly, the area is a rather deeply dissected plateau. Elevations range from 1,500 feet in eastern Adair County to 500 feet along the Grand and Illinois Rivers. The entire area lies in the drainage basin of the Arkansas River. The western part of Cherokee County is drained by the Grand (Neosho) River. The Illinois River and its main tributary, Barren Fork, drain the remainder of the area except for the southeastern portion which is drained by Sallisaw and Little Lee Creeks.

**STRATIGRAPHY**

**SURFACE FORMATIONS**

**CANADIAN (1)**

**DOLOMITIC LIMESTONE**

Character and distribution. Along the lower course of Rock Branch in sec. 7, T. 19 N., R. 25 E., dolomitic limestone underlying the Burgen sandstone is excellently exposed. So far as known this is the only exposure of the base of the Burgen in the area under consideration. The rock is a very finely crystalline, hard, massive dolomitic limestone. The upper part appears finely laminated as a result of weathering, and contains some edgewise conglomerate. Some layers appear cherty, but no chert was observed. Occasional sandy spots were noted. The top of the formation is some 25 feet above the Illinois River, but only the upper 15 feet of the formation are exposed.

Age and correlation. The dolomitic limestone just described is entirely unlike any of the Tyner or Burgen dolomitic limestones, but resembles very closely the upper Arbuckle limestone of the Arbuckle Mountain area, Oklahoma. Unfortunately no fossils were observed, and correlations must, therefore, be made on the position and lithology of the formation. On these two criteria this limestone is tentatively correlated with part of the upper Arbuckle limestone of Canadian age.

North at Spavinaw, Oklahoma, cherty dolomite the age of the "Swan Creek zone" of the Cotter formation in Missouri of Canadian age is exposed, and just west of Flint, Oklahoma, about 2 miles north of the north line of Adair County, in a small tributary of Flint Creek, about 25 feet of fine grained dolomite resembling somewhat the Spavinaw occurrence underlie white sand of the Burgen type. In the absence of fossils the exact correlation of these eastern Oklahoma occurrences of pre-Burgen rocks cannot be told. It is probable that they

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are of Canadian age, but they need not be strictly contemporaneous in spite of their occurrence at the top of the Canadian, for Canadian time was followed by a period of warping and peneplanation which in places removed considerable thicknesses of the Canadian before the advent of Ordovician seas. Furthermore, the various formations of Canadian age are themselves separated by unconformities. Thus, in northern Arkansas the Canadian section is, in descending order, Black Rock limestone, 200 feet; Smithville limestone, 200 feet; Powell limestone, 200 feet; Cotter dolomite, 500 feet; and Jefferson City dolomite, 400 feet; but the Black Rock and Smithville are only developed locally, and the Powell is locally absent. It is probable that similar conditions exist in eastern Oklahoma making each exposure of Canadian rock a difficult problem in correlation.

Stratigraphic relations. The contact of the Canadian (?) limestone with the overlying Burgen sandstone is very sharp, and only slightly undulating. Strata above and below the contact are perfectly parallel. There can be no doubt that the relation is one of unconformity.

ORDOVICIAN
BURGEN SANDSTONE

Character and distribution. The Burgen sandstone is exposed in four anticlinal folds along Illinois River. The type locality of the formation as described by Taff 4 is Burgen Hollow about 6 miles northeast of Tahlequah. He described the formation as being composed entirely of sandstone, and attaining a thickness of over 100 feet. Apparently the basin is not exposed in this area. The writer has not seen the Burgen in its type locality, but along the eastward flowing stream in sec. 1, T. 17 N., R. 22 E. he measured the following partial section:

### Section of Burgen sandstone, sec. 1, T. 17 N., R. 22 E.

<table>
<thead>
<tr>
<th>Description</th>
<th>Ft</th>
<th>In</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burgen Sandstone (contact with Tyner indefinite)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Sandstone; white to ferruginous, hard, massive, fine and even grained, mostly angular, makes ledge and water falls</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>15. Sandstone; white, somewhat ferruginous, even bedded in 5° layers, fine, angular, somewhat friable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Sandstone; thin and unevenly bedded, somewhat shaly, merges with above</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>13. Sandy shale; green, heterogeneous, full of rounded quartz grains</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>12. Covered; probably sandstone or shaly sandstone</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>11. Sandstone; white, fine grained, massive, somewhat ferruginous</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>10. Sandstone; white to green, interbedded with sandy green shale</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

(Continued on page 535)

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### Section of Burgen sandstone, cont'd.

<table>
<thead>
<tr>
<th>Description</th>
<th>Ft</th>
<th>In</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Sandy shale; alternating thin laminae of green shale and sand</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>8. Shaly, sandy dolomite limestone; looks conglomeratic</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>7. Calcareous sand; white, hard, thin bedded; thin shale bed at base; few pelecypods</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>6. Calcareous sand; white, very hard; many pelecypods</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>5. Shale; green, hard, slaty; rare streaks of sand</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>4. Interbedded green shale, sandy shale, shaly sand, thin hard sandstone and hard sandy dolomite limestone; more shaly near top</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3. Sand; white, hard, very fine grained</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2. Sandy dolomite limestone; buff, very hard, numerous cephalopods</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1. Sand; white, very fine grained</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Covered to river | 6  | 0  |

Across the river in sec. 31, T. 18 N., R. 23 E., the top of the Burgen is 100 feet above the river. Here the upper half resembles the section just described, but the lower half is so obscured by slump from the upper beds that its character can scarcely be detected. It is probably sandstone. From this locality the Burgen plunges northward, but soon rises to the surface again in the vicinity of sec. 2, T. 18 N., R. 23 E. Here the writer measured the following partial section:

### Section of Burgen sandstone, sec. 2, T. 18 N., R. 23 E.

<table>
<thead>
<tr>
<th>Description</th>
<th>Ft</th>
<th>In</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burgen Sandstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Sandstone; thin bedded, possibly somewhat shaly</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>5. Covered</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4. Sandstone; brown, massive</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>3. Dolomite limestone; buff, very fine grained, hard, massive</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>2. Sandy dolomite limestone; buff, very sandy</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>1. Sandstone; massive, exposed to creek</td>
<td>12</td>
<td>0</td>
</tr>
</tbody>
</table>

### TYNER FORMATION

<table>
<thead>
<tr>
<th>Description</th>
<th>Ft</th>
<th>In</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burgen Sandstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Sandstone; thin bedded, possibly somewhat shaly</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>5. Covered</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4. Sandstone; brown, massive</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>3. Dolomite limestone; buff, very fine grained, hard, massive</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>2. Sandy dolomite limestone; buff, very sandy</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>1. Sandstone; massive, exposed to creek</td>
<td>12</td>
<td>0</td>
</tr>
</tbody>
</table>

Time was not available to map in detail the Burgen along Illinois River in the Sillou Springs quadrangle; hence, the area of undifferentiated Burgen and Tyner on the geologic map. Along Illinois River at the base of the road cut in sec. 16, T. 19 N., R. 24 E. the following section was measured.

### Section of Burgen sandstone, sec. 16, T. 19 N., R. 24 E.

<table>
<thead>
<tr>
<th>Description</th>
<th>Ft</th>
<th>In</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chattanooga Shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burgen Sandstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Sandstone; more thin bedded, possibly somewhat shaly; contact with Chattanooga not seen, but Chattanooga is exposed not over 5 feet above</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

(Continued on page 536)
Section of Burgen sandstone, Cont'd.

10. Sandstone; soft, friable .......................... 4 0
9. Covered ............................................ 3 0
8. Sandstone; white, soft ................................ 1 6
7. Sandy dolomite limestone; brown, quite sandy; contains many cephalopods ............. 1 6
6. Dolomite limestone; brown, finely crystalline with blotches of more crystalline dolomite .. 3 6
5. Dolomite limestone; brown, very finely crystalline; thin bedded .......................... 6 6
4. Sandy dolomite limestone; buff to brown, massive, like bed 2 but upper few feet are harder and less sandy ........................................... 10 0
3. Sandstone; soft, coarse, made up of rounded frosted quartz grains ......................... 3 0
2. Sandy dolomite limestone; buff, very fine grained, with many disseminated rounded sand grains ............................................... 2 0
1. Sandstone; white, soft, massive, top few inches very hard; exposed to river .......................... 9 0

From this locality the Burgen plunges northward and eastward, but soon rises to the surface in the northwestern part of T. 19 N., R. 25 E. Along Rock Branch, in sec. 7, T. 19 N., R. 25 E., the writer measured the following excellently exposed section:

Section of Burgen sandstone in sec. 7, T. 19 N., R. 25 E.

CHATTANOOGA SHALE
SYLAMORE SANDSTONE

8. Sandstone; conglomeratic, pebbles of green shale ........................................ 2 6

BURGEN SANDSTONE

7. Sandstone; alternating soft and hard in thin beds; some of the softer layers are greenish and somewhat shaly; near the middle a zone of cephalopods .................................................. 7 0
6. Sandstone; brown, in part black, soft, friable ................................................. 3 0
5. Sandstone; hard .................................... 1 0
4. Sandstone; soft .................................. 2 0
3. Sandstone; hard, massive ......................... 1 0
2. Sandstone; thin bedded .......................... 2 0
1. Sandstone; hard, massive; makes cliff overlooking Illinois River .................. 44 0

CANADIAN (1) DOLOMITIC LIMESTONE

Dolomite limestone; very finely crystalline, hard, massive; the upper part appears thin bedded as a result of weathering and contains some edgewise conglomerate; some layers appear cherty but no chert was observed; occasional sandy spots; exposed ......................................... 15 0
Covered to river ...................................... 10 0

A small patch of Burgen is brought to the surface by folding in secs. 9 and 16, T. 19 N., R. 25 E.

The cephalopods found in bed 7 of the above section appear to be identical with those found in bed 7 of the section exposed in sec. 16, T. 19 N., R. 24 E., and identical with those found in bed 2 of the section exposed in sec. 1, T. 17 N., R. 22 E. On the basis of this zone of cephalopods one may reconstruct a complete section of the Burgen by adding to the base of the first measured section described beds 1 to 6, inclusive, of the last section described. This gives a thickness of 96 feet 3 inches for the total thickness measured by the writer.

The presence of a zone of dolomite limestone, sandy dolomite limestone, green shale and shaly sandstone near the middle of the Burgen changes the prevalent conception that the Burgen is pure saccaroidal sandstone. This zone is rather widespread. The writer has noted it in several wells drilled west of Cherokee County (see figures 106 and 107, pp. 543 and 553).

Age and correlation. The following fossils collected by the writer from bed 6 of the Burgen exposed in sec. 1, T. 17 N., R. 22 E., have been identified by Ulrich.

- *Matheria* n. sp. (a Black River genus)
- *Palloraconcha* sp. (very much like a Cincinnati species but not good enough to identify with certainty)
- *Raphistomina* sp. (scarce and distinguishable from *R. denticulata* a Black River species)
- Fragment of last whorl of a large shell that suggests a *Lopha* sp. like *L. amphi* and *L. tropidophora*, both Richmond species.
- *Patelloid* sp. not very different from the Black River species *Patella* sp., *Halma* sp.
- *Bretania* sp. with different from the Black River species *Halma* sp.
- *Pinctada* sp. like *P. santipauli* (abundant)
- *Apaches* sp.

The cephalopods collected by the writer (see measured sections) according to Ulrich probably belong to a new genus with peculiarities that require more study.

Apparently it combines some old characters with other features that appear mainly in Trenton and younger deposits.

In view of the prevailing opinion that the Burgen corresponds to the St. Peter, it is disappointing to find that none of the pelecypods is specifically the same as any of the St. Peter genus. Besides these pelecypods the rock yielded one specimen each of three gastropods which again have no representatives in the St. Peter of Minnesota.

As you doubtless know, I have long insisted that the Burgen does not fall into the place to which it is usually assigned by Oklahoma geologists—that is about the middle of the Simpson. It is either older than the base of the Simpson and of the age of some part of the Buffalo River series, or it is much younger—probably Black River. The fossil evidence is lamentably indecisive and really goes little farther than to prove the Ordovician age of the Burgen. Nor do we get any quite satisfactory help from the paleogeographic aspects of the problem. The St. Peter
waters doubtless came in from the south, the Decorah from the north, and as there is no satisfactory evidence to show that the Burgen connects laterally with any member of the Buffalo River series, and as no species of fossils is known to be common to them, there remains no compelling reason for placing the Burgen beneath the Black River. Moreover, the ostracodes, and in fact the preponderance of the faunal evidence as a whole, favor Black River. On the other hand, the Burgen cephalopods suggest primitive stock; but that may mean only that they are modified descendants of their northern ancestors whose early Ordovician history is unknown. No faunas of northern origin of that date have yet been discovered. Besides, the Burgen cephalopods are not closely related—even genetically—either to the St. Peter species figured by Sarsden or to the three new genera that I am describing from a limestone in northwest Arkansas that must be very nearly of the age of the St. Peter.

In view of these facts I am, somewhat reluctantly, I confess, forced to the conclusion that the Burgen is a much younger deposit than the St. Peter and probably that it is represented in the Arbuckle region by the sandstone that is locally developed, especially on the northeast flank of that uplift, at the base of the Bromide and above the Criner. The sand probably was blown in from eroding surfaces of Buffalo River sandstones on the west side of the Ozark uplift, which we have every reason to believe was emerged at that time.6

In view of the indefiniteness of the correlation of the Burgen sandstone the name Burgen should be applied to the eastern Oklahoma beds rather than St. Peter. Ulrich's suggestion that the Burgen is the basal sandstone of the Bromide formation of the Simpson group is not entirely out of line with subsurface evidence, but if the writer's suggestion that the lower Tyner is lower Simpson in age proves to be correct, the Burgen must be older than Ulrich suggests it to be. Possibly it is the basal sandstone of the Oil Creek formation of the Simpson group.7 (See pages 545, 546 and Map No. XLV.)

Stratigraphic relations. The Burgen overlies unconformably the Canadian (?) dolomite. The upper contact of the Burgen is seldom exposed, and its stratigraphic relations to the Tyner formation are thus uncertain.

TYNER FORMATION

Character and distribution. The Tyner formation is exposed in four anticlinal areas. It receives its name from Tyner Creek which empties into Barren Fork in the vicinity of Proctor. The Tyner Creek section is poor. Here at the top of the formation just below the Sylamore sandstone are approximately 6 feet of brown to gray, finely crystalline, dolomitic limestone underlain by two feet of buff, very finely crystalline, dolomitic limestone, the top 3 inches of which are cherty and sandy. The interval from the base of this bed to the creek bed is approximately 30 feet, but the exposures are poor. This interval ap-

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pears to be mainly shale, with a few sandstone beds. A one-foot bed of sandstone was noted at one locality 4 feet below the upper limestones. A much better section was measured by the writer in the railroad cut on the north bank of Barren Fork in sec. 9, T. 17 N., R. 24 E.

Partial section of Tyner formation in sec. 9, T. 17 N., R. 24 E.

SYLAMORE SANDSTONE MEMBER OF CHATTANOOGA FORMATION

16. Sand; hard, tight, conglomeratic, impure
17. Clay; soft, ferruginous; an ancient soil

TYNER FORMATION

14. Dolomite limestone; brownish gray, finely crystalline, massive; about 3 feet from top is small lens of sublithographic brownish gray limestone; basal 5 inches are harder and weather as part of bed 15; the base is cherty .8

15. Sandstone; top 6 inches very hard, cemented with siliceous carbonate; the middle is soft, white, honeycombed; the basal 1½ inch is harder but not as hard as the top

12. Dolomite limestone; brown, very finely crystalline

11. Shale; dark gray, hard, somewhat dolomitic

10. Sand; white, hard, porous, fine grained with imbedded large round quartz grains; becomes shaly toward base, massive

9. Argillaceous dolomite; greenish gray, very finely crystalline; grades downward into hard dolomitic shale which breaks with a conchooidal fracture; basal ½ inch sandy and shaly

8. Shale; green, weathers variegated, shaly

7. Sandy shale; green, hard, very sandy

6. Sandy dolomitic limestone; brown, very finely crystalline

5. Shale; green, fissile, containing a few sand beds especially toward base

4. Magnesian limestone; brown, hard, very finely crystalline, slightly sandy, thinly laminated; fragments of pelmecyphila

3. Shale; green fissile, weathers variegated; occasional sandy streaks

2. Magnesian shale; green, conchooidal fracture, hard; much like basal part of bed 9

1. Sandy dolomitic limestone; brown, massive, becomes very sandy toward base grading into white sand; exposed

Covered to water level

---

The writer has not seen the Tyner exposed in Baumgartner Hollow. According to Taff, some 20 feet of interbedded brown sandstone, calcareous sandstone, and bluish or greenish shale are exposed.8

The complete section of the Tyner formation is exposed along Illinois River just northeast of Tahlequah. The section given below is

a composite section containing the data on several measured sections. Beds 1 to 19, inclusive, were measured at the Eagle Nest in the SW 1/4 sec. 13, T. 18 N., R. 22 E.; beds 20 to 35, inclusive, were measured along the road ½ mile south, and the information contained under beds 36 and 37 is a summary of the data gathered on the upper Tyner beds.

Composite section of the Tyner formation exposed in the anticlinal area along Illinois River northeast of Tahlequah.

FERNAVAL LIMESTONE

19. Limeomite; light gray, coarsely crystalline, highly fossiliferous; absent along Eagle Bluff in secs. 24 and 15, T. 18 N., R. 22 E.; maximum thickness noted 10 ft. 0 in.

FITE LIMESTONE

38. Limeomite; light gray, subbituminous, hard, with biotomes of crystalline calcite; often near the middle contains a lens of brownish fine grained dolomite limestone; sparingly fossiliferous; thickness rather constant where protected from pre-Chattanooga erosion by Fernvale limestone; maximum noted 8 ft. 0 in.

TYNER FORMATION

37. Dolomite limestone; gray to brown, finely crystalline, very hard, massive; often near middle contains a lens of brownish gray dense textured limestone, varies in thickness from 6 to 12 feet.

36. Chert and cherty dolomite; varies from a chert bed 6 inches thick to a cherty dolomite; marks a distinct change in sedimentation; always present at base of bed 37; maximum thickness noted 1 ft. 6 in.

35. Dolomite limestone; brownish, very finely crystalline, massive, may be absent locally; the thin black sandstones and black sandy dolomite limestones noted in many localities prove to be the same as bed 34; maximum thickness 2 ft. 0 in.

34. Sandy dolomite limestone; brown to black, very hard, slightly sandy 6 ft. 0 in.

33. Sandstone; white to gray, heterogeneous, unassorted, a little calcareous cement, massive 2 ft. 0 in.

32. Dolomite; grey, buff, very finely crystalline, earthy, much less hard than above dolomites, massive 2 ft. 0 in.

31. Shale; green, hard, fissile, very slightly sandy 1 ft. 0 in.

30. Dolomite shale; greenish, very hard, breaks with conchoidal fracture, approaches argillaceous dolomite 6 ft. 0 in.

29. Dolomite limestone; buff, very finely crystalline, earthy, massive 2 ft. 0 in.

28. Shale; green, slightly magmatic, conchoidal fracture 1 ft. 0 in.

27. Sandy shale; green, quite sandy (Continued on page 541)
between this lower Tyner sequence and the Burgen could scarcely be more than 10 feet. Adding 10 feet to the total thickness of the above section gives a thickness just 2 inches less than 91 feet for the total Tyner section known to the writer.

The Tyner formation dips northward from the Eagle Nest, and is below the surface at a point about 1½ miles to the northeast. It soon rises again in the vicinity of the NE.¼ sec. 5, T. 18 N., R. 23 E. The Tyner gradually disappears to the northeast due to pre-Chattanooga folding and penepelation. The upper Tyner dolomitic limestones have not been seen north of the Eagle Nest. In sec. 2, T. 18 N., R. 23 E., the Tyner is only about 40 feet thick, and is composed mainly of shale. There is Tyner along the west bank of Illinois River in T. 19 N., R. 23 E., and some in sec. 18, T. 19 N., R. 24 E., but in sec. 10, T. 19 N., R. 24 E., the Tyner is completely absent, unless a covered zone 5 feet thick between the Burgen and Chattanooga happens to be Tyner. This seems improbable. In the Ordovician exposure along Rock Branch the Chattanooga formation rests upon middle Burgen, and there is no evidence of Tyner in the exposure of pre-Chattanooga rocks just west of Flint.

A significant fact concerning the stratigraphy of the Tyner formation is the existence of a distinct break in sedimentation at the base of bed 14 of the Barren Fork section and its equivalent, bed 36 of the Illinois River section. This break is marked by the distinctly cherty character of the basal portion of the upper dolomitic limestones, and by a distinct change in sedimentation. The beds just above the break are hard, massive, finely crystalline dolomitic limestones; those below are shales, sandstones, and dolomitic limestones that are softer and more fine grained than the upper beds. Apparently the upper dolomitic limestones do not rest upon the same bed in all cases. In many exposures along Illinois River a thin bed of black sandstone or black sandy dolomite underlies the cherty bed, but in several places a bed of very finely crystalline dolomitic limestone intervenes.

Another possible break in sedimentation in the Tyner is at the top of bed 7 of the Illinois River section. The earthy dolomites below the top of bed 7 are quite unlike any of the superjacent beds in that they are softer and oftener more coarsely crystalline. Occasionally the upper beds of this series, both in wells and at the outcrop, are glauconitic, and the shales overlying these beds in wells are usually in part red. So many beds of the Tyner shales weather into variegated colors that it is impossible to tell at the outcrop which bed, if any, would be red if unweathered. The different lithology of these lower Tyner dolomites, the glauconitic nature of some of them, and the presence of a zone of red shales immediately above them in wells suggest a break in sedimentation.

For the sake of convenience the Tyner may be divided into upper, middle, and lower parts. The upper Tyner is composed of beds 36 and

37 of the Illinois River section, the middle Tyner is composed of beds 8 to 35, inclusive, and the lower Tyner is composed of all beds between the base of bed 8 and the top of the Burgen sandstone.

The Tyner formation is widespread underground in Oklahoma. The section penetrated in the Shell Petroleum Corporation's No. 1 Owens, in the NW.¼, NE.¼, sec. 25, T. 16 N., R. 19 E., is remarkably similar to the section exposed along Illinois River, except that the beds are thicker than at the outcrop. This is well shown in figure 106. Map No. XLV gives the writer's conception of the changes which the Tyner undergoes when traced southward and westward underground in Oklahoma. The broader relations of the Tyner will be discussed in subsequent paragraphs.

![Figure 106. Northeast-southwest section of pre-Chattanooga formations through Cherokee and Adair counties, Oklahoma.](image)

**Age and correlation.** The Tyner formation is sparingly fossiliferous. Near the center of sec. 2, T. 17 N., R. 22 E., Ulrich collected from "dolomitic sandstone" (bed 37 of the writer's Illinois River section), *Camarocladia rugosa*. From the underlying cherty dolomite fauna:

Ulrich regards *Camnacadia rugosa* as a dependable guide fossil of the upper Decorah (upper Iowa member), and states that the fauna of the cherty dolomite indicates Black River. Thus the evidence collected to date indicates that the upper Tyner is Black River in age. Subsurface evidence is entirely in accord with this conclusion.

The main part of the Tyner formation (beds 1 to 35, inclusive, of the Illinois River section) has to date proved to be practically unfossiliferous. Fragments of pelecypods from bed 25 of the Illinois River section and from bed 4 of the Barren Fork section were observed. Samples were collected from every bed of the Tyner and examined for microfossils in the laboratory, but none was observed. In Baumgarner Hollow (south side sec. 32, T. 18 N., R. 23 E.) Ulrich* found a ledge of sandstone containing:—

"a few imprints of undeterminable species of pelecypods and better moulds of an orthid with simple plications that suggests Dimorthis species (a) high Decorah fossil, but may be a Pleurodictys. Its only value is that it tends further to establish the presence of late Decorah beds in the Tyner."

On the bank of Barren Fork in the southwest corner of sec. 10, T. 17 N., R. 24 E. Taff found a layer of roughly laminated sandstone crowded with fairly good casts of shells. Taff was not more specific than to state that the "layer lies under the Chattanooga shale." Concerning these fossils Ulrich says*:

There are three species of *Pullocha* closely allied to and, with such material, practically indistinguishable from *P. subovalis*.* P. incisa*, and *P. sinnata*. Then there is a species of *Modiolopsis* related to *M. myrioides*, a Trenton fossil; a *Whitecoria* that is not very near any described species; and a *Rhytima* that is not well enough preserved for exact determination. With nothing more to go on I think can of no other horizon than late Cincinnati or early Richmond.

In the light of the writer’s studies of the Barren Fork section the presence of Cincinnatian rocks seems improbable. The writer did not do detailed work in sec. 10, but in sec. 9, T. 17 N., R. 24 E., studied a section of Tyner underlying Chattanooga shale, the upper bed of which is undoubtedly the equivalent of beds 36 and 27 of the Illinois River section which on paleontologic and subsurface evidence are known to be of Black River age. If Cincinnatian beds are present in the writer’s section (page 539) they must be the beds diagnosed as Sylamore.

However, the lithology of the Sylamore in this section is quite unlike that of the fossiliferous sandstone collected by Taff, and furthermore, it is difficult to believe that a thin deposit of Cincinnatian sandstone could have withstood pre-Chattanooga erosion. It would seem that either beds of Cincinnatian age come into the section in sec. 10, T. 17 N., R. 24 E., or that the fossils do not faithfully portray the age of the rock. In view of the Cincinnatian aspect of some of the St. Peter pelecypods it is possible that Black River or Chazyan species may partake of these characteristics when environmental conditions are right.

It is unfortunate that Taff did not include a measured section with his collection. Until the exact stratigraphic position of his collection is determined it is believed that based on the writer’s studies in sec. 9, T. 17 N., R. 24 E., and regional stratigraphic and structural considerations it is most logical to assume that Taff’s collection came from beds below bed 14 of the Barren Fork section, and that the Cincinnatian aspect of the fossils is due to the poor preservation and to the tendency of certain early Ordovician species to partake of Cincinnatian characteristics.

A great deal of subsurface data is available on the correlation of the Tyner formation (page 542) and its relation to the Simpson group of beds of the Arbuckle Mountain sequence. This data is summarized in Map No. XLV. The Tyner formation is the northeastern fringe of the Simpson. The upper Tyner is readily traced into the Bromide formation of the Simpson group. According to the writer’s interpretation of underground conditions the middle Tyner shales are gradually replaced by sandstone (“Wilcox” sand) to the west of the outcrop. Accompanying this lateral gradation sandstone beds not strictly contemporaneous with the middle Tyner probably come into the section above and below the equivalent of the middle Tyner. Thus the middle Tyner loses its identity in a thick body of sand as it is traced toward the Arbuckle Mountains, but it is probable that it is Black River in age. If this is true the stratigraphic break at the top of the middle Tyner is not of great time value and is represented in the Arbuckle Mountains by Black River sediments.

The possible stratigraphic break at the base of the middle Tyner (page 542) is herein considered to be the boundary between Black River and Chazyan deposits in eastern Oklahoma. The evidence for the Chazyan age of the lower Tyner is not conclusive but decidedly suggestive. Microfossils found in wells below the red shale in the lower Tyner dolomitic limestone are decidedly suggestive of lower Simpson, hence Chazyan, rather than Black River. A red shale found below the thick ‘Wilcox’ sand section of the Seminole-Wewoka area is interpreted to be the same bed as the red shale so widespread in the basal part of the middle Tyner in northeastern Oklahoma. Granting that this correlation is correct, the lower Tyner belongs far down in the Simpson, and is Chazyan in age. The red shale has not been noted south of

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Wewoka in the immediate vicinity of the Arbuckle Mountains. If it represents a break in sedimentation, its absence in the Arbuckle area can be logically interpreted to mean that the Arbuckle section is complete and without breaks of the magnitude represented by the red shale farther north.

To summarize; the upper Tyner formation is of Black River age as proved by fossils collected at the outcrop and by underground tracing of beds. The middle Tyner is probably Black River in age as suggested by subsurface studies. The lower Tyner is possibly Cazy in age. This correlation is based upon the presence of a probable stratigraphic break at top of the lower Tyner, upon the different lithology of the lower Tyner, upon the meager microfaunas found to date in wells in the lower Tyner, and upon the tracing of the red shale of the middle Tyner and underlying beds toward the Arbuckle Mountains.

Stratigraphic relations. The Tyner formation is overlain by the Fite limestone in the vicinity of the great bend in the Illinois River just northeast of Tahlequah, but the Fite is absent because of pre-Chattanooga erosion at the Eagle Nest, and the Chattanooga rests upon the Tyner from this point northward and eastward. Farther eastward the entire Tyner is cut out. See figures 106 and 107. In the Barren Fork area the Chattanooga rests upon the upper Tyner dolomitic limestones. The contact of the Tyner with superjacent beds is in all cases one of unconformity.

The basal contact of the Tyner is seldom, if ever, accurately located, and, therefore, the stratigraphic relations of the Tyner formation to the underlying Burden sandstone are uncertain.

FITE LIMESTONE

Name. Taff included in the upper part of his Tyner formation of the Illinois River area a group of limestones the upper bed of which is distinct both in lithology and fauna from the underlying beds. Because this bed is so distinct and because it is absent in the type locality of the Tyner it is herein termed the Fite limestone from excellent exposures on the estate of Dr. Fite in sec. 11, T. 17 N., R. 22 E.

Character and distribution. The Fite limestone is a hard, light gray sublithographic limestone attaining a thickness of 8 feet where protected from pre-Chattanooga erosion by the Ferneale limestone. Blotsches of crystalline calcite within the sublithographic matrix are almost invariably present, and often near the middle of the bed there is a lens of brownish fine grained dolomitic limestone. Fossils are rare and fragmentary. The Fite limestone occurs only in the anticlinal area just northeast of Tahlequah. It is not present in the Barren Fork area.

CHEYENNE AND ADAIR COUNTIES

of Tyner exposures, and has been removed by pre-Chattanooga erosion from all Ordovician exposures along Illinois River northeast of Eagle Bluff (center SE 1/4 SE 1/4 SW 1/4 sec. 13, T. 18 N., R. 22 E.)

Age and correlation. The following fossils collected by the writer and Ulrich have been identified by Ulrich:

<table>
<thead>
<tr>
<th>Fossil Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetradium n. sp.</td>
<td>(much like T. cellulare but with much larger tubes and corresponding larger stems).</td>
</tr>
<tr>
<td>Colpomya cf. faba</td>
<td></td>
</tr>
<tr>
<td>Gyrodonta aff. C. billingsi</td>
<td>(has thinner shell).</td>
</tr>
<tr>
<td>Lophophora perangulata</td>
<td>(the Richmond variety).</td>
</tr>
<tr>
<td>Lissipora cf. miulea</td>
<td></td>
</tr>
<tr>
<td>Dalmanella jugosa (Minnesota variety)</td>
<td></td>
</tr>
<tr>
<td>Plectambonites (Sowerbyella)</td>
<td></td>
</tr>
<tr>
<td>Leperditia caeugena</td>
<td>(Bighorn variety).</td>
</tr>
<tr>
<td>Isoehilina n. sp.</td>
<td></td>
</tr>
</tbody>
</table>

According to Ulrich:

The Dalmanella and Sowerbyella are of specific types that are unknown beneath the Trenton, and both are most like early Richardson species; and the Gyrodonta is of the section of the genus that ranges upward to late Silurian. The specimens are too poor for positive specific identification but what they do show is in no wise contradicts their interpretations as lower Richmond fossils. In other words, I still correlate the Fite limestone with the Wyckoff limestone of southern Minnesota and the lower, pure limestone part of the Bighorn limestone of Wyoming. If this correlation is correct then it gives us our first positive clue to the relations of the Wyckoff and Ferneale limestones, because the latter clearly overlies the supposed equivalent of the former in northeastern Oklahoma.13

The Fite limestone was originally correlated by Ulrich as Black River, and has been considered as Black River by the majority of Oklahoma stratigraphers including the writer. A limestone with identical lithologic characteristics and occurring in the same stratigraphic position is widespread underground in Oklahoma, and is known as the "dense lime." It seems likely that at least the upper part of this "dense lime" is the Fite limestone. It can easily be traced into the Greater Seminole District, but south in the vicinity of Ada it either pinches out or changes in character. In the light of Ulrich's identification of the Fite limestone as pre-Ferneale Richmond it seems best to assume that the "dense lime" pinches out, for rocks of pre-Ferneale Richmond age have not been identified in the Arbuckle sequence. Certain dense textured limestones found in wells in the vicinity of Ada have been correlated with the "dense lime," but these dense beds contain an entirely different microfauna and are readily correlated with beds which lie below the horizon of the "Seminole" sand and just above the "Wilcox" sand in the St. Louis area. Thus the subsurface evidence, so far as it goes, tends to corroborate Ulrich's diagnosis of the Fite limestone as a pre-Ferneale Richmond age formation.

early Richmond rather than Black River, but the possibility still remains that the "dense lime" found in wells is Black River or early Trenton in age.

Stratigraphic relations. The Fite limestone overlies the Tyner formation unconformably, and is unconformably overlain by the Fernvale limestone or Chattanooga formation. In all cases the contacts are extremely sharp and marked by most abrupt breaks in sedimentation, yet no discordance in dip is discernible. Underground in Oklahoma an occasional bed of sandstone is present between the Fite and Fernvale limestones.

FERNVALE LIMESTONE

Character and distribution. This limestone is exposed in the Ordovician inlier along Illinois River just northeast of Tahlequah. It is not present in the section exposed along Barren Fork, nor in the excellent exposure of Tyner along the Illinois River in secs. 13 and 24, T. 18 N., R. 22 E., and has not been noted north of the latter locality. The Fernvale is excellently exposed in the road cut in sec. 12, T. 17 N., R. 22 E. It is mapped with the Tyner on the geologic map. Throughout the area of its outcrop this formation is a light gray, coarsely crystalline limestone, in places replete with well preserved fossils, and attaining a thickness of 10 feet.

Age and correlation. On the basis of its fauna and lithologic character the limestone just described is correlated with the Fernvale limestone of lower Richmond age, of western Tennessee. The Fernvale is a very widespread and overlapping formation. It occurs in the Arbuckle Mountains as the uppermost bed of the Viola limestone. The Fernvale is the "Viola" limestone of the oil fields.

Because this limestone is so distinct lithologically and faunally from the underlying Fite limestone with which it was formerly mapped, it is here distinguished as a separate formation, Fernvale limestone.

Stratigraphic relations. The contact of the Fernvale with the underlying Fite limestone is easily determined, and is not marked by discordance in dip. At this contact in wells there is often a thin bed of sandstone which in rare instances reaches a thickness of 5 feet. The contact of the Fernvale with subjacent formations throughout Oklahoma and the Mississippi Valley is one of unconformity.16

SILURIAN

ST. CLAIR LIMESTONE

Character and distribution. This formation is exposed in four

localities in the southern part of the area under consideration. South of the southeast corner of Cherokee County near Marble in T. 13 N., R. 23 E. it is more fully exposed and consists of thick, massive beds of pinkish white, coarsely crystalline limestone often containing small cavities about which the rock is more coarsely crystalline. The base of the formation is not exposed at any locality in eastern Oklahoma; thicknesses up to 100 feet have been recorded. At the top of the formation and separated from the main body of limestone by an unconformity in the vicinity of Marble are 5 to 8 feet of white coquina-like limestone which, although mapped as St. Clair in previous publications, is here distinguished as a separate formation, the Frisco limestone of the Arbuckle Mountains section.

Age and correlation. The fauna collected by Taff from the upper portion of the St. Clair near Marble according to Ulrich "reminds in some respects of the Osgood, in others of presumably later Niagaran faunas at Chicago and in Sweden."17 This is Ulrich's upper St. Clair, which he believed to be younger than the typical St. Clair of Arkansas, and which he correlated as Osgood (Rochester). In view of the great thickness of the St. Clair in eastern Oklahoma, and in view of the presence of the typical St. Clair fauna in the pink-crimoidal bed of the Chimneyhill limestone in the Arbuckle Mountains it is believed that the typical St. Clair is present in eastern Oklahoma below the beds containing the fauna found by Taff. The fauna of the typical St. Clair, some 200 species in all, is unlike any other fauna found to date on the North American continent. Its "nearest correlative is found in southern Indiana where a locally developed bed with a similar fauna lies apparently just beneath the horizon of the Osgood limestone. The St. Clair, therefore, must fall somewhere in the upper part of the Clinton group of the Niagaran series."18

Stratigraphic relations. The base of the St. Clair is not exposed in eastern Oklahoma. (See page 574.) The unconformity between the St. Clair proper and the overlying Frisco limestone is reported to be readily recognizable. It represents all of the upper Niagaran and all of the Cayugan of Silurian time, and the greater part of the lower Devonian. The Henryhouse and Haragan marls of the Hunton group were deposited at that time, and since the correlatives of these formations are present in western Tennessee in the Brownspart, Rockhouse and Birdsong formations, they may have also been deposited in eastern Oklahoma, and removed by subsequent erosion. In the exposure north of Bunch, and in the exposure in the northeast portion of T. 14 N., R. 23 E., the St. Clair is overlain by the Boone formation. Near Cookson it underlies the Chattanooga shale.

DEVONIAN
FRISCO LIMESTONE

Character and distribution. The Frisco limestone is exposed south of Cherokee County in the vicinity of Marble where it is a 5 to 8 foot bed of coquina-like limestone overlying unconformably the St. Clair limestone. (See page 559.) It may or may not be present in the exposures mapped as St. Clair limestone in Cherokee and Adair counties. The tendency of pre-Chattanooga erosion to cut more deeply into the section as the unconformity is traced northward may favor the assumption that the Frisco limestone is probably absent from the more northern exposures of the St. Clair.

Age and correlation. The limestone bed under discussion contains an upper Oriskany fauna, upper-lower Devonian. It is the equivalent of the Frisco limestone of the Hunton group and of the Little Saline limestone of southeastern Missouri. This Devonian limestone was mapped as St. Clair by Taff, but obviously it cannot be called St. Clair because the latter is of middle Silurian age. The writer proposes the name Frisco limestone for this bed because the fauna and lithology prove it to be the direct equivalent of the Frisco limestone of the Arbuckle Mountain region.

Stratigraphic relations. The unconformity at the base of the Frisco limestone has been discussed. (See page 549.) It is separated from the overlying beds by an unconformity, where overlain by the middle Devonian sandstone the time break is shortest. Taff reports that the calcareous beds at the base of the "Sylamore" seem to blend with the top of the St. Clair.

SALLISAW SANDSTONE

Character and distribution. This formation is a calcareous sandstone of earliest middle Devonian age which occurs in the vicinity of Marble where it has been mapped with the Sylamore sandstone. Inasmuch as the true Sylamore sandstone is herein considered to be of Mississippian age, the beds containing the middle Devonian fossils are separated from the Sylamore, and given the name Sallisaw sandstone from exposures along Sallisaw Creek. The distribution of this sandstone is unknown. The middle Devonian fossils were found in one place only. It is probable that this sandstone is present only as remnants beneath the true Sylamore sandstone. It may or may not be present in the two exposures mapped as Sylamore in T. 14 N., R. 23 E. Taff mentions that the Sylamore sandstone of the Marble area is calcareous near the base. Inasmuch as the middle Devonian fossils were collected from calcareous sandstone, further collecting may prove the entire calcareous basal Sylamore to be Sallisaw sandstone.

MISSISSIPPIAN

CHATTANOOGA FORMATION

Character and distribution. The Chattanooga formation is well exposed in Cherokee and Adair counties along streams that have cut their courses through the Boone formation. The formation consists of hard, fissile, well-jointed black shale 20 to 60 feet in thickness with a local sandstone member, the Sylamore, at its base. The Sylamore sandstone member varies greatly in thickness and character. In northern Cherokee and Adair counties a zone of impure sandstone and sandy shale varying in thickness up to one foot, and grading upward into the Chattanooga shale can usually be detected. In this same area the Sylamore may be a rather coarse grained, ferruginous sandstone containing pebbles of phosphatic material and shale. In a few localities in this northern area the Sylamore is massive sandstone resembling the Burgen and attaining a thickness of 10 feet. Just south of Cherokee County, in T. 13 N., R. 23 E., the Sylamore attains its best development. Here it attains a thickness of 30 feet according to Taff, and is composed of massive, generally even textured sandstone with a few small phosphatic pebbles and fragments of fish bones.

Age and correlation. The middle Devonian age of certain beds mapped as Sylamore in the Marble area has been discussed. (pages 550, 551.) In the northern part of the area under discussion the Sylamore can scarcely be anything but the introductory phase of the Chattanooga shale. Every exposure examined by the writer shows a gradual gradation from sandstone through impure sandstone and sandy shale into the non-sandy shale of the Chattanooga. The Chattanooga shale is herein considered to be of Mississippian age and, therefore, the Sylamore is classed as Mississippian. In central Missouri the Sylamore is almost certainly of Mississippian age for it rests upon the highly eroded edges of the Snyder Creek shale of uppermost Devonian age. The black shale of the Chattanooga contains conodonts and the ubiquitous Protoselonia (Sporangites) huronensis. It is the western continuation of the Chattanooga shale of northwestern Arkansas which contains conodonts that prove it to be the equivalent of the true Chattanooga of Tennessee. The Chattanooga and its equivalents, the Ohio shale, the New Albany shale, the Woodford chert, and the middle Arkansas novaculite have long been assigned to the lower Mississippian by Ulrich although most geologists have assigned them to the upper Devonian. As additional evidence is gathered, Ulrich's diagnosis seems to be correct. Ulrich and Bassler failed to find a single species of conodonts from the upper Devonian Portage shales of New York in the Chattanooga or Ohio shales except locally at the base of the Ohio in Kentucky.

where Devonian conodonts associated with Schizobolus truncatus Hall are found. They, therefore, correlate the greater part of the Ohio and all the Chattanooga shale as Mississippian. In Missouri the Grassy Creek shale, the northward extension of the Chattanooga, “rests with marked unconformity on strata of Ordovician, Silurian and Devonian age and appears to be closely related to the overlying largely clastic Kinderhook beds.” Moore includes the Chattanooga shale as the basal member of the Kinderhookian. Butts presents a good review of the problem, and Swarts has recently presented additional evidence toward the correlation of the typical Chattanooga as Mississippian. Briefly, the faunal character of the Chattanooga, its close relationship with the Kinderhook, and its overlapping nature are strong points in favor of its correlation as basal Mississippian.

Stratigraphic relations. The Chattanooga formation overlaps all older formations. The accompanying figure 107 brings this out clearly. Near Marble the formation is seen to rest upon the Sallisaw Creek sandstone, or Frisco limestone, just northeast of Tahlequah it rests upon the Fernvale limestone; along Eagle Bluff it lies upon the upper Tyner limestones; in sec. 2, T. 18 N., R. 23 E., it rests upon middle Tyner shales, and at Spavinaw it rests upon the Carbonate dolomite. (See also fig. 106). As the basal contact of the Chattanooga is traced eastward the formation is seen to lie upon progressively older strata resting upon Tyner dolomites in the Barren Fork exposures, and upon middle Burgen in sec. 7, T. 19 N., R. 25 E. White shows the same overlapping nature of the formation in the subsurface of northeastern Oklahoma. This unconformity at the base of the Chattanooga is not accompanied by any discordance in the dip of the beds except if considered regionally. No beds of post-Camden Devonian age have been recognized in eastern Oklahoma, and thus the hiatus at the base of the Chattanooga is great, but like most breaks in the early Paleozoic this break is not evidenced by an unconformity of the highly angular type.

Both the Chattanooga and the Sylamore sandstone member are absent in the exposures of the St. Clair 1½ miles and 4 miles northwest of Bunch.

The Chattanooga is overlain by the Boone formation. The contact in all cases is very sharp, and marked by a most abrupt change in sedimentation. In places the upper contact of the Chattanooga is slightly undulating, and a bed of glauconitic, phosphatic, green clay shale occasionally intervenes between the Chattanooga and overlying Boone.

formation. If the correlation of the Chattanooga as basal Kinderhook is correct, and the correlation of the St. Joe member of the Boone as Fern Glen is correct, there is an hiatus at the top of the Chattanooga involving the upper Kinderhook formations of Missouri. It is realized, however, that the Chattanooga may be in part the product of lateral gradation of some of these upper Kinderhook formations.

BOONE FORMATION

Character and distribution. The Boone formation is the surface rock over most of Cherokee and Adair counties. It is difficult to obtain accurate measurements of the thickness, but Taff reports thicknesses ranging from 100 feet to 375 feet. Over most of the area it is readily divided into two members, a thin lower limestone member practically free from chert, the St. Joe limestone member, and an upper chert member which is the main part of the formation.

The St. Joe member is present at the base of the Boone in many places in northern Cherokee and Adair counties, and varies greatly in thickness and character. In the west side of sec. 34, T. 17 N., R. 26 E., and at a locality 3 miles to the west it is composed of fine grained, white to pinkish, even-beded limestone 5 to 15 feet thick. In the NW¼ sec. 13, T. 17 N., R. 23 E. it is a light-colored crinoidal limestone 10 to 15 feet thick. The exposure in sec. 36, T. 18 N., R. 22 E. presents a different character. Here, according to Taff, “the beds consist of dull blue and earthy fossiliferous limestone in the lower part, followed above by thicker and harder limestone beds, the thickness of the whole being 6 feet.” A few miles to the north along Eagle Bluff, Snider describes a series of “dark gray and green shales with thin lenses and nules of limestone” varying from 5 to 40 feet or possibly more in thickness, due to deposition upon the uneven surface of the Chattanooga and also to an unconformity at the top. He believes these beds to be absent to the north and northwest unless the thin bed of soft green shale at the top of the Chattanooga in the Spavinaw region and along Cabin Creek happens to be the equivalent. According to Snider, in the exposures of St. Joe along Illinois River, it is composed of about 30 feet of thick bedded, crinoidal limestone.” The writer has studied the St. Joe at numerous localities in northern Cherokee and Adair counties. Just north of Eagle Bluff the member is composed, from the bottom up, of 67½ feet of massive, rough bedded, sparingly fossiliferous gray to dark gray, fine-grained limestone, 1 foot of calcareous shale, 2 feet of calcareous shale and shaly limestone, and 4½ feet of massive, light-colored limestone with a tendency to be crystalline and containing crinoid stems. The shaly beds in the middle pinch out in a distance of 100 yards allowing the two massive limestone beds to come together. Just southeast of Flint, a short distance north of the north boundary of Adair County, the following section, from the top down, was measured:

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34. Moore, Raymond C., Early Mississippian formations in Missouri; Missouri Bur. Geol. Min. 2nd ser., vol. XXI, p. 26, 1924.
Section of the St. Joe member of the Boone formation southeast of Flint.

CHERT MEMBER OF BOONE FORMATION

ST. JOE MEMBER OF BOONE FORMATION

<table>
<thead>
<tr>
<th>Description</th>
<th>Ft.</th>
<th>in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, massive, fine grained, sparingly fossiliferous; more thin bedded at base</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Shale; soft, calcareous</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Limestone, massive, very fine grained</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Shale; calcareous with thin beds of limestone</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Shale; similar to above bed with many more streaks of limestone especially toward the base; contains many crinoid stems and a few brachiopods</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Limestone; massive to thin bedded, dark, dense, finely granular to slightly crystalline, some what crinoidal</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Clay shale; soft, greenish</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

CHATANOOGA SHALE

The two sections just described do not resemble the typically coarse crystalline crinoidal limestone of the St. Joe of parts of Arkansas, but they apparently resemble certain exposures of the St. Joe in the northern part of the Eureka Springs and Harrison quadrangles of Arkansas where the St. Joe is composed of 10 to 15 feet of coarse crystalline crinoidal limestone at the top separated from a basal massive bed by about 5 feet of thin bedded shaly limestone. In places in Arkansas the St. Joe contains an unconformity in the middle of it believed to be of slight time value because the beds above and below contain a Fern Glen fauna. Siebenthal has studied similar breaks at and near the same horizon in the Wyandotte quadrangle, Oklahoma, and the pinching out of the middle shale member north of Eagle Bluff noted above is correlated as essentially the same phenomenon. The unconformity mentioned by Snider at the top of his “Kinderhook” may be the same thing.

The chert member of the Boone is predominantly chert, although in fresh exposures the limestone is noticeably quite plentiful. Concerning the cherts Snider says;

The cherts in the lower part of the member are very dense and almost white in color. As a rule, those in the upper part are more porous and of a yellow or brownish color. It is, however, impossible to separate the member into mappable units in view of the small number of good exposures.

In the Joplin district the Short Creek oolite is an important bed near the top of the upper Boone. An oolite at Kingston, Arkansas,

some 55 feet below the top of the Boone is probably the same bed. The Short Creek is present in the east half of the Wyandotte quadrangle, Oklahoma, but loses its oolitic character or pinches out west of Spring and Neosho Rivers. So far as known this bed has not been found in the rest of Oklahoma, but its horizon or the horizon of the chert above the Short Creek is present as indicated by fossils collected by Snider.

Age and correlation. The lithology, stratigraphic position and fauna of the St. Joe member in Oklahoma indicate that it is the westward extension of the typical St. Joe of Arkansas. The typical St. Joe is Fern Glen, lowermost Osagian, in age. The so-called Kinderhook fauna of Snider seems to be more nearly a Fern Glen fauna, and the shaly character of the strata containing it is in all probability merely a local variation from the more typical lithology of the St. Joe. Moore concurs with the writer in assigning this fauna to the Fern Glen, but warns against assuming that no beds of true Kinderhook age are present between the Chatanooga and the St. Joe in this region. “I have seen at one or two places in southwestern Missouri, and one of my students has reported in northern Arkansas a place where beds which are probably truly Choteau are present. In the Arbuckle Mountain area the Sycamore limestone is Choteau in age, which indicates that the Kinderhook sea extended well to the southwest.” Snider reports lower Burlington fossils from the St. Joe along Illinois River, and Taff says that the St. Joe of the Tablequah quadrangle, exclusive of the outcrop in sec. 36, T. 18 N., R. 22 E., and also the lower beds of the chert member contain a Burlington fauna. He reports Spirifer grimesi Hall, which occurs in the St. Joe of Arkansas, and in the Burlington and Keokuk; and also Schizoblastus sayi Shumard, a form which has not yet been reported from rocks of the Fern Glen-St. Joe zone, but which does occur in the lower Burlington. A form showing affinities with S. sayi has been found in the New Providence shale of Kentucky considered to be Fern Glen in age. The Fern Glen-St. Joe and the Burlington contain many forms in common, and this form may yet be found in rocks of the former zone.

In at least one exposure in the Eureka Springs quadrangle, Arkansas, just west of the type locality of the Boone, the Fern Glen fauna persists up into the Boone above the St. Joe member. In Boone County, Arkansas, the remainder of the Boone is said to be mostly Burlington and Keokuk in age except for the beds above the Short Creek oolite which are considered early Warsaw.” Moore is in partial agree-

36. Snider, C. E., op. cit., p. 35.
39. Purdue, A. H., and Miser, H. D., op. cit., p. 10-

40. Snider, C. E., op. cit., p. 35.
42. Snider, C. E., op. cit., p. 35.
43. Moore, Raymond C., personal communication.
ment with these correlations except that he believes that the upper Burlington is absent, the lower Burlington is partially developed and the Short Creek oolite in addition to the cherts above is Warsaw in age.\textsuperscript{48} He gives the same correlation for the Boone of northeastern Oklahoma and southwestern Missouri. Snider collected Burlington fossils from the lower part of the chert member in Oklahoma, and lower Warsaw fossils from the upper cherts near Silwell, Adair County. The continuity of the Boone in Oklahoma with that of Arkansas and southwestern Missouri coupled with the evidence presented above indicates that the Boone ranges in age from Fern Glen to lower Warsaw in age possibly containing within it an hiatus representing upper Burlington time. The correlation of the Boone is considered further in the paragraphs dealing with the correlation of the Mayes formation. There the writer will point out the possibility that the Boone is represented in the Caney shale of the Arbuckle region. According to recent correlations by Ulrich the upper part of the Boone novaculite of the Ouachita area may be Boone in age.\textsuperscript{49}

**Stratigraphic relations.** The Boone formation rests unconformably upon the Chattanooga shale except at two localities northwest of Bunch where it rests directly upon the St. Clair. The unconformity is evidenced in the field by a local thin bed of phosphatic, glauconitic shale at the top of the Chattanooga, by the somewhat uneven surface of the Chattanooga in places, and by the patchy development of the St. Joe member. In northern Arkansas the St. Joe is nearly always present, and rests on beds varying in age from St. Peter to Chattanooga. Locally there are unconformities within the St. Joe, and at one place at the top of beds of Fern Glen age in Arkansas. The patchy development of the St. Joe in Oklahoma may be partially due to a post-Fern Glen unconformity of local proportions. In wells a glauconitic zone which may mark an unconformity is often found at the top of the Fern Glen.

The upper surface of the Boone in Cherokee and Adair counties is even and without evidences of unconformity. North of the boundary of Cherokee County in the vicinity of Pryor, Mayes County, hills of Boone chert are seen rising through the overlying Chester formations.\textsuperscript{50} In the Harrison and Eureka Springs quadrangles, Arkansas, the upper surface of the Boone is slightly uneven, and the overlying Hindsville limestone is often conglomeratic.\textsuperscript{51}

**MAYES FORMATION**

**Name.** The term Mayes was applied by Snyder\textsuperscript{52} in 1915 to the group of beds, largely limestone, which lies between the typical cherty Boone formation and the shale of the Fayetteville formation.

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\textsuperscript{48} Moore, Raymond C., op. cit., pp. 231-236 and correlation chart.
\textsuperscript{49} Ulrich, E. O., Post-silurian boulders in the Ouachita “Caney” shale and the age of the chert containing them: Oklahoma Geol. Survey Bull. 45, p. 33, 1927.
\textsuperscript{50} Snider, L. C., op. cit., p. 36.
\textsuperscript{51} Pursell, A. H., and Miser, H. D., op. cit., p. 12.
\textsuperscript{52} Snider, L. C., op. cit., pp. 2-25.
Keokuk-Burlington assemblage, presents certain radical differences." As a result of his studies Girty suggests that the "Spring Creek" be classified as upper Boone."

It is this "Spring Creek"—upper Boone fauna that is found in the lower part of Snider's Mayes. An attempt should be made to follow the Arkansas nomenclature in the naming of eastern Oklahoma formations, but in this case it is hardly feasible to do so for the name Spring Creek is invalid, and the upper part of the Boone of the Batesville area has not been proved to be the exact equivalent of the upper part of the Boone of Boone County. After canvassing the subject rather widely Girty concluded that the more conservative hypothesis is to correlate the upper part of the Boone of the Batesville area with the Warsaw of the typical Boone, and to correlate the middle part of the Boone of the Batesville area with the Keokuk-Burlington part of the typical Boone. The writer believes that until this hypothesis is proved by the detailed tracing of beds, the name Boone should not be applied to the rocks containing the "Spring Creek" fauna, and that a suitable name should be found.

In Oklahoma the term Mayes has been applied to the rocks containing this "Spring Creek" fauna, but has also been applied to rocks of Chester age. The writer proposes to restrict the term Mayes to the rocks containing this fauna, and to classify the upper beds of Snider's Mayes, mainly developed north of Cherokee County, as limestone except in a few cases to the north of Cherokee County where beds of Batesville age seem to be present. The Mayes thus restricted is developed mainly in western Cherokee and Muskogee counties, but does occur in southern Mayes County. Perhaps it would be better to discard the term Mayes, and to apply a new name to the beds of "Spring Creek" age. However, the name Mayes has gained wide circulation among Oklahoma geologists, and most of them use the term in approximately the same sense the writer proposes.

Character and distribution. The Mayes formation is made up of limestone, black argillaceous limestone, and black limy micaceous slaty shale, and is often abundantly fossiliferous. It is best developed in the Muskogee quadrangle where, south of Fort Gibson, the writer has measured 70 feet of black argillaceous limestones and shales with the base not exposed. The same peculiar lithology has been noted in the vicinity of Huibert, and along Grand River in southern Mayes County. It is apparently absent, or at least

is thinner, in the Tahlequah quadrangle where the lower Fayetteville limestone is reported to rest upon the Boone formation.

**Age and correlation.** The fauna of the Mayes formation of the Fort Gibson area is identical with that of the "Spring Creek" and upper Boone limestones of the Batesville district, Arkansas. Snider also recognized the correct age of the lower part of his Mayes in Cherokee, Mayes and Muskogee counties. Without question the Mayes is equivalent to a portion of the Caney shale of the Arbuckle area.

The exact position of the Mayes and equivalents in the standard Mississippian column, however, is uncertain. It is older than Chester because beds of Chester age overlie it, and because it is totally lacking in typical Chester forms of life. Snider classified the Mayes as Chester, but, as pointed out, he included beds of Fayetteville age in his Mayes. His collections showing the typical "Spring Creek" fauna do not contain typical Chester fossils such as *Diplogrammus elegans*. The Mayes and equivalents have generally been classified as Meramecian, and this is as definite as the present evidence warrants. If the upper Boone of the Batesville district is of early Warsaw age, as suggested by Girty, the "Spring Creek" must be Warsaw, or very nearly Warsaw, for the upper Boone and "Spring Creek" contain the same fauna and have certain lithologic characteristics in common. It follows that the Mayes formation, containing as it does the "Spring Creek" fauna, may be simply a portion of the upper part of the Boone of northeastern Oklahoma completely transformed in lithologic and faunal characteristics to the southwest. The writer inclines to this interpretation, but he believes that more actual tracing of beds should be done before it can be definitely proved. The mapping of these beds done thus far has not been done with this particular problem in mind. In this connection it is interesting to note that the beds mapped as Boone in secs. 12 and 13, T. 15 N., R. 20 E., and secs. 7 and 18, T. 15 N., R. 21 E., are black limestones and limy shales typical of the Mayes formation.

The problem is of regional proportions. In the words of Girty:"

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57. Girty, George H., personal communication.
58. Snider, L. C., op. cit., p. 34 and faunal chart. Note fauna of collections 3, 4, 5, and 6 of Snider's Grand River section is this material.
59. Snider, L. C., op. cit., p. 29. Bed 2 of Snider's Grand River section is this material.
60. Girty, George H., personal communication.
61. Snider, L. C., op. cit., p. 34 and faunal chart. Note character of the fauna from localities 3, 4, 5 and 6A of Snider's Mayes.
in western sens. To the south and east, on the other hand, this limestone lens surely gave way to elastic deposits, for one can scarcely doubt that the "Krubstone group" of Indiana and Kentucky, the Waverly group of Ohio, the Marshall formation and Coldwater shale of Michigan, and in part the "Siliceous group" of Tennessee were in a broad way contemporaneous. Although these formations, which comprise sands, both fine and coarse, and shales of various colors including black, with but small proportions of intermingled calcareous matter are so strikingly different from the Burlington and Keokuk in lithologic characteristics, they differ even more strikingly in their fauna content. If these faunal and lithologic transitions took place, it seems likely from all the evidence that the sediments and fauna of the Batesville region now known as Boone were in the transition zone where the calcareous lens was merging with its elastic equivalent.

The writer believes that the elastic equivalent of this great lens to the southwest may be the basal part of the Caney shale, the fauna of the limestone facies having been completely replaced by a black shale fauna. The Caney under this interpretation would contain not only the equivalent of the typical Mayes (the possible equivalent of the Warsaw part of the Boone) and the equivalents of the Fayetteville and Pitkin, but also the equivalent of the Osage portion of the Boone formation at its base.

The evidence afforded by the numerous borings between Cherokee County and the Arbuckle Mountains, though now generally construed to show that the horizon of the Boone formation is lacking in the Arbuckle area because its fauna and lithology are not there, can be interpreted, and not without reason, to demonstrate that the Boone grades laterally to the south and southwest into limy shales and black limestones which are surely the basal part of the Caney shale.

Stratigraphers familiar with subsurface conditions in Oklahoma are agreed that the black limestone facies of the "Mississippi lime" so well developed underground in the Muskogee area can be traced continuously into the outcropping basal part of the Caney shale. The problem is to connect the black limestone of the Muskogee area with the outcrop only a few miles to the east. It was the belief of Buchanan64 that this black limestone is the Mayes formation, a formation younger than Boone, and that the Boone is completely cut out just west of its outcrop by an unconformity at the base of the Mayes. Buchanan now believes that the black limestone in question may be partially equivalent to the Warsaw portion of the Boone, but still believes that the Osagian part of the Boone is cut out just west of its outcrop.65 Under this interpretation the Boone could not be represented in

65. Buchanan, Geo. S., personal communication.
the Caney shale. The writer must agree that the black shaly limestone has nothing in common with the typical cherty Boone formation, but that it is identical with the Mayes, a formation which may be uppermost Boone in age. However, the presence of occasional thin beds of fine grained light colored limestone and cherty limestone within the black limestone section of the Muskogee area coupled with the regional considerations outlined above, lead the writer to consider this black limestone section as a remarkable variant of the Boone formation. In addition, as the black limestone is traced underground into Kansas it is found to merge laterally with the “Mississippi lime” of Kansas, which is generally considered to be of Boone age. In central and northern Oklahoma thin beds of black limestone are found intercalated with light colored cherty limestones of the Boone facies. It would seem that the replacement of the cherty limestones of the Boone formation by black argillaceous limestone began at the top of the Boone progressing downward until the entire section of cherty beds was replaced. Under this interpretation the basal part of the Caney shale would be Boone in age. Both the writer’s and Buchanan’s interpretations are given in figure 108.

A more thorough study of the outcrop must be made before either hypothesis can be proved. It must be established that the Mayes formation as delimited by the writer either rests upon the top of the Warsaw part of the Boone or is a black limestone facies of it. Under the circumstances only the most detailed tracing of beds coupled with faunal studies of the entire Mayes and Boone formations can furnish the desired evidence. In addition the most southerly exposures of the Boone as mapped must be carefully examined for the presence or absence of beds of black shaly limestone, especially at the base of the Boone, and the accompanying faunas studied in detail. Until this is done the correlation of the black limestone facies of the “Mississippi lime” must remain in doubt. The writer regards his hypothesis as a possible explanation of the true conditions, but feels a distinct lack of field data with which to substantiate his suspicions.

To summarize, the Mayes formation is the age of the “Spring Creek” and upper Boone limestones of the Batesville district, Arkansas. In the light of the evidence presented to date the latter formations are believed to be the possible equivalents of the upper Boone limestone of early Warsaw age, but the possibility that they are younger than Warsaw cannot be totally dismissed. The black shaly beds of the Mayes and equivalents were deposited under conditions totally unlike those under which the crystalline limestones and cherts of the typical Boone were deposited, and hence the unlike faunas of the Mayes and typical Boone can be attributed to environmental conditions as logically as to actual difference in age. However, the actual tracing of the Mayes facies into the typical Boone facies has not been done, and the writer deems this necessary when the fauna and lithology of the beds in question do not offer conclusive proof as to their correlation. The writer favors the hypothesis of lateral gradation from beds of limestone and chert into beds of black shaly limestone and shale, and suggests that the entire Boone may have been replaced to the southwest by black shaly limestone and shale which form the basal part of the Caney shale. The fauna of the Caney shale is not a Boone fauna, but a black shale fauna of the type found in the Fayetteville, Moorefield and Mayes formation. That this fauna or closely related faunas could have existed earlier than Mayes time when conditions of environment were right is indicated by certain faunas of probable Glen age in Tennessee and by the presence of certain rather typical forms of this black shale fauna in the Sycamore limestone of Kinderhook age. Perhaps the term Mayes is more properly a facies name than a formational name.

Stratigraphic relations. The writer has not seen the lower and upper contacts of the Mayes formation. Apparently there is no evidence of unconformity between the Mayes and Boone in the area under consideration. The Batesville sandstone and Moorefield shale which underlie the Fayetteville shale in Arkansas are not present in Cherokee and Adair counties; hence there is an hiatus between the Mayes and overlying Fayetteville. So far as known no physical evidences of this hiatus are present.

FAYETTEVILLE SHALE

Character and distribution. The Fayetteville shale is a widespread belt of shale separating the Mayes formation from the Pitkin limestone. It occurs in the southern part of Cherokee and Adair counties, and along the western margin of Cherokee County. In the Tahlequah quadrangle, the formation is described as two shale members separated by a sandstone member. The lower shale member is a black fissile shale in the lower part with lighter colored shales in the upper part grading upward into the Wedington sandstone member and containing a limestone member close to its base which Snider included in his Mayes. It varies from 110 feet in the northeastern part of the quadrangle to about 20 feet in the southwestern portion. The Wedington sandstone member is exposed only in the northeastern part of the quadrangle, eastern Adair County, and attains a thickness of 40 feet. It thins to the south and west at the same time becoming shaly allowing the upper and lower shale members to come together. The upper shale member is a gray shale containing a bed of fossiliferous limestone and attaining a thickness of 30 feet. It thins westward.

and in the western part of the quadrangle the Fayetteville is composed almost entirely of black shale except for the limestone beds near the top and near the base. To the west in the Muskogee quadrangle, and to the northwest in the Pryor quadrangle the formation is composed of black shale with a limestone bed at a variable distance below the top and another at the base included by Snider in his Mayes formation. In these quadrangles the Fayetteville varies from 20 to 90 feet in thickness.

**Age and correlation.** The basal limestone of the Fayetteville contains a fauna of Chester, Upper Mississippian, age. This basal limestone is apparently more persistent in Oklahoma than in Arkansas, and north of Cherokee and Adair counties becomes well developed, making up the greater part of Snider's Mayes formation.

The black fissile shales of the Fayetteville are often fossiliferous, containing cephalopods and pelecypods. Often *Canevelia nasuta* Girty which also occurs in the Moorefield shale of Arkansas, and the Caney shale of the Arbuckle Mountain area of Oklahoma is abundant. This fauna is also Chester in age.

In Arkansas a fauna of Chester age has been obtained from the Wedington sandstone member of the Fayetteville formation.

The upper shales and lenticular limestone member contain an abundant fauna of brachiopods, bryozoans and a pentremitid. This fauna is also of Chester age, and is said to be much like that of the overlying Pitkin limestone.

The exact position of the Fayetteville within the typical Chester section of the Mississippian Valley is unknown. Most of the fossils considered by Weller to be horizon markers within the Chester have not as yet been found in the Chester of Oklahoma and Arkansas. Furthermore, the deposition of black shale in Oklahoma and Arkansas permitted the growth of black shale faunas which are foreign to the typical Chester section. The typical Chester section can be traced southward into northern Alabama, but as the section is traced southward through Alabama black shales containing black shale faunas come into the section and finally replace the limestone, sandstones and calcareous shales of the typical Chester sequence, resulting in the Floyd shale of the southern Shades Valley, Alabama. The same gradation into black shales appears to have taken place to the southwest from the typical Chester section in Illinois. The Arkansas and eastern Oklahoma section containing alternating black shales, limestones and sandstones is in a position analogous to certain sections in northern Alabama, and the Caney shale of central Oklahoma is in the position of the Floyd shale. The Fayetteville shale can be traced underground in Oklahoma into the Caney shale. The limestone members disappear, and the Fayetteville is essentially nothing but black shale, somewhat calcareous, long before the Caney outcrop is reached.

Perhaps the best correlation that can be made on the basis of the evidence published to date is that made by Weller in 1915 when he correlated the Fayetteville with the Okaw, middle Chester, of southwestern Illinois. After analyzing all the faunas listed to date from the Mississippian of Oklahoma and Arkansas, the writer arrived at the same conclusion.

To the north in the Joplin region the equivalent of the Fayetteville is found in the calcareous and shaly phases of the Carterville formation.

**Stratigraphic relations.** The Fayetteville shale appears to lie with perfect conformity upon the Mayes formation in Cherokee and Adair counties, but to the north hills of the Boone formation are seen rising through the Chester beds. Granting that the correlations adopted in this paper approach the truth, the upper Meramecian and lower Chester are absent. Certainly there appears to be no equivalent of the Batesville sandstone and underlying Moorefield shale of the Arkansas sequence. There is thus an hiatus between the Mayes and Fayetteville formations which is not evident in Cherokee and Adair counties by a basal conglomerate or discordance in dip.

The contact of the Fayetteville with the overlying Pitkin also appears entirely conformable. However, in northern Arkansas Ul-

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rich, and Purdue and Miser suggest a slight break between the formations.

**PITKIN LIMESTONE**

**Character and distribution.** The Pitkin limestone overlies the Fayetteville shale throughout Cherokee and Adair counties. In the Tahlequah quadrangle it varies in thickness up to 70 feet. Where it is thinnest the beds are granular, earthy and shaly; the thickest sections contain massive beds of fine grained drab limestone. In the Muskogee quadrangle the Pitkin varies little from a thickness of 50 feet, and consists of interbedded fine grained massive layers and softer granular and somewhat oolitic layers. The Pitkin thins rapidly to the north, and has not been observed north of Cherokee County. The massive fine grained strata crowded with *Archimedes* are not easily confused with any other formation found in the area.

**Age and correlation.** The Pitkin limestone contains a fauna of Chester, upper Mississippian, age. The fauna is said to be quite like that of the upper Fayetteville, and it may, therefore, be upper Okaw (Glen Dean) in age; but Weller and Snider incline to the view that it corresponds to that of the Menard limestone of the Mississippi Valley section of upper Chester age. The abundance of *Archimedes* in the Pitkin, and its position in the section suggest that it may be the equivalent of the Bangor limestone (mostly Glen Dean) of the Alabama section. However, the faunal evidence presented by Weller and Snider coupled with a possible break in sedimentation at the base of the Pitkin argue in favor of a Menard age for the limestone. The Menard is not noted for an abundance of *Archimedes*, and the most typical species of the Menard have not been found in the Pitkin. The fauna of the Pitkin, however, is incompletely known, and therefore its exact age may be in doubt until more work has been done. Ulrich once suggested that the Pitkin may contain at its top beds younger than any known Chester in the Mississippi Valley due to a longer period of erosion between Mississippian and Pennsylvanian time in the Mississippi Valley.60

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68. Snider, L. C., op. cit., p. 41.

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**CHEEROKEE AND ADAIR COUNTIES**

**Stratigraphic relations.** In Cherokee and Adair counties the Pitkin lies with conformity upon the Fayetteville, but in parts of northern Arkansas a slight break may exist. (See page 567.) The contact of the Pitkin with the overlying Morrow formation is one of unconformity. Both the Pitkin and the overlying Hale sandstone member of the Morrow formation vary considerably in thickness, and the Pitkin is cut out by post-Mississippian erosion north of Cherokee County.

**PENNSYLVANIAN MORROW FORMATION**

**Character and distribution.** The Morrow formation overlies the Pitkin limestone throughout Cherokee and Adair counties. The formation consists in ascending order of the Hale sandstone member, the limestone member, and the upper shale member.

The Hale is composed of sandstone, but contains locally important shale and fossiliferous limestone beds, and thins irregularly to the west from a thickness of 110 feet in southeastern Adair County to a few feet in western Cherokee County. In the latter area it is often absent or represented by a thin shale bed at the base of the limestone member.

The limestone member is a hard, fine grained to crystalline rock usually containing a shale in the middle which often contains beds of sandstone and limestone. The member becomes shaly at the top appearing to grade into the upper shale member. In eastern Adair County the quantity of interbedded shale is much greater than in western Cherokee County where limestone greatly predominates. Northward from the Muskogee quadrangle the limestone member thins rapidly, and becomes more sandy especially at its base. In western Cherokee County where the Morrow limestone lies directly upon the Pitkin limestone in many instances some confusion may exist regarding the separation of the two beds. Roundy reports a few places in eastern Oklahoma where rocks of Morrow age are mapped as Pitkin. The two beds can usually be distinguished by the lighter color and more crystalline nature of the Morrow limestone, and by the presence of numerous corals and absence of abundant *Archimedes* in the Morrow. The limestone member is thickest in western Cherokee County where it attains a thickness of 200 feet in places. It is thinnest to the east and northwest.

The upper member of the Morrow is blue to black shale with local deposits of sandstone and fossiliferous limestone, and at.

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one locality coal." The member reaches a maximum thickness of 100 feet, and in general thins westward. It varies in thickness due to erosion prior to the deposition of the overlying Winslow formation.

Age and correlation. The Morrow formation contains an abundant and varied fauna. The formation is continuous with the Morrow group of Arkansas. The Hale sandstone member of the Oklahoma Morrow is the same as the Hale formation of Arkansas, and the middle limestone member in all probabilities represents the Brentwood limestone member of the Boyd shale. However, the greater thickness of the limestone in Oklahoma and the relative thinness of the Haley may possibly be due to a partial replacement of the Hale sandstone by limestone, an entirely plausible condition because of the calcareous nature of the Hale. The upper shale member in all probability represents the shale of the Boyd, and the thin limestone beds of this shale are in the position of the Kessler limestone member of the Boyd. Coal found in the Boyd between the two limestone members is found at one locality in Oklahoma. To the south the equivalent of the Morrow is the Wapanucka limestone of the Arbuckle Mountain region. Certain shales below the limestone of the Wapanucka are also known to contain a Morrow fauna.

The fauna of the Morrow formation is of great interest because it represents one of the oldest Pennsylvanian faunas known. In its generic expression the fauna may be said to have a Mississippian aspect because of the presence of Pentremites, Crambrochites, Amsicrypta, Archimedes, Glyptopora, Brachythyreus, Eumetria and Sphenodus, but only the Eumetria is specifically indetical with Mississippian forms, the other genera being represented by new species. These genera, with the exception of Pentremites, are rare. In all, only four common forms in the Morrow, Fenestella serrulata, Rhombopora tabulata, Rhombopora attenuata, and Spiriferina transversa, and two rare forms Deltasoma arkansanum and Eumetria vera, are unquestionably identified with Mississippian species. On the other hand some 22 species of a Pennsylvanian aspect were introduced in Hale time, and none of the 49 species of a Pennsylvanian aspect found in the Morrow has been found in the Mississippian, whereas many are typically Pennsylvanian. These factors coupled with the identification of Pottsville plants from the coal bed by David White, and the presence of an unconformity at the base leave little doubt as to the early Pennsylvanian age of the Morrow.

Stratigraphic relations. The Morrow formation rests unconformably upon the Pitkin limestone, but the unconformity is usually not marked by discordance in dip. The Hale sandstone member and the underlying Pitkin limestone both vary in thickness, and the Pitkin is cut off at the north boundary of Cherokee County due to post-Mississippian erosion. In northern Arkansas the Pitkin is also cut off to the north, and pebbles of Pitkin limestone are found in the overlying Hale sandstone. There is also an unconformity at the top of the Morrow which cuts deeply into the upper shales, and which cuts out the entire Morrow formation north of Cherokee County.

WINLSOW FORMATION

Character and distribution. The Winslow formation is exposed in extreme southeastern Adair County, and in the southern half of Cherokee County. Equivalent beds in extreme northwestern Cherokee County are mapped as Cherokee. The lower 200 to 450 feet of the Winslow are composed of shales and interbedded shaly sandstones except for local more massive sandstones and occasionally conglomeratic sandstones at the base. Above this lower series in the Tahlequah quadrangle comes a series of more massive and harder sandstones with some interbedded shales and shaly sandstones some 450 feet thick. The sandstone beds of this zone thicken to the east and are more shaly to the west in the Muskogee quadrangle. In the latter quadrangle a thin coal bed occurs in this series. In the Tahlequah quadrangle the upper 150 to 200 feet of the Winslow are composed mainly of shale with some thin sandstone beds, and are mapped as the Akins shale member. The same horizon is represented to the west in the Muskogee quadrangle by about 100 feet of shale, variable sandstone beds and local beds of coal, but is not mapped as Akins shale because the more shaly nature of the underlying sandstone series makes mapping of the shale-sandstone contact difficult and inaccurate. When traced northward the Winslow formation as a whole is seen to become less sandy and more calcareous, and merges with the Cherokee shale.

Age and correlation. The Winslow formation is Pennsylvanian in age, but has not yielded sufficient fossils for a more detailed correlation. By areal geologic mapping Taff determined the equivalency of the Akins shale member and the upper part of the McAlester formation. Also Taff determined that a part of the upper sandstone series is equivalent to the Hartshorne sandstone, and that the lower 600 to 800 feet of the Winslow are Atoka in age. In the Muskogee folio, published after the Tahlequah folio, he was inclined to assign all but the lower 200 to 400 feet of the Winslow to the
McAlester. Briefly, according to Taff, the Winslow contains equivalents of the Atoka, Hartshorne, and McAlester formations, but the limits of these formations within the Winslow are indefinite. The Winslow is continuous with the Cherokee shale to the north, and with the Winslow formation of Arkansas.

Stratigraphic relations. The Winslow lies unconformably upon the Morrow formation. The contact of the two formations is usually discernible, especially in those instances where the Winslow rests upon the heavy limestones of the Morrow, but in a few instances the contact is difficult to locate because of the sandy nature of the upper shale member of the Morrow. The variations in thickness of this shale member, and the local conglomeratic character of the lower Winslow sandstones are evidences of unconformity. Like most unconformities of the Ozark region this unconformity is not angular except when considered broadly. In general the unconformity cuts more deeply into the Morrow formation as it is traced westward across the area under discussion, and cuts out the entire Morrow formation north of Cherokee County.

QUATERNARY

TERRACE SAND AND RIVERALLUVIUM

Character and distribution. Along the immediate valleys of the Arkansas and Grand (Neosho) Rivers terrace sand consisting of fine yellow sand and silt with local patches of quartzose gravel at or near the base occurs. These terrace deposits are found from the borders of the river bottoms upward more than 100 feet. Both the Arkansas and the Grand (Neosho) Rivers, but especially the Arkansas, have developed flood plains, composed of sand, silt and gravel.

Age and correlation. Taff assigns these deposits to the Quaternary system. The terrace deposits are referred to as Pleistocene, and the river alluvium as Recent.

SUBSURFACE FORMATIONS

PRE-CAMBRIAN

GRANITE

The oldest rock exposed in northeastern Oklahoma is the granite outcrop in Spavinaw Creek about sixteen miles north of Cherokee County. Although once considered a granite dike, it is now generally conceded to be a granite peak of pre-Cambrian age. Granite is logged from 1,395 to 1,440 feet in the Adair Oil and Gas Company's No. I Brown, NE 1/4 SE 1/4 NW 1/4 sec. 32, T. 19 N., R. 25 E., and from 1,760 to 1,831 feet in the Gahoma Oil

98. Gould, Chas. N., op. cit., p. 54.
the topography of the granite basement the post-granite, pre-burgen interval will vary from place to place. Considerable work is now being done on siliceous residues by the Missouri Geological Survey and others, and this work will doubtless be of value in subdividing this important interval where cuttings are available.

PRE-ST. CLAIR, POST-FERNVALE FORMATIONS

The base of the St. Clair limestone is not exposed in southern Cherokee and Adair counties, and farther north where older rocks are exposed the Chattanooga formation rests upon the Fernvale limestone. The problem of which beds underlie the St. Clair in the southern part of the area is, therefore, a problem of subsurface.

SYLVAN SHALE

A diamond drill boring at Marble revealed a few feet of greenish shale below the St. Clair which in all probability is the Sylvan shale. The same shale has been found in other borings drilled immediately to the south of the area under discussion. Undoubtedly the Sylvan also underlies the St. Clair in southern Cherokee and Adair counties, for the Sylvan to the writer's knowledge is never known to be absent in any area where the St. Clair or other limestones of the Hunton group are present.

GLAUCONITIC AND OOLITIC MEMBERS OF THE CHIMNEYHILL LIMESTONE

Below the equivalent of the St. Clair, the pink-crinoidal member of the Chimneyhill limestone in the Arbuckle Mountains are the glauconitic member of the Chimneyhill and the underlying oolitic member. The glauconitic member averages 15 feet in thickness and is of Brassfield age; the oolitic member averages 5 feet in thickness and is either Brassfield or Edgewood in age. Both are locally absent along the outcrop, and often absent in wells. The glauconitic member has been noted in wells drilled just south of Cherokee County, and the oolitic member doubtfully recognized. It is believed that these beds may underlie the St. Clair limestone at least locally in Cherokee and Adair counties.

STRUCTURE

GENERAL

Cherokee and Adair counties are situated upon the southwest flank of the Ozark uplift, a broad domal fold the axis of which passes southwest from the St. Francis Mountains, Missouri, through these counties. So far as exposures permit the determi-

nation of structure the folding of the north half of Adair County and of northeastern Cherokee County is gentle, the attitude of the strata in general being rather flat. From this part of the area the strata dip more steeply to the south and southwest, and are thrown into broad faulted synclines. The faults are of the normal type, generally downthrown to the northwest, and trend northeast-southwest. They are of small throw; the greatest displacement is about 600 feet. Some of the faults pass into anticlinal folds apparently not closely associated with faulting are found.

FAULTS AND FOLDS

The most westerly fault in the area under consideration, known as the Locust fault, is a normal fault downthrown to the west bringing the Chester formations in contact with the Boone.

Just east of the southwestern extremity of the Locust fault in sec. 6 and 7, T. 17 N., R. 20 E., a small north-south fault with downthrow to the west brings the Boone formation in contact with the Pitkin limestone.

Southeast of the Locust fault and north of Hubert a complicated system of faults brings the Boone in contact with younger formations up to the Winslow. One fault trending northeast from the CWL. T. 17 N., R. 20 E., intersects an arc-shaped fault trending roughly east and west in about sec. 28, T. 18 N., R. 20 E. The downthrow of these faults is to the southeast. Two parallel curved faults intersect the arc-shaped fault in sec. 31, T. 18 N., R. 21 E. Between the two small faults is an elevated block of Boone. A third curved fault merges with the most southerly, of the parallel faults, and intersects the arc-shaped fault at its eastern extremity leaving a downthrown block of Winslow.

A fault with the downthrown side to the northwest extends from near the SW. cor. T. 17 N., R. 20 E., south of Hubert, to the SW. cor. T. 18 N., R. 22 E. The rocks to the north of the fault are strongly flexed upward as a result of drag. To the northeast this fault is lost in the chert covered hills of the Boone formation, but the folding on Illinois River which brings the Ordovician rocks to the surface is in the strike of this fault, and may be closely related as suggested by Snider.

South of the last mentioned fault is a broad syncline, the southern limit of which is faulted by a long fault downthrown to the northwest which extends in a northeasterly direction from the Arkansas River just south of Fort Gibson, Muskogee County, to a point some 2 miles south of Tahlequah. The anticline along Baumgarner Hollow is in the strike of this fault. The gentle north-

101. White, Luther H., op. cit., p. 149.
ern limb of the syncline is broken by three small faults also trending northeast-southwest and downthrown to the northwest. One of these small faults is lost in the Boone hills just north of Tahlequah, but may resolve itself into the anticle on the Illinois River northeast of Tahlequah.

Another fault downthrown to the northwest extends from a point about 2 miles east of Greenleaf in a northeasterly direction to the chert covered hills of the Boone formation south of Welling. It also faults the south flank of a syncline. The fault grades into an anticle to the southwest, and the folding along Barren Fork is in the strike of the fault to the northeast.

Extending from the southwestern corner of Cherokee County northeastward is a syncline also bordered on the southeast by a fault which extends from the NE. cor. T. 13 N., R. 21 E., to sec. 25, T. 15 N., R. 23 E. This fault is downthrown to the northwest, and grades into an anticle to the southwest. The syncline is broken along its axis by a fault extending from sec. 8, T. 14 N., R. 22 E., to a point east of Waukilla. Another shorter fault passes south of, and parallel to, the latter fault through Cookson. This fault is downthrown to the southeast, whereas the longer fault along the axis of the syncline is downthrown to the northwest, the result being an elevated synclinal block between the faults.

The largest fault in the area enters Adair County at its southwest corner and passes northeast past Bunch to a point north of Lyons. Unlike most of the larger faults described, its downthrow is to the southwest. Between this fault and the fault bordering the syncline described in the last paragraph is an elevated anticlinal block plunging to the southwest. East of the fault the general dip of the rock is to the north except where the strata are displaced by the small fault which crosses the northern portion of T. 14 N., R. 25 E. Like the larger fault the downthrow of the small fault is to the southeast.

Two small faults are present in eastern Adair County. One just south of Baron faults a small basin. It strikes in a northerly direction; the downthrown side is to the west. The other, just east of Stillwell, strikes in an easterly direction at right angles to the axis of an illdefined syncline. The downthrown side is to the south.

**ANTICLINES**

Two anticlines in southwestern Cherokee County directly associated with faults at their southwest extremities have already been mentioned. The anticlines along Illinois River, Baumgarner Hollow, and Barren Fork to be discussed in the following paragraphs are located to the northeast of, and in the strike of faults, but the Boone formation on which very little structural work can be done crops out in the intervening area, making it impossible to determine the exact relationship of the faults to the folds.

The anticle at the great bend in the Illinois River just northeast of Tahlequah is an asymmetrical fold with its highest point in sec. 31, T. 18 N., R. 23 E., where the Burgen sandstone rises in cliffs 100 feet above the river. While doing stratigraphic work in this area the writer noted several minor undulations and faults along the flanks of the anticline. These minor folds and faults are responsible for the extension of the Tyner outcrop northward beyond Eagle Bluff. In the southwestern part of sec. 13, T. 18 N., R. 22 E., the top of the Tyner formation is far enough above the river to permit the exposure of Burgen, but poor and uncertain exposures and covered areas made it impossible to determine the presence of Burgen with any degree of certainty. The exposure of Tyner in Baumgarner Hollow may mark a minor undulation on the flank of the larger fold.

The Barren Fork in T. 17 N., R. 24 E. cuts through the flank of an anticlinal fold the high point of which is probably north of the stream.

While mapping the Ordovician along Illinois River in the Siloam Springs quadrangle several folds were observed. The work in this area was strictly reconnaissance in nature, but the larger structural features were quite apparent and well brought out by the areal distribution of the formations. Two periods of folding, one in pre-Chattanooga time, and one in Pennsylvanian time complicate the structure somewhat. Figures 106 and 107 (pp. 543 and 553) should be kept in mind during the following discussion.

The distribution of the undifferentiated Tyner and Burgen along Illinois River in T. 18 N., R. 23 E., and T. 19 N., Rs. 23 and 24 E., marks two anticlinal folds. The axis of the larger fold passes northeasterly from sec. 2, T. 18 N., R. 23 E. The rocks dip north and west from the axis to the sharp bend in the Illinois River in sec. 24, T. 19 N., R. 23 E. from which they again begin to rise into another fold the apex of which is probably to the northwest of the bend. The larger fold appears to be part of a line of folding which extends in a northeast-southwest direction from the anticline just northeast of Tahlequah to the anticline just west of Flint, Oklahoma, which brings the Canadian dolomite to the surface.

A syncline intervenes between the anticline just discussed and another one located in the vicinity of the mouth of Rock Branch in T. 19 N., R. 25 E. This anticline is rather sharp, and is well expressed by the areal geology. A minor fold brings the Burgen sandstone to the surface a short distance to the southeast of this fold.

Three small anticlines, one in sec. 36, T. 14 N., R. 23 E., which brings the St. Clair limestone to the surface, one in sec. 3, T. 17 N., R.
20 E., and adjoining section to the north, which brings the Morrow formation to the surface, and one in secs. 29 and 30, T. 18 N., R. 20 E., which brings the Chattanooga shale to the surface are so close to faults as to suggest that they are the result of warping accompanying faulting.

In western Cherokee County there are two small sharp anticlines, the axes of which trend at right angles to the axes of the broad synclines. These folds are also close to faults, but they are sharper folds than those described above. One of these in sec. 36, T. 14 N., R. 21 E., brings the Boone formation to the surface over a small area. The other in sec. 1, T. 16 N., R. 19 E., and cutting across sec. 6, T. 16 N., R. 20 E., into sec. 36, T. 17 N., R. 19 E., also brings the Boone to the surface. The former fold is domal, whereas the latter is a sharp elongate anticline.

The distribution of the Chattanooga shale along streams marks several gentle anticlinal folds not already mentioned. These are located as follows: sec. 36, T. 17 N., R. 25 E., and adjoining section to the east, sec. 20, T. 16 N., R. 25 E., along Spring Creek in T. 19 N., R. 21 E., and extending into sec. 30, T. 19 N., R. 22 E., and sec. 12, T. 19 N., R. 20 E., and just southeast of Watts. In sec. 12, T. 19 N., R. 20 E., the Ordovician is brought to the surface over a small area on the north bank of Spring Creek.

It is not to be assumed that the streams which reveal many of the anticlines cut the crests of these folds. In some instances where the writer has noted that the strata dip toward the stream, the stream has merely cut a flank of the anticline.

AGE OF FOLDING

The faults and folds just described were formed during a period of diastrophism subsequent to the deposition of the Winslow formation. They are, therefore, of post-McAlester age, if Taff's correlation of the upper Winslow is correct. Detailed structural work on the projection of the anticline into which the fault which crosses the N.E. cor. T. 13 N., R. 21 E., passes to the southwest, demonstrates nicely that this fold passes beneath the undisturbed beds of the Savanna sandstone. The folding, therefore, took place at least in this one instance at the close of McAlester time. It is interesting to note that Morgan describes a period of uplift and block faulting affecting the Stonewall quadrangle toward the close of Savanna time. Since Savanna time the rocks of Oklahoma have been subjected to several periods of deformation.

Cherokee and Adair counties were undoubtedly subjected to folding of a gentler nature at an earlier date. In northern Arkansas, which belongs to the same structural province, exposures permit of a closer

study of these periods of deformation. Without attempting to describe the entire geologic history of these areas, the results of the more important periods of deformation will be set down in the following paragraphs.

Considering the Osage anticline, Arkansas, as an example, it is found that the Powell limestone, uppermost Canadian, is absent from the crest of the fold in two places, and that in these localities the Cotter dolomite is more strongly flexed than the younger beds. This is attributed to post-Canadian folding and erosion. The complete break in deposition at the close of Canadian time affected the entire continent, but the exact conditions in Cherokee and Adair counties are unknown because the top of the Canadian is exposed in only one locality.

The next important period of folding and subsequent penepplanation; namely, that of late Devonian, pre-Chattanoogaan time, manifests itself both in Arkansas and Oklahoma by the overlap of the Chattanooga formation on the eroded edges of the older rocks. This overlap has already been described (page 544.)

Another period of folding and subsequent erosion of continental proportions took place in post-Mississippian, pre-Pennsylvanian time. As a result of this the Pitkin limestone is absent from the Osage anticline, the Fayetteville shale is thinner than usual, and the Mississippian formations are more strongly flexed than the Pennsylvanian. Also in northern Arkansas the Pitkin limestone thins northward due to erosion. This is also the case in Cherokee County.

A complete break in sedimentation occurred at the close of Morrow time. Subsequent erosion removed the Floyd shale from parts of Arkansas, and cut deeply into the upper Morrow shale in Oklahoma. On the Carrollton dome, Arkansas, the Winslow is arched much less than the Morrow.

IOIL AND GAS GEOLOGY

DEVELOPMENT

No commercial production of oil or gas has been obtained to date in Cherokee and Adair counties, but several showings have been reported. Authentic records of most of the test wells drilled are not in existence. The logs of some of the test wells are given in the Appendix. In the following paragraphs the writer will give what little information is available on the other borings that have been drilled in these counties.

The Stilwell Oil and Gas Company's Paden No. 1 drilled in the NW.1/4 SE.1/4 sec 7, T. 15 N., R. 26 E., was dry, and abandoned at a total depth of 2,265 May 27, 1916. The J. H. Devenburg well drilled by Shonefelt, et al, in the SE.1/4 SE.1/4 NE.1/4 sec 34, T. 16 N., R. 25

104. Powers, Sidney, personal communication.
E., was dry and abandoned at a total depth of 600 feet. The test well put down by Rice, et al., in the SE.1/4 SE.1/4 NW.1/4 sec. 20, T. 17 N., R. 20 E. was dry at a total depth of 1,850 feet. The well drilled by Shuler and George in the NE.1/4 NW.1/4 sec. 30, T. 17 N., R. 20 E., was abandoned June 12, 1919, at a total depth of 1,512 feet without finding showings of oil or gas. The boring in sec. 12, T. 17 N., R. 22 E., encountered a strong flow of sulphur water. Its total depth is reported at depths varying between 1,000 and 1,414 feet. A shallow unsuccessful boring is reported to have been drilled in sec. 3, T. 18 N., R. 23 E. The S. S. Whitford and Company’s Gormley No. 1 in the NW.1/4 SW.1/4 NE.1/4 sec. 18, T. 17 N., R. 22 E., made enough gas between 300 and 350 feet to supply some of the surrounding farm houses.

The Portland Oil and Gas Company’s Whitlock No. 1 in sec. 24, T. 18 N., R. 21 E., was abandoned as a dry hole. A well drilled in sec. 21, T. 17 N., R. 21 E., found some oil, and a well drilled in sec. 21, T. 17 N., R. 20 E., encountered a sand with a fair showing of oil at 800 feet. Slight showings of oil and gas have been reported from wells drilled in sec. 8, 21, and 23, T. 17 N., R. 20 E.**

OIL AND GAS POSSIBILITIES

STRUCTURE

The structure has already been described. (pages 574-79.) Numerous anticlinal folds are known to occur, and many others may be present in the area of the Boone outcrop. The well drilled in the NE.1/4 SW.1/4 sec. 35, T. 19 N., R. 23 E., was located close to the apex of a broad anticline. The well drilled in sec. 12, T. 17 N., R. 22 E., was drilled on the southwest flank of a sharper anticline. The well drilled in the SW.1/4 NE.1/4 NW.1/4 sec. 36, T. 19 N., R. 21 E., was located near the eastern end of a broad anticlinal fold. The other wells have not been drilled on known anticlinal structures, and the two most pronounced anticlines, the one southwest of Hubert, the other southeast of Greenleaf, have not been drilled.

RESERVOIR ROCKS

Numerous sandstone beds in the Winslow formation, the Hale sandstone member of the Morrow formation and the Wedington sandstone member of the Fayetteville formation are of sufficient porosity to be good reservoir rocks for the storage of oil or gas, but these formations are at, or very close to, the surface over a great part of Cherokee and Adair counties and, therefore, cannot be considered seriously as possible reservoir rocks in these counties.

The Sylamore sandstone (Misener sand of the oil fields) is more deeply buried in southwestern Cherokee County, and may locally be thick and porous enough to form an excellent reservoir. Also the St. Clair and Frisco limestones and certain sand beds in the Tyner formation may locally be quite porous. The Burgen sandstone which underlies the entire area except where it is exposed is a most excellent reservoir rock. It is most deeply buried in the western and southern parts of the district.

The eroded upper surface of the Canadian dolomitic limestone is often porous, and produces considerable oil in certain places in Oklahoma. To date production has been found in these limestones over 500 feet below the top. Locally sandstone beds occur. In the Shell Petroleum Corporation’s Owens No. 1 recently drilled in the NW.1/4 NE.1/4 sec. 25, T. 16 N., R. 19 E., the top of the Canadian was encountered at 423 feet, and penetrated to 616 feet 9 inches. In this well the Canadian is mostly cherty and non-cherty dolomitic limestone with occasional thin sand beds one of which was porous enough to hold a large supply of water. The interval from the top of the Canadian to the granite is in all probability mostly dolomitic limestone with a few sand beds. Some sand beds are reported in this interval from the well drilled in the SW.1/4 Cor. sec. 4, T. 17 N., R. 20 E., but little confidence can be placed in the drillers’ interpretations of the lithology of this interval because the dolomitic limestone is often broken up by the drill into a fine “sand.” If the stratigraphy of this interval is anything like it is in northern Arkansas, beds of porous sand can be expected. The well recently drilled by the Independent Oil & Gas Company in the NE. Cor. sec. 6, T. 16 N., R. 27 W., Madison County, Arkansas, found the top of the Canadian at 630 feet, a 3-foot sand bed at 775 feet, a 13-foot sand bed at 1,490 feet, a 5-foot sand bed at 1,625 feet, a 42-foot sand bed at 2,048 feet, and no sand between the dolomitic limestones and the granite.

In short, several good reservoir rocks are present in Cherokee and Adair counties, some of them; namely, some Winslow sandstones, the Hale sandstone, the Sylamore sandstone, the St. Clair and Frisco limestones, some Tyner sandstones, the Burgen sandstone and the upper portion of the Canadian dolomitic limestones, known to produce oil and gas farther west in Oklahoma where they are deeply buried.

SOURCE ROCKS

The source of the oil produced in Oklahoma today is a subject upon which little of a conclusive nature can be said. The dark shales of the Winslow, Morrow, Fayetteville, Mayes, and Chattanooga formations can be considered as possible source rocks. The Chattanooga black shale is considered the source of all pre-Boone oil by a large school of geologists. Another school, increasing in numbers, believes that the

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Simpson formation and Tyner formation are the source rocks of this oil, and still another school is debating the possibility of the enormous thickness of Cambrian, Ozarkian, and Canadian dolomitic limestones, some of them teeming with the remains of past life, being the source of much of the oil. All of these rocks are present in Cherokee and Adair counties, but most of them are at, or very near, the surface. If the speculations of the last mentioned school of geologists prove to be at least in part true, the possibilities of oil and gas in these counties are enhanced because the rocks of these ages are more deeply buried, and in many cases probably more steeply but not too steeply folded. Also the Cambrian, Ozarkian, and Canadian formations are well punctuated by unconformities, and it is a generally known fact that many of the producing horizons of the great oil pools of the world are along unconformities.

CONCLUSIONS

The writer cannot encourage prospecting for oil and gas in Cherokee and Adair counties. Several anticlinal folds are present, and the stratigraphic column contains many good reservoir rocks and also rocks generally conceded to be source rocks. However, the horizons known to produce oil in commercial quantities in Oklahoma today which also occur in the counties either crop out or are very close to the surface and have thus far yielded small shows of oil and gas. It is entirely possible that small unimportant producers similar to a few in southeastern Wagoner County may be found. The possibilities of the area seem to be bound up in the possibilities of finding oil in the great series of Cambrian, Ozarkian, and Canadian sediments which lies between the Burgen sandstone and the granite. The drilling of test wells to the pre-Cambrian on top of the anticline southwest of Hubert and on the top of the anticline southeast of Greenleaf would more definitely test the possibilities of these counties.

APPENDIX

WELL RECORDS

Sec. 15, T. 14 N., R. 14 E., Adair County, Oklahoma

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Shell Petroleum Corporation R. T. Owens No. 1 NW 1/4 NW 1/4 NE 1/4 sec. 25, T. 16 N., R. 19 E., Cherokee County, Oklahoma

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(Continued on page 584)
## Cherokee and Adair Counties

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**Cherokee Oil & Gas Company, Bixey No. 1 SW 1/4 NE 1/4 NW 1/4, sec. 36, T. 19 N., R. 21 E., Cherokee County, Oklahoma.**

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(Continued on page 586)
### Pottawatomie County

By
T. E. Weirich

**Location**

Pottawatomie County is located in the central part of Oklahoma. It is bounded on the south by the Canadian River. Included within its boundaries are Tps. 5 to 11 N., Rs. 2 to 4 E., and a part of Rs. 5 and 6 E. Total area of the county is about 750 square miles.

**Topography**

The county is drained by the Canadian River and the North Fork of the Canadian and their various tributaries, the most important of which are Little River and Salt Creek. The flood plains of these streams are, in general, about a mile wide and lie at an elevation of approximately 850 to 950 feet above sea level. Summits of the hills are at an elevation of 1,000 to 1,100 feet above sea level. The county presents an appearance of heavily wooded, low lying, undulated hills.

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### Stratigraphy

**Surface Geology**

The Pontotoc group of sands, shales, and conglomerates outcrop in the eastern part of the county. The overlying Asher formation out-

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### Table: Stratigraphic Information

<table>
<thead>
<tr>
<th>Formation</th>
<th>Top Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red lime</td>
<td>2410 - 2466</td>
</tr>
<tr>
<td>Bk. red and brown, good dark brown oil sand, oil showing good</td>
<td>2510 - 2513</td>
</tr>
<tr>
<td>Red lime, hard</td>
<td>2510 - 2570</td>
</tr>
</tbody>
</table>

*Gahoma Oil & Gas Company, Crittenden No. 1, NE 1/4 NE 1/4 SW 1/4 sec. 35, T. 19 N., R. 23 E., Cherokee County, Oklahoma.*

<table>
<thead>
<tr>
<th>Formation</th>
<th>Top Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel, dirt</td>
<td>0 - 4</td>
</tr>
<tr>
<td>Lime</td>
<td>9 - 91</td>
</tr>
<tr>
<td>Bk. lime, wtr. sand</td>
<td>91 - 93</td>
</tr>
<tr>
<td>White lime</td>
<td>93 - 170</td>
</tr>
<tr>
<td>Bk. lime, wtr. sand</td>
<td>170 - 172</td>
</tr>
<tr>
<td>White chalky lime,</td>
<td>172 - 194</td>
</tr>
<tr>
<td>Shale</td>
<td>191 - 194</td>
</tr>
</tbody>
</table>

*Adair Oil & Gas Company, Artie Brown No. 1, NE 1/4 SE 1/4 NW 1/4 sec. 32, T. 19 N., R. 25 E., Adair County, Oklahoma.*

<table>
<thead>
<tr>
<th>Formation</th>
<th>Top Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deby</td>
<td>0 - 4</td>
</tr>
<tr>
<td>Lime</td>
<td>4 - 10</td>
</tr>
<tr>
<td>Flint</td>
<td>10 - 14</td>
</tr>
<tr>
<td>Lime, 10&quot; at 50 ft.</td>
<td>14 - 18</td>
</tr>
<tr>
<td>Lime</td>
<td>18 - 25</td>
</tr>
<tr>
<td>White sand</td>
<td>25 - 52</td>
</tr>
<tr>
<td>Flint</td>
<td>52 - 110</td>
</tr>
<tr>
<td>Lime</td>
<td>110 - 234</td>
</tr>
<tr>
<td>Flint</td>
<td>234 - 259</td>
</tr>
<tr>
<td>Black shale</td>
<td>259 - 289</td>
</tr>
<tr>
<td>Black shale</td>
<td>289 - 364</td>
</tr>
</tbody>
</table>

*Formation          | Top Bottom |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown sandy lime</td>
<td>2570 - 2620</td>
</tr>
<tr>
<td>Red lime, hard</td>
<td>2620 - 2705</td>
</tr>
<tr>
<td>Brown sandy lime</td>
<td>2705 - 2790</td>
</tr>
<tr>
<td>Red lime, hard</td>
<td>2790 - 2850</td>
</tr>
<tr>
<td>Brown sandy lime</td>
<td>2850 - 2885</td>
</tr>
<tr>
<td>lime, T. D.</td>
<td>2885 - 2950</td>
</tr>
</tbody>
</table>

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*Figure 109. Index map of Oklahoma showing location of Pottawatomie County.*

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1. *Geologist, Tidal Oil Co., Tulsa, Oklahoma.*

(Originally published as Bulletin 49-TT, May, 1930)
crops in the western part. The normal dip of these surface beds is eighty feet per mile toward the west.

Surface geology has been some aid leading to the discovery of pre-Pennsylvanian oil pools in Pottawatomie County. Such surface folds are not of the antecedent type but are "noses" typical of the general region.

**SUBSURFACE GEOLOGY**

Continuity of formations below the surface in the county is broken by many unconformities. However, the Pennsylvanian section is generally quite conformable. Subsurface formations occurring in Pottawatomie County are shown in the following table:

**Subsurface formations in Pottawatomie County.**

<table>
<thead>
<tr>
<th>AGE</th>
<th>FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pennsylvanian</td>
<td>ASHER</td>
</tr>
<tr>
<td></td>
<td>PONTOTOC</td>
</tr>
<tr>
<td></td>
<td>ADA</td>
</tr>
<tr>
<td></td>
<td>BELLE CITY</td>
</tr>
<tr>
<td></td>
<td>FRANCIS</td>
</tr>
<tr>
<td></td>
<td>SEMINOLE</td>
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<tr>
<td></td>
<td>HOLDENVILLE</td>
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<tr>
<td></td>
<td>WEWOKA</td>
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<tr>
<td></td>
<td>WETUMKA</td>
</tr>
<tr>
<td></td>
<td>CALVIN</td>
</tr>
<tr>
<td></td>
<td>STUART</td>
</tr>
<tr>
<td></td>
<td>BOGGY</td>
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<tr>
<td></td>
<td>SAVANNA</td>
</tr>
<tr>
<td></td>
<td>McALESTER</td>
</tr>
<tr>
<td></td>
<td>HARTSHORNE</td>
</tr>
<tr>
<td></td>
<td>ATOKA</td>
</tr>
<tr>
<td></td>
<td>WAPANUCKA</td>
</tr>
<tr>
<td>Mississippian</td>
<td>CANEY</td>
</tr>
<tr>
<td></td>
<td>WOODFORD</td>
</tr>
<tr>
<td>Devonian</td>
<td>HUNTON</td>
</tr>
<tr>
<td>Silurian</td>
<td>SYLVAN</td>
</tr>
<tr>
<td>Ordovician</td>
<td>VIOLA</td>
</tr>
<tr>
<td></td>
<td>SIMPSON</td>
</tr>
<tr>
<td>Cambrian</td>
<td>ARBuckle</td>
</tr>
</tbody>
</table>

**GEOLOGIC HISTORY**

Pottawatomie County and its environs has experienced many intense periods of uplift during its geologic history.

The thickness of Arbuckle limestone or the Ordivician section as a whole is unknown in this county, as no well has reached this horizon or the underlying pre-Cambrian granite. The exposure of these formations in the Arbuckle Mountains, a few miles to the south, gives some information as to the history during the Cambro-Ordovician ages. Their thickness, as compared to that found in northern Oklahoma, suggests a sinking of the sea floor in the region of what is now the Arbuckle Mountains or a transgression of the sea from the south. This relative sinking continued throughout the deposition of Arbuckle lime, Simpson formation, Viola limestone and Sylvan shale. The presence of regional unconformities between various members of the Ordovician suggests exposure of these sediments at times. Their dip was probably toward the south as each member has been leveled leaving thicker portions on the south, i.e., the Burgen, Tyner and Wilcox are much thicker in the immediate Arbuckle region than in Creek County and vicinity. The "post-Wilcox" member is 100 feet thick in Pottawatomie County as compared to 25 feet in Creek County. The Viola limestone is 500 to 750 feet thick in the Arbuckle Mountains as compared to 30 feet in Lincoln County.

**STRUCTURE**

In general, beds from the upper Boggy to the Asher formation are competent. This group does not reflect the attitude of lower beds. Most geologists use the Viola limestone as a key bed. Attitude of this formation is satisfactorily reflected by the overlying Sylvan shale. Due to the erratic thickness of the Hunton formation in parts of the county, its upper surface does not reflect the structure of the Sylvan shale or lower beds. Where the Hunton is missing entirely, the Woodford, Caney and even the Wapanucka may be used as markers for the attitude of lower beds.

The Seminole district produces its oil from a great pre-Pennsylvanian structural plateau. Contours on the Viola lime picture the structure as an arch dipping away from the Arbuckle Mountains. This structural condition was mapped and named the "Hunton Arch" by Dott. Apparently throughout Tps. 4 to 6 N., Rs. 1 to 10 E., trends of folds are radiating from the Arbuckle Mountains. Dip of the pre-Pennsylvanian rocks in this area will average 350 feet per mile. The region contained within Tps. 7 to 9 N., Rs. 4 to 7 E., is occupied by the structural plateau. Here the pre-Pennsylvanian dips are usually more gentle than to the south, averaging but 125 feet per mile. The Viola lime on the Seminole plateau seldom reaches an elevation below sea level.

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higher than 3,000 feet. Accumulation of oil usually occurs within areas enclosed by the -3,200-foot contour line. (See fig. 110).

The difference in thickness of Hunton lime or Chattanooga shale is not influenced by the attitude of underlying rocks. The highest well structurally may have a greater thickness of these formations than a lower well. This condition has been amply illustrated by Leversen.*

Contouring of individual pools does not in general exhibit rational features. The Seminole district must be treated in a broad way in order to obtain a true picture of conditions.

![Structure map of greater Seminole district](image)

**Figure 110. Structure map of greater Seminole district**

**DEVELOPMENT**

The oil pools of Pottawatomie County in order of their discovery are: South Maud, Earlsboro, Pierson, St. Louis and North Maud. (See figure 111.)


The first producing oil well in Pottawatomie County was drilled by the Maud Oil and Gas Company in the NW 1/4 NW 1/4 NE 1/4 sec. 18, T. 7 N., R. 5 E., in 1920. The producing horizon is the Hunton lime, topped at a depth of 3,730 feet. The initial production of this well was 14 barrels per day. This discovery led to the drilling of three additional Hunton lime wells, their total production being relatively small. This small production is being completely absorbed by the later St. Louis field development.

The original wells in sec. 18, T. 7 N., R. 5 E., have been highly important in the history of Pottawatomie County development. The elevation of the Hunton limestone here is structurally high as compared to that of the Wewoka field, the latter being one of the earlier discoveries of the region.

Information on the attitude of the subsurface formations on the north flanks of the Arbuckle Mountains, together with the knowledge that the Hunton lime was abnormally high structurally, in sec. 18, T. 7 N., R. 5 E., gave geologists the first intimation of an arch extending northward from the Arbuckle Mountains into Pottawatomie and Seminole counties.

**EARLSBORO FIELD**

The Earlsboro field was discovered by the completion of a well drilled by Morgan and Flynn on March 1, 1926, which had an initial production of 200 barrels per day. The producing formation, found at a depth of 3,557-82 feet is commonly referred to as the Earlsboro sand. The horizon is correlated with the Boggy formation, about one hundred feet above the base.

Subsequent development was restricted to the Earlsboro sand. The prolific nature of the nearby Seminole field prompted an intensive exploitation of the Wilcox sand in the vicinity of Earlsboro. Two wells were drilled to this horizon with unsatisfactory results, but they proved the presence of Wilcox at a satisfactory datum elevation. The Wilcox discovery well was drilled by the Gypsy Oil Company in the NE cor. sec. 16, T. 9 N., R. 5 E. The well was completed for an initial production of 8,050 barrels per day. Intensive development of the Wilcox sand throughout the area was immediately started.

The field, as now defined, lies in an east-west direction. (Sec figure 112.) It is well defined by dry holes to the north and south, but is being extended to the east. It is partially outlined on the west. Considered in a broad manner, the field occurs on an anticline. It is well known among geologists that the speed with which the wells were drilled caused crooked holes, whose vertical measurements resulted in untrue datum elevations.

On May 1, 1930, the field had 4,170 producing acres. At that time it had produced 92,755,218 barrels of oil, an average per acre yield
Figure 111. Map showing location of Pottawatomie County fields.

Figure 112. Structure map of Earlsboro field. Contours on top of Vioi limestone. Contour interval, 100 feet.
of 22,234 barrels. The advent of air and gas lift has been a big factor in the prolific production of wells in the field.

**ST. LOUIS POOL**

The Darby and Independent companies completed the first well in the St. Louis pool on July 20, 1926 for an initial production of 125 barrels in the SE 1/4 NE 1/4 sec. 15, T. 7 N., R. 4 E. This well may be referred to as the second discovery well since the original discovery was made in sec. 18, T. 7 N., R. 5 E. The producing formation is the Hunton lime, topped at 3,652 feet. The hole was later carried down to the Wilcox sand which proved to be dry. The outstanding characteristic of this well was the abnormal thickness (348 feet) of the Hunton. Development of the Hunton lime horizon was continued throughout the St. Louis district with occasional tests to the Wilcox sand with unsatisfactory results.

Mid-Continent and McColough are the discoverers of the Simpson production in the St. Louis pool. Their Smith No. 1, NW 1/4 NW 1/4 SE 1/4 sec. 25, T. 7 N., R. 4 E., was completed on March 20, 1928, for an initial production of 2,007 barrels. This discovery gave a new impetus to the district as the new Simpson sand well gave the area possibilities similar to the other fields in Seminole and Pottawatomie counties.

On July 26, 1928, the Magnolia completed a well for an initial production of 6,169 barrels in the NW 1/4 SE 1/4 sec. 19, T. 7 N., R. 5 E., in the true Wilcox sand. A number of Simpson wells in the immediate vicinity were deepened to this new producing horizon. Total per acre yield from the true Wilcox in the St. Louis will undoubtedly exceed that of any horizon in either Seminole or Pottawatomie counties. Its average per acre yield from the more prolific leases will probably exceed 100,000 barrels per acre.

The St. Louis pool is now producing from the Hunton, Simpson, and true Wilcox horizons. This field is only partially outlined. (See figure 113.) Its productive area is spreading over the most of T. 7 N., R. 4 E.

The true Wilcox sand follows structure definitely according to the law of anticinal accumulation. The -3,050 foot contour line on the Viola lime outlines its productivity.

**PEARSON POOL**

The Pearson pool is located in the southwest part of T. 7 N., R. 4 E., and the southeast part of T. 7 N., R. 3 E. It was opened by Croxton and Bueckin whose well located in the SW 1/4 NE 1/2 sec. 19 T. 7 N., R. 4 E., came in for an initial production of two hundred seven barrels from the Hunton. Continued exploitation of the Hunton
lime at lierson has expanded its production until there are approximately 600 producing acres. The average per acre yield was 5,420 barrels on May 1, 1930. A few wells in T. 7 N., R. 3 E., are producing oil from the Viola limestone.

**MAUD POOL**

The Maud Pool is located in the northeast part of T. 8 N., R. 4 E., and the northwest part of T. 8 N., 5 E. The Tidwell Oil Company's well in sec. 3, T. 8 N., R. 4 E., had small production in the Misener sand which was later abandoned. In sec. 24, T. 8 N., R. 4 E., the Amerada followed with a 53-barrel Huntan well. In sec. 18, T. 8 N., R. 5 E., the Pure Oil Company had the first large Misener producer which had an initial production of 3,000 barrels per day. This well started an intensive development of this sand. To date the Maud field has been strictly a Huntan lime and Misener sand pool. Production is controlled somewhat by the thickness of the Misener sand. Exploitation of the Wilcox sand has been disappointing due to the lack of proper structural conditions.

**ASHER POOL**

Simms Petroleum Company completed the first well in the Asher Pool on May 28, 1929 for an initial production of 3,630 barrels per day from the Viola lime at a depth of 3640-3690 feet. Subsequent development has proven the presence of a steeply dipping dome. (See figure 114.) On May 1, 1930, there were 26 completed wells. The total production on this date from the field was 2,127,018 barrels, an average per acre yield of approximately 8,000 barrels per acre.

The Asher Pool is especially important since it has added the Viola lime as a prolific producing horizon in southern Pottawatomie County.

**FUTURE POSSIBILITIES**

The differentiation of pools in Pottawatomie County is a difficult matter. Extensions of the present pools are quite probable. Although any statements predicting the future possibilities of Pottawatomie County extensions are conjectured, it is safe to predict a great amount of new production for the county. The complete picture will possibly show a band of Hunton and Misener sand production throughout portions of T. 7 N., R. 4 E.; T. 8 N., R. 4 E., and T. 9 N., R. 5 E., regardless of the location of anticlines. The eastern part of the county should also have its share of Ordovician pools. The western part of the county is evidently low structurally, insofar as the pre-Pennsylvanian horizons are concerned, but is not completely condemned in these horizons. The Pennsylvanian sands of this portion of the county will bear exploitation.
**LINCOLN COUNTY**

_by_ 

Dollie Radler 

**General Statement**

Lincoln County has long been prospected for oil and gas. At the present time there are five producing fields in the county, all but one (Chandler) of which have been thoroughly prospected and their limits defined. Since the discovery of the Oklahoma City and Chandler fields there has been great leasing activity in the western half of the county and there is promise of new fields being opened in the next few years. This paper summarizes the development to date and tends to show the different structural conditions found in the area.

**Location and Area**

Lincoln County is situated in the central part of the State. It extends from T. 12 N. to the center of T. 17 N., inclusive, and from R. 2 E. to R. 6 E., inclusive, embracing an area of 990 square miles. Chandler, the county seat, lies in the central part of the county.

**Acknowledgments**

The writer gratefully acknowledges the assistance of Robert L. Cassingham in the preparation of maps used in this report, B. H. Harlton for sample determinations, W. A. Carruth for drafting of the maps, and Sidney Powers for valuable suggestions and criticisms. Appreciation is expressed to the Amerada Petroleum Corporation for permission to publish the report.

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*Figure 115. Index map of Oklahoma showing location of Lincoln County (Originally published as Bulletin 40-VV, May, 1930).*
Topography

Lincoln County is located within the Sandstone Hills Region. The topography is that of a gentle hilly country. The western part of the county is largely prairie with low rolling hills, while the eastern part is timbered and the streams have dissected the surface giving rise to a rough topography. Limestones from escarpments capping the tops of the hills west of Kendrick and Avery. The surface varies in elevation from 1,080 feet above sea level, at the town of Carney in the northwestern part of the County, to 760 feet, where Deep Fork of Canadian River flows out of the county. Deep Fork of Canadian River and its tributaries drain the entire county with the exception of a small portion in the extreme northwestern part of the county which is drained by the Cimarron River.

The County is served by five railroads, the main line of the Frisco, M. K. & T. and Ft. Smith & Western, branch lines of the Rock Island, and Santa Fe. Chandler, Stroud and Davenport are the most important towns.

GEOLOGY

Surface Formations

Shales, sandstones and limestones of upper Pennsylvanian age (Neva to Pawhuska) compose the rocks cropping out in the eastern part of the county, and shales and sandstones of basal Pennsylvanian age (Stillwater Group) compose the surface rocks in the western part. Gould has shown the approximate Permian-Pennsylvanian contact as an irregular north-south line extending through the center of the County.

The reader is referred to the geologic map of Oklahoma, for the location of the formation boundaries, areas covered by different outcropping formations, and for the location of surface faults.

STILLWATER FORMATION

The Stillwater formation as described by Aurin, Officer, and Gould includes a series of red and gray sandstones, red shales and occasional limestones. Its base is the base of the Cottonwood limestone which has been traced across western Pawnee County south to the Payne County line, but cannot be followed into Lincoln County. The highest of the persistent members found in the area is the Fort Riley limestone which has been traced south to the Cimarron River in the extreme northeastern corner of the county. Other members of this formation are not differentiated in the county.

ESKRIDGE SHALE

Following Gould's classification the Eskridge is the highest Pennsylvanian formation lying just below the Cottonwood limestone. In its type locality it consists of brown, green and yellow shales but in this area it merges with the undifferentiated red beds.


NEVA LIMESTONE

The Neva limestone lies immediately below the Eskridge shales. This formation in Lincoln County is a series of thin limestones and thin shales, red to gray in color. It can be traced a short distance into the county, but farther south changes from limestone and shale to sandstone and shale and merges with the other undifferentiated red beds.

ELMDALE FORMATION

The Elmdale formation is composed of variegated shales with thin limestones, the most persistent member being the Cushing limestone exposed near Cushing. It can be followed south from Cushing across Lincoln County, passing near Chandler, Sparks and Prague, and finally disappears in northeastern Pottawatomie County.

SAND CREEK FORMATION

The Sand Creek formation consists of two prominent limestone members, the Foraker, 60 to 110 feet thick at the top, and the Grayhorse, 4 feet thick at the base, with intervening shales and thin limestones. In Lincoln County the limestones change to thin shales and sandstones.

BUCK CREEK FORMATION

The Buck Creek formation consists of a series of shales and limestones with two sandy zones near the top. Its aggregate thickness is 175 feet. This formation is exposed in the northeastern part of the County.

PAWHUSKA FORMATION

The Pawhuska formation consists of three beds of heavy gray limestone with intervening shales and sandstones. It is exposed in the extreme eastern part of Lincoln County near Stroud and is the oldest formation exposed in the county.

Subsurface Formations

PENNYSylvanian ROCKS

Rocks of Pennsylvanian age extend below the surface to depths varying from 3,800 feet in the Stroud field, to 4,500 feet at Chandler and to 5,600 feet in sec. 13, T. 13 N., R. 1 W., six miles west of the county line. They consist of alternating shales, sands and thin limestones.

The Pennsylvanian is of commercial importance at Davenport where production is obtained from two sands, the Peru or Upper sand at an approximate depth of 2,600 feet, and the Prue sand which is the main producing horizon of the field at depths of 3,250 to 3,400 feet. The production in the Peru sand has been limited to a very small area in section 3, T. 14 N., R. 5 E. Initial production ranges from 50 to 425 barrels per day of 51° oil. This sand varies between 18 and 25 feet in thickness, is very lenticular and contains lime and shale partings.
The Prue sand is a micaceous lenticular sandstone and varies in thickness from 30 to 110 feet in the field and grades into a sandy shale and limestone or pinches out entirely on the edges of the field. Initial production ranges from 15 to 1,100 barrels. Oil and gas is also found in both the Layton and Prue sands at Chandler in section 7, T. 14 N., R. 4 E.

The Bartlesville sand produces oil and gas in commercial quantities in the Shaffer pool, section 31, T. 17 N., R. 5 E., and is of minor importance in other areas. Nearly all wells on structure have shows of oil or gas in the Bartlesville horizon but in many areas sand conditions are poor and production is not found in commercial quantities.

**MISSISSIPPIAN ROCKS**

**"MISSISSIPPI" LIMESTONE**

The Mississippian in this area consists of about 250 feet of dark fine grained argillaceous limestone, which is called locally "Mississippi lime" in the Stroud field and the "Mayes" limestone member of the Caney formation farther west in the county. The Magnolia Petroleum Corporation Benedict No. 2, SW 1/4 SE 1/4 sec. 8, T. 14 N., R. 4 E., was completed for an initial of 5,000 barrels per day from what is believed to be the top of this formation.

**CHATTANOOGA SHALE**

The “Mississippi” limestone is underlain by approximately 45 feet of Chattanooga shale which is a black, non-calcareous fine grained shale. Fossils found in this formation comprise *Sporangites huronensis* and conodonts. The Chattanooga shale is equivalent to the Woodford chalk of the Arbuckle Mountains.

**DEVONIAN-SILURIAN ROCKS**

**HUNTON LIMESTONE**

The Hunton limestone consists of a white crystalline limestone varying in thickness up to 110 feet. This formation contains characteristic micro fossils which distinguish it from the older limestones. The contact between the Chattanooga and Hunton is an erosional unconformity. The Hunton lies conformably on the Sylvan shale.

Oil in commercial quantities has been found in the Hunton in the Skellyville Pool, secs. 5, 6, 7, and 8, T. 15 N., R. 6 E. It occurs in the erosional zone at the top of the formation.

**ORDOVICIAN ROCKS**

**SYLVAN SHALE**

The Sylvan shale is a gray to light green fine textured shale about 50 feet thick. It is considered in this report as belonging to the Ordovician although there is considerable discussion as to its age. A few graptolites occur in the lowermost portion.

**VIOLA LIMESTONE**

Underlying the Sylvan shale is the Viola limestone which is a buff colored, fine grained to coarsely crystalline limestone about 30 feet thick. The upper portion is milky white and flaky which has lead to the local name of “buttermilk lime”. The remainder is more dense and much harder. The Viola contains few micro fossils. Its presence is usually determined by lithology and by stratigraphic position in the section. The Sylvan shale lies conformably on the Viola.

**SIMPSON FORMATION**

Lying conformably below the Viola limestone is the Simpson formation. The upper part consists of brown dolomite about 10 feet thick and is probably the reservoir for the heavy oil produced at Stroud, although it was called Viola at the time the field was drilled. Below this Simpson dolomite is the Wilcox sand which is of commercial importance in the Stroud field where it is found at approximately 4,000 feet and at Chandler where Magnolia Petroleum Corporation’s discovery well, sec. 8, T. 14 N., R. 4 E., was completed for an initial of 600 barrels in this horizon at a depth of 4,970 feet. A dry hole drilled by Slick in sec. 5, T. 14 N., R. 4 E., had 107 feet of this sand underlain by 70 feet of green, fine grained shale with sandstone partings and then drilled 270 feet of what is locally known as “Second Wilcox” sand. The first sand is believed to be the main producing horizon at Seminole and the second the “Wilcox” sand as originally named. The complete section of the Simpson formation has not been penetrated by the drill in this county.

**Surface Structure**

The strata of Lincoln County have a northwest-southeast strike and a southwest dip of 35 feet per mile. The normal structure is interrupted to form local anticlines and terraces. There is considerable surface faulting through the west line of R. 5 E. The extent of this faulting in the subsurface strata is unknown because of lack of data. Surface anticlines that have been thoroughly prospected reveal that the structure is reflected in the subsurface strata.

**DEVELOPMENT**

Owing to the proximity of Lincoln County to the Cushing field it has long received the attention of oil producers. Many wildcat tests having been drilled which had excellent showings of oil and gas before commercial production was found. Development of commercial production in the county began early in the fall of 1923 with the discovery of the Stroud field by the Union Petroleum and Supply Company. A development map of the county is shown (Map No. XLVI).
STROUD POOL

The Stroud Pool is located in secs. 2, 11, and 12, T. 14 N., R. 6 E., in Lincoln County, and sec. 7, T. 14 N., R. 7 E., of Creek County, three miles southeast of the town of Stroud.

The discovery well was drilled by the Union Petroleum and Supply Company in the SE. cor. sec. 2, T. 14 N., R. 6 E., located on the west side of a closed surface anticline (fig. 116). This well encountered Wilcox sand from 4,086 to 4,088 feet and was completed for an initial of 560 barrels of 42 gravity oil, September 1, 1923. This well started a campaign of drilling and for the first time rotary drilling was used in this part of Oklahoma.

The townsite of Key West is just east of the discovery well near the top of the surface anticline. Companies paid large sums for leases on town lots and many wells were started in the townsite. Very few of these wells showed any profit because of too close spacing of wells.

Initial production of wells ranged from 50 to 2,500 barrels per day. The field covers an area of approximately 400 acres of which half is in Creek County. The limits of the field are well defined as shown by the subsurface map, figure 117.

The field will yield ultimately an estimated figure of 18,000 barrels per acre.

DAVENPORT FIELD

The Davenport field is located in secs. 34 and 35, T. 15 N., R. 5 E., and secs. 2, 3, 4, 10 and 11, T. 14 N., R. 5 E., just east of the town of Davenport. The field was discovered by Morgan and Flynn in Sep-
Figure 118. Surface map of Davenport field. Contour interval, 10 feet.

Figure 119. Subsurface map of Davenport field. Contour interval, 20 feet.

Development progressed rapidly in the field. Wells were completed for initial productions ranging from 15 to 1,100 barrels per day from the Prue sand. On January 2, 1926, the Prairie Oil and Gas Company completed their No. 6 Stout, SW 34, NE 14 NW 34 sec. 13, T. 14 N., R. 5 E., for an initial of 300 barrels of 51 gravity oil from the Peru sand, 2,630 to 3,638 feet. Only a very small area in section 3 produced from this horizon. The wells having initials ranging from 15 to 300 barrels.

Several wells in the field have been carried to the Wilcox sand. These encountered shows of oil in the Pennsylvanian sands below the Prue but only water in the Wilcox. The meager control indicates that the structure is not reflected in the older rocks.

The Davenport oil field covers an area of 2,000 acres with an ultimate estimate per acre yield of 5,000 barrels.

The development of the Davenport field has been ably described by Brandenthaler, Schlater, and Kent and the reader is referred to their report for more detailed information on the field.

*Brandenthaler, B. R., Schlater, K. C., Kent, H. M. Engineering report on the Davenport oil field, Lincoln Co., Okla.: Dept. of Cons. Bureau of Mines Report in cooperation with the State of Okla. & Bullis, Ch. of Com. (This writer believes that the sand described in this report as Layton is Peru sand.)*
SKELLYVILLE POOL

The Skellyville Pool is located in secs. 5, 6, 7, and 8, T. 15 N., R. 6 E., three miles northwest of the town of Stroud. The discovery well cated in the SE 1/4 NE 1/4 SE 1/4 sec. 6, T. 15 N., R. 6 E. This well was completed October 13, 1924, for an initial of 150 barrels in the was drilled by the Independent Oil and Gas Company, No. 1 Erp, lo-Dutchersand, 3,770 to 3,777 feet, later deepened January, 1926, to 4,304 feet, encountering a hole full of water in the Wilcox sand, 4,170 to 4,190 feet. It was then plugged back to 4,030 feet and was completed in the Hunton limestone for an initial of 75 barrels after shot. This field is small and very erratic. The production is from the Hunton limestone and accumulation is in a porous zone at the contact between the Chattanooga and Hunton.

Initial productions ranged from 15 to 1,000 barrels per day. There were no wells of any importance completed in the Dutchersand.

There is very little structure on either the surface (fig. 120) or subsurface (fig. 121) and accumulation seems to be at the erosional uncon-
are nine oil wells and one gas well on this structure. The structure is very small and is completely drilled up. Initial productions ranged from 50 to 1,900 barrels per day.

CHANDLER POOL

The Chandler Pool is located in secs. 7, 8 and 17, T. 14 N., R. 4 E. This area has been prospected for several years. A gas well was completed by Green and Hines, Norton No. 1, SW 1/4 NE 1/4 sec. 7, T. 14 N., R. 4 E., February 25, 1924, for an initial production of six million cubic feet of gas in sand found at a depth of 3,305 to 3,307 feet believed to be the Peru sand which produces at Davenport. This well was offset to the west by Magnolia in their No. 1 Benedict, SE 1/4 NW 1/4 sec. 7, T. 14 N., R. 4 E., completed February 26, 1927, for 85 barrels in the same sand. This led to the completion of two more wells in this sand in section 7.

Further drilling led to the completion of Magnolia's No. 1 Gilliam, SW cor. section 8, for an initial production of 35 barrels in the Perun sand, 3,952 to 3,990 feet. Their No. 2 Gilliam, NE 1/4 SE 1/4 SW 1/4 sec. 8, was completed for 105 barrels in what is believed to be Simpson dolomite after encountering a hole full of water in the "Wilcox" sand 5,052 to 5,077 feet.

The discovery well in the "Wilcox" sand, which gives promise of being a very prolific producing horizon, was completed July 28, 1929 by Magnolia in their No. 1 Decker, SE 1/4 SW 1/4 SE 1/4 sec. 8, a depth 4,950 to 4,973 feet with an initial production of 1,400 barrels. The completion of this well started an active drilling campaign which has resulted in the completion of numerous wells in the "Wilcox" sand and has led to the discovery of a new producing horizon believed to be Burgess sand which had been passed by in other wells drilled. This well is Magnolia's No. 2 Decker, SW 1/4 SE 1/4 section 8, which blew in for 5,000 barrels at a depth of 4,675 to 4,690 feet while drilling with rotary tools. This is believed to be a freak well and production from this horizon will probably not be of great commercial importance.

The number of producing horizons found in the field, together with the area now covered by production, gives promise that the field will be one of the largest found in the County. Structurally the field is located on a surface nose. Subsurface data to date indicate a closed anticline covering two sections.

SUMMARY

All fields in the county except the Chandler Pool have been thoroughly prospected. The discovery of prolific production in this field has led to increased activity in the west half of the county. The surface geology has been thoroughly mapped and parts have been core drilled. Correlations are difficult in both surface and core drill work. On account of the existence of many producing sands in the stratigraphic section of this area it is believed that other oil fields will be found.

HUGHES COUNTY

By

J. Phillip Boyle

This report is written for the purpose of giving in a general way the geology, both surface and subsurface, and its relation to the past and future production of oil and gas in Hughes County, Oklahoma.

Acknowledgments

In compiling this report some of the data used has been obtained from the following individuals and bureaus to whom the writer wishes to express his thanks for their assistance:

Charles N. Gould, Oklahoma Geological Survey; Luther H. White; J. A. Hull Company; Roy D. Jones, Oklahoma City; J. D. Watson, Tulsa; Arthur Burress and Louis Roarik, Okmulgee; Fred Capshaw and William J. Armstrong, Oklahoma City; the United States Geological Survey, and the Oklahoma Geological Survey.

Location

Hughes County is located a little south of the east-central part of the State. It extends from Tps. 4 to 9 N., inclusive, and from Rs. 8 to 12 E., inclusive, or 19 whole townships and parts of 7 others. The entire area is approximately 790 square miles.

Figure 122. Index map of Oklahoma showing location of Hughes County. (Originally Published as Bulletin 40-XX, May, 1930)
Hughes County is located in a region of sandstone hills and broad gentle valleys. The topographic features are an expression of the outcropping sandstone formations which make up the hills. The broad valleys are due to the outcropping of the shale formations. Although the difference of only 400 feet occurs between the tops of hills and the bottoms of the valleys.

The county is drained by two rivers, two creeks, and their tributaries. The northern divide parallels the course of the South Canadian River, paralleling the river through the county about six miles to the north. North of this divide the water flows into the North Canadian River. The southernmost divide crosses the county through the southern half of T. 5 N. The area between the northern and the southern divides is drained by the South Canadian River. The area lying south of the south divide is drained by Caney and Muddy Boggy creeks.

The lowest point above sea level is in the bed of South Canadian River where it crosses the east line of the county. The maximum elevation in the county is approximately 1,150 feet, located in sec. 3, T. 7 N., R. 11 E.

**GEOLOGY**

The formations exposed in Hughes County, with the exception of Recent deposits occurring in river bottoms, and a few Pleistocene deposits, belong to the Pennsylvanian system. These layers of sediments consist of sandstones, shales, conglomerates, and limestones. The shales, which are usually found in the valleys, are in predominance, while the sandstones, usually expressed topographically by the hills, are second in abundance.

The regional dip of the formations exposed at the surface in Hughes County is to the northwest at the rate of 50 to 80 feet per mile. This normal dip of the formations has been disturbed in almost every township by local folding and faulting.

**Surface Formations**

**GUERTIE SAND**

This formation occurs in a narrow irregular strip through the south part of T. 5 N., R. 9 E., along the north line of T. 4 N., R. 9 E.; thence runs diagonally across T. 4 N., R. 10 E., and extends into the southwest corner of T. 4 N., R. 11 E. It lies unconformably upon all the Carboniferous beds exposed, and its original source was probably that of an old course of South Canadian River. It is apparently of the same age as like formations found in Wagoner County along the Arkansas River. It is composed of loose sand, quartz, and quartzite pebbles. Further south this formation is found overlying the Cretaceous.

The material in this formation has been derived from all formations crossed and eroded by the river during the time when the Canadian followed a different course from the present one, and at a higher level. It was probably laid down just prior to the time the Canadian River started cutting its way through the first layers of the Calvin sandstone in the vicinity of Calvin. This formation varies in thickness from 0 to 50 feet. The dip, which is the gradient of the old river, is at the rate of about four feet per mile; thus, the old stream had about the same gradient as the present Canadian River.

**FRANCIS FORMATION**

This formation is the highest Pennsylvanian formation exposed in Hughes County. Only the lower one-third of this formation occurs within the boundaries of the county. It outcrops in the east one-third of T. 9 N., R. 8 E., and in sec. 2, T. 8 N., R. 8 E.. The total thickness is approximately 100 feet.

**SEMINOLE CONGLOMERATE**

The Seminole conglomerate is exposed in a strip approximately two miles wide, from sec. 6, T. 9 N., R. 9 E.; thence south and west to sec. 11, T. 8 N., R. 8 E.. It again enters the county with a wider exposure of 2½ to 3 miles wide, through the center of the north line T. 7 N., R. 8 E., and bears southward until it crosses the county line in sec. 17, T. 6 N., R. 8 E.. Its exposure is marked by more or less rugged hills, with sharp escarpments usually covered by black jack vegetation, or by long rounded hills covered with gravel.

This formation is composed of shales and sandstones, with many conglomerate beds in the sandstones. The top, middle, and base of this formation are marked by heavy sandstone layers, and in these members occur the conglomerate horizons. The conglomerate is composed of chert and quartz pebbles, which are usually well rounded, and white to yellow and dark red in color. The cementing material contains a high percentage of iron. The clays and shales occurring in this formation are rather well stratified where exposed, and are blue, red, and yellow in color, and very sandy in character.

The dip of this formation is approximately 4° northwest. The entire formation has an approximate thickness of 170 feet.

**HOLDENVILLE SHALE**

The Holdenville shale, directly underlying the Seminole, is exposed in a narrow strip, from one to three miles wide, across the county from the center of the north line of T. 8 N., R. 9 E.; thence south and westward to the center of the west line of T. 6 N., R. 8 E.. It varies in thickness from 200 feet in the northern part of the county to 200 feet in the south.
In the north this formation is composed chiefly of shales interstratified with a few sandstone members. It contains some thin-bedded limestone members in the south, but is made up principally of shales. Its outcrop is not noticeable except where the sandstones come to the surface, and where the thin-bedded limestone members are exposed. The outcrop of the top of this formation is made much more noticeable by the abrupt change in topography caused by the lowest member of the Seminole formation.

Wewoka Formation

This formation is one of the thickest in the county, and is exposed over an area six to eight miles wide, running in a southwesterly direction and covering all or parts of Tps. 5 to 9 N., Rs. 33 to 10 E. The Wewoka is composed of soft brown sandstone interstratified with soft blue clays and occasional limestone lenses. The formation thickens to the northeast and in the northern part of the county, has an approximate thickness of 600 to 650 feet. The thickness is approximately 700 feet in the south end of the county. Most of the beds of the Wewoka are soft and are therefore unmappable because of covering, but some of the harder sandstone ledges resist erosion sufficiently to make high escarpments.

Wetumka Shale

The Wetumka shale occurs directly under the Wewoka formation and above the Calvin sandstone. It is composed almost wholly of friable, laminated clay shales, interstratified with a few thin-bedded sandstone lenses. The top of the formation is well defined by the prominence of the lowest member of the Wewoka. The bottom of the formation is hard to distinguish from the underlying Calvin and can only be determined by the change in color in the shales.

The Wetumka is exposed in a narrow strip across the entire county from north to south. It is found over an area approximately one to three miles wide, from sec. 5, T. 9 N., R. 11 E., to sec. 33, T. 5 N., R. 9 E. The thickness increases from north to south, having a variable thickness of 100 to 200 feet.

Calvin Sandstone

This formation, lying directly under and grading into the Wetumka shale, is most noticeable of all formations outcropping in this county. This is because it forms a long line of east-facing escarpments running in a northeast-southwest direction, overlooking the valley floor of the Senora formation. The formation is composed chiefly of massive sandstone. At the top occurs some 50 to 60 feet of thin-bedded sands and clays which are easily weathered, and do not show prominently in the topography. The formation thickens from the south toward the north from 140 to 260 feet. It is particularly noticeable by the growth of oak forests.

Hughes County

Senora Formation

The Senora is exposed in all or a part of Tps. 4 to 9 N., Rs. 9 to 12 E. This formation is composed principally of interstratified sandstones and shale beds, having a thickness of 400 to 600 feet in the north end of the county. It thins to the south by the lensing of the sandstone beds. In some areas these thin-bedded sandstones are sufficiently hard that the exposure can be easily mapped, but as a whole the formation is not well exposed.

Stuart Shale

The Stuart shale, directly underlying the Senora formation, is exposed in Tps. 4 and 5 N., Rs. 10 and 11 E., except where covered by the Guertie sand, and along the southeast side of T. 4 N., R. 9 E. Its exposure varies from two to four miles in width. This formation varies in thickness from 100 feet to approximately 200 feet and thicken toward the northeast.

The formation is composed of three members: an upper and lower shale member, separated by a variable sandstone, 10 to 50 feet thick. The lower member of this formation, which carries a sandstone-chert conglomerate, has an approximate thickness of 100 feet. This member is covered by timberland. The upper member is exposed principally in the escarpments below the lower sandstone member of the Senora.

The strike of this formation as it enters Hughes County is almost due northeast-southwest, but changes to an almost east-west direction because of the anticlinal folds and faults found some 12 miles to the south.

Thurman Sandstone

The Thurman sandstone is exposed in a small part of sec. 13, T. 5 N., R. 11 E.; has a wide exposure over the east two-thirds of T. 4 N., R. 11 E.; and is not found again exposed in the county with the exception of a very small area in sec. 31, T. 4 N., R. 10 E., and secs. 34, 35, and 36, T. 4 N., R. 9 E.

This formation is composed of one principal conglomerate bed consisting of chert pebbles mixed with coarse quartz sand, which, together with some sandy shale members, make up the formation. After the deposition of this prominent member of the Thurman, the sediments became finer, resulting in fine-grained sandstones. The formation reaches a thickness of about 200 feet in this area, but decreases toward the west. The upper sand members of the Thurman contain beds of shale, and in the extreme western exposure there are some small lenses of limestone.

The normal dip of the Thurman is north and west 60 to 100 feet per mile. The sandstone forms rugged hills covered with oak vegeta-
BOGGY SHALE

The Boggy shale is the oldest formation exposed in Hughes County and covers a small area of approximately 2½ square miles in the southeast corner of T. 4 N., R. 11 E. It directly underlies the Thurman sandstone and overlies the Savanna sandstone where the latter is present. It consists of a great thickness of shale and irregularly distributed thin-bedded sandstones.

The formation thickens from the southwest toward the northeast, being approximately 500 feet thick in the southwest part of the county and 1,000 feet thick in the northeast part. The heaviest sandstone member occurs near the base of the formation, and is known to oil producers as the Salt sand.

Stratigraphic Section, Hughes County

<table>
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<tr>
<th>AGE</th>
<th>FORMATION</th>
<th>THICKNESS Feet</th>
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<tr>
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<td>PLEISTOCENE</td>
<td>Guertie sand</td>
<td>0-50</td>
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<td></td>
<td>Francis formation</td>
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<tr>
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<td>Senora formation</td>
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</tr>
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<td>600-750</td>
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<td></td>
<td>Thurman sandstone</td>
<td></td>
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<tr>
<td></td>
<td>Boggy shale</td>
<td></td>
</tr>
</tbody>
</table>

HUGHES COUNTY

Subsurface Formations

SAVANNA FORMATION

This formation is approximately 1,000 feet thick in the south end of the county, and thins rapidly toward the northeast to approximately 100 feet. It is composed of alternate layers of shales and sandstones. The Savanna produces both oil and gas in its sandstone members. It directly underlies the Boggy formation, but is not found present in some areas.

MCALESTER FORMATION

This formation is principally shale with some sandstone members. Most of these sandstones are found at the base of the formation, and are known as the Doehl and Gilcrease sands in the various pools of the county.

The normal dip of the formation is northwest. The McAlester formation is thinnest in the northwest part of the county where it is approximately 300 feet thick, but increases to approximately 650 feet in the southeast.

HARTSHORNE SANDSTONE

This formation is principally important on account of its association with the lowest and most valuable coal bed in the Choctaw coal field. It lies just below the McAlester formation and is present in the southern part of the county, but probably is not present to the northwest.

ATOKA FORMATION

The Atoka formation is made up of a great thickness of shales with some sandstone and limestone members. The sandstone members occur near the middle of the formation and are known as the Ditcher sand series. The formation varies in thickness from 350 to 1,000 feet, thickening from the northwest toward the southeast.

WAPANUCKA (MORROW) LIMESTONE

This formation occurs throughout Hughes County. Its normal dip is to the northwest. It consists of shales, sands, and limestones; and varies in thickness from 100 to 350 feet. The Wapanucka limestone comes to the surface approximately 12 miles south of the county.

PAPOOSE-CROMWELL HORIZON

Lying unconformably upon the Caney shale (and the Pitkin limestone farther north) occurs a horizon of variable thickness of 200 to 400 feet, carrying sand members known over the county in various oil pools as the Lyons-Quinn, Papoose, and Cromwell sands. This horizon, consisting predominantly of sandstones, is interstratified with shale layers. To date, in Hughes County, it is the principal producing hori-
zon. This horizon is usually distinguished by the lowest lime member of the Morrow formation directly overlying it.

**CANEY SHALE AND BOONE FORMATION**

The Boone formation, directly underlying the Caney shale, is of Osage and Meramec age. It consists of one limestone member overlain by a shale member. This limestone member is variable in thickness. It is found to thicken from the southwest toward the northeast in well logs.

The Caney shale, directly overlying the Boone, has a variable thickness and an unconformable contact with the Cherokee shales above. A few miles north of the north line of Hughes County, the upper member of the Mississippian (the Pitkin limestone) occurs as a massive limestone member, but as this formation is traced south into Hughes County it is found to grade into shale and thin limestone lenses.

**CHATTANOOGA SHALE**

This formation, the lowest member of the Mississippian, consists of a hard, well-laminated shale, dark brown to black in color. It directly underlies the lower member of the Mississippi lime, and is one of the best datum horizons in eastern Oklahoma. It has a variable thickness and overlaps all older formations down to and including the Arbuckle limestone.

**MISENER SAND**

This formation, composed of wind-blown sand, occurs in scattered areas in the northern part of the county. It is usually white in color and very clean. Where present it lies upon the Hunton, Sylvan, or Viola limestone and directly underlies the Chattanooga shale. It is unconformable at the top and bottom.

**HUNTON FORMATION**

This formation, Siluro-Devonian in age, directly underlies the Chattanooga shale, where the Misener sand is absent. It converges toward the northeast. Where present, this formation directly overlies the Sylvan shale, Misener sand, and the Viola limestone.

**SYLVAN SHALE**

This formation, Richmond in age, directly underlies the Hunton formation where present, and where the Hunton is absent, it directly underlies the Chattanooga shale. It is a calcareous shale, white and blue to green in color, and varies in thickness, thickening toward the southwest.

**VIOLA LIMESTONE**

This formation, Ordovician in age, is found throughout the county, and is one of the principal datums used by geologists for correlating the formations lying below the Mississippian. It is white to gray in color, usually hard, and has an approximate thickness of 60 to 80 feet in the northeastern part of the county, thickening toward the southwest. Its normal dip is to the southwest.

This formation directly underlies the following formations: the Misener sand, Sylvan shale, Hunton formation, and Chattanooga shale. It is an important casing point in the drilling of wells to the Simpson formation.

**SIMPSON FORMATION**

**WILCOX SAND**

This formation represents the upper sand member of the Simpson formation in this area. It has been found present everywhere in Hughes County where drilling has gone deep enough to penetrate it. It directly underlies the Viola limestone and directly overlies the Tyner horizon. It has a variable thickness, thickening from the northeast toward the southwest.

This formation is most productive of oil and gas, and at the present time wells producing from this horizon are limited to the north and extreme western parts of the county.

**TYNER FORMATION**

This formation consists of a series of alternating white to green sands and green, white, and red shales. It is the lowest producing member of the Simpson formation in this county and is easily distinguished from the upper Simpson members by its color and the character of the sand grains. The formation dips normally to the southwest at the rate of 20 to 30 feet per mile. The top of this formation is usually marked by a white sand or a fine-textured green shale.

The Tyner series has been found present everywhere in Hughes County where wells have been drilled to a sufficient depth to penetrate the horizon. It is found to be much thicker in the southeastern part of the county than in the northeastern part.

**BURGEN LIMESTONE**

This limestone, consisting of a single member, is found in the northeast part of the county and has a thickness of from 30 to 70 feet. It represents the lowest limestone member of the Simpson formation and directly overlies the Burgen sand. The writer does not have any well records which have penetrated the Burgen horizon in the south and east parts of the county.

**BURGEN SANDSTONE**

The Burgen sand directly underlies the Burgen limestone and lies unconformably upon the Siliceous lime, with the exception that in some instances a shaly member occurs below the sand.
ARBUCKLE (SILICEOUS) LIMESTONE

This limestone, found over wide areas throughout the State, has a variable thickness in eastern Oklahoma. It lies unconformably upon the granite and the Reagan sandstone where the Reagan is present. There is a wide unconformity at the top. The thickness of the Arbuckle limestone in Hughes County has not been ascertained by drilling.

This limestone is Cambro-Ordovician in age. It is likely to produce some gas at the top of the formation under favorable conditions, but the writer does not know of any production coming from this limestone in Hughes County.

Surface Structure

The nose is the predominant type of surface structure producing oil or gas in Hughes County. Very often, beginning with the top contour of the nose, and extending eastward, a terraced condition exists, with the production lying just west and north of the terrace. Sometimes these terraced structures end with a fault on the east side which become closed structures with depth.

In addition to the terraced nose, almost every other type of surface structural condition is found in the county, from the long anticlinal type to the small dome. Surface geology in Hughes County is very import-

ant as it usually reflects a more disturbed condition in the lower formations. Anticlinal types of structures are more likely to be found east of the outcrop of the Calvin sandstone. See figures 123-126 for types of surface structures.

The two most recent changes in the surface conditions of Hughes County occurred during a wide-spread period of peneplanation, probably in Jurassic times. The second important change occurred when the South Canadian River started cutting through the old surface level, or which the Guertie sand was laid down.

Subsurface Structure

The major structural conditions existing in Hughes County consist of one major synclinal basin which almost covers the southeast part of the county east of the outcrop of the Wetumka formation. This basin plunges rapidly east from the outcrop of the Wetumka.

West of this outcrop the Arbuckle floor rises rapidly to the Seminole County area on the west and to Okfuskee County on the north. These lower formations are also affected by the proximity of some large faulted anticlines on the south, and the Ada arch to the west. The movements causing this synclinal basin on the east were gradual and were more or less continuous almost up to the present time. This
Arbuckle high in the west part of the county was present during the deposition of all the Pennsylvanian rocks. This condition resulted in a wedge-like cross-section of each formation, with the sharp end of the wedge toward the west and the blunt end toward the east, the rapidity and amount of thickening dependent upon the rapidity of the sea advance and retreat during the time each formation was laid down. The greatest wedging seems to have taken place prior to the deposition of the Hartshorne sandstone, but the thickening in the formations above the Hartshorne continues to the surface beds.

OIL AND GAS DEVELOPMENT

Hughes County has been proved oil and gas territory for many years. One of its outstanding fields is the Papoose field located in the northern part of the county and extending into southern Okfuskee County. This field, discovered in 1923, reached a peak of 39,814 barrels of oil per day early in 1925. Production is mainly from the Gilcrease and Papoose sands, with initial outputs ranging from 30 to 3,600 barrels per day. Gas in this field is important also and the amount per well varies from 10 to 100 million cubic feet. These sand horizons occur at depths of 3,070 and 3,350 feet respectively. Tests to the Wilcox sand, found at a depth of 4,130 feet, have proved unproductive of oil or gas. Map No. XLVII shows the various producing horizons of Hughes County.
OIL AND GAS IN OKLAHOMA

ALABAMA

The Alabama oil and gas field, located in the northern part of T. 9 N., R. 11 E., was opened in 1917 with a gas well by Gillispie and others. Deeper drilling in the area started in 1925 and oil production ranging from 20 to 200 barrels was obtained in the Deaner and Lyons-Quinn sands at depths of 2,910 and 3,130 feet.

ALLEN

The Allen dome, originally developed in Pontotoc County, has proved productive northward both in southeastern Seminole and southwestern Hughes counties. The Wilcox sand discovery well in the Allen field was drilled by the Sinclair Oil & Gas Co., No. 2 Amos-B, SE. cor., NE. 1/4, SW. 1/4 sec. 7, T. 5 N., R. 8 E., Seminole County. This well found the Wilcox at 4,158 feet on Sept. 16, 1928 for a production of 40 barrels per hour. Shallower horizons which produce in the Allen field are Boggy, Savanna, Wapanucka, Cromwell, and Gilcrease. This structure is located on a nose of which plunges northeast from the Arbuckle uplift.

This field, opened in 1918, had shallow gas production and later oil from the Lyons-Quinn horizon found at a depth of 2,900 feet. The wells ranged from 10 to 30 barrels in daily output, though the main importance of this field is for gas.

FUHRMAN-TRANSCONTINENTAL

This pool was one of the major spots of interest in the latter part of 1925 as a result of the discovery well drilled by the Fuhrman Petroleum Company and the Transcontinental Oil Company in sec. 26, T. 9 N., R. 9 E., for 1,200 barrels of oil per day at a depth of 3,360 feet from the Lyons-Quinn sand.

HOLDENVILLE

One of the first wells in the Holdenville pool was drilled by the Penn-West Oil Company in sec. 4, T. 7 N., R. 8 E., with a production of 16 million cubic feet of gas per day and 5 barrels of oil. The producing horizons are the Booch, Gilcrease, Smith, Hunton, and Wilcox. The Wilcox is found at a depth of 4,180 feet with oil production as high as 4,000 barrels per day, having a gravity of 39°B.

NEWMAN

This field, discovered by W. C. Newman and associates in 1923, was famous because of the “Vaseline” well, located in sec. 31, T. 8 N., R. 12 E. This well produced from the Lyons-Quinn horizon encountered at a depth of 3,710 feet at a rate of fifty barrels per day, and the oil was of 38°B. gravity and a paraffin base.

HUGHES COUNTY

WETUMKA

The Wetumka field is located in the northern part of T. 9 N., R. 10 E. It was opened in 1919. Wells in the Deane and Hunton horizons produced initially at a rate of fifty to eight hundred barrels of 39°B oil per day. The Deane is encountered at 2,900 and the Hunton at 3,755 feet. The Wilcox has been found barren at 4,000 feet.

WEWOKA

The Wewoka field, located principally in Seminole County, covers a part of western Hughes County. The important producing horizons of this field are: Smith sand, (the upper part of the Cromwell horizon); the Sykes sand, (also of the Cromwell); the Hunton limestone; and the Seminole sand, (of the Simpson formation). The important production from the Seminole sand in Hughes County centered in sec. 5, T. 7 N., R. 8 E.

YEAGER

The Yeager oil and gas field, opened in 1917, is located in T. 8 N., R. 10 E. The surface formations are the Wewoka and Wetumka of Pennsylvanian age. The wells produce from the Booch, Gilcrease, Lyons-Quinn, and Wilcox horizons, encountered at depths of 2,790, 3,040, 3,520, and 3,920 feet respectively, at the rate of 25 to 500 barrels per day initially and 1 to 30 million cubic feet.

Future Production of Oil and Gas

From the oil producers’ standpoint, Hughes County may be divided into two areas: one which lies west of the exposure of the Wetumka formation, where subsurface conditions controlling the production of oil and gas will be found approximately equivalent to the horizons in eastern Seminole and southern Okfuskee counties; and the other area which is defined by the producing fields in the western part of the county.

The eastern area will probably not be as prolific in oil and gas production as the western. All sands will be found at greater depths, increasing in depth from west to east, and from north to south. Map No. XLVII shows type well logs in the various parts of the county.
TULSA COUNTY

By
W. F. Cloud

INTRODUCTION

The purpose of this report is to present a brief and concise summary and history of oil and gas development in Tulsa County since these products were first discovered in 1901. The information presented is largely a revision of that published in Oklahoma Geological Survey Bulletin 19 published in April, 1917.

This report summarizes past and present drilling operations and production in Tulsa County; describes the surface and subsurface geology; discusses surface and subsurface structure, as to location, origin, and effect upon the accumulation of oil and gas; and shows in a general way what may be expected as to future production and development.

The information presented here has been compiled from many sources, a large part of which has been previously published. Such detailed and professional information is available in public libraries, past issues of various technical journals of the oil industry, and in the libraries and records of the many oil companies that have operated within Tulsa County.

Figure 127. Index map of Oklahoma showing location of Tulsa County. (Originally Published as Bulletin 40-RR, May, 1930)
Tulsa County is located in the central part of northeastern Oklahoma. It extends from the north half of T. 16 N., northward to include all of T. 22 N., and from R. 10 E. to R. 14 E., inclusive. This county is bounded on the north by Osage, Washington, and Rogers counties, on the east by Rogers and Wagoner counties, on the south by Wagoner and Okmulgee counties, and on the west by Creek and Osage counties. It is composed of 12 entire townships and parts of 11 others. The county is somewhat irregular in outline, and has a maximum length north and south of 39 miles. Its maximum width east and west is 30 miles through T. 19 N. The approximate area is 587 square miles.

Topography and Drainage

Tulsa County is located in the Sandstone Hills Region of the State. That part of the county lying north and east of the Arkansas River is largely a level prairie plain broken in places by low escarpments. South and west of the Arkansas River is also a prairie plain, but upon that plain are many rugged sandstone capped hills, which are covered with blackjack oak trees. These sandstone capped hills reach their maximum relief near the town of Red Fork in T. 19 N., R. 12 E., where they are approximately 200 feet above the surrounding plain.

The highest point in the county is near the center of sec. 21, T. 19 N., R. 10 E. Here the sea level elevation is 1,017 feet. The lowest point is near the SE. cor. sec. 25, T. 17 N., R. 14 E., where the Arkansas River crosses the east county line into Wagoner County. The elevation here is 550 feet above sea level.

The southern part of the county is drained by the Arkansas River and its tributaries, the principal ones of which are: Hailey Creek, Broken Arrow Creek, Polecat Creek, Posey Creek, and Snake Creek. The part of the county which lies in T. 19 N., west of the City of Tulsa is drained into the Arkansas River by Mud and Anderson Creeks. The northern part of the county is drained into the Verdigris River by Bird Creek and its numerous tributaries.

Acknowledgments

The writer wishes to thank the following individuals, geologists who have cheerfully aided and assisted in compiling the information presented in this report: Frank C. Green, Shell Petroleum Corporation; Robert H. Dott, Sunray Oil Company; Robert H. Wood, and Ed Bloesch, consulting geologists; H. E. Rothrock, Superior Oil Corporation; and L. H. White, J. A. Hull Co. The stratigraphic research project of the American Association of Petroleum Geologists and the Reiter-Foster Oil Corporation, as well as the Shell Petroleum Corporation furnished information used in compiling the geologic cross-sections. The Oklahoma Geological Survey and its staff furnished valuable counsel and information.

TULSA COUNTY

STRATIGRAPHY

Surface Formations

The formations exposed on the surface of Tulsa County are shales, sandstones, and limestones of Pennsylvanian age, including Allegheny and Conemaugh time. The oldest rocks belong to the Cherokee shale group. The youngest rocks are the sandstone and shale members of the Ochelata formation. Arranged in ascending order, that is, the oldest first, they are as follows: Cherokee shales, Fort Scott limestone; Wewoka formation the equivalent of the Labette, Oologah, and part of the Nowata; Nowata shale; Coffeyville formation, including the Checkerboard limestone near the base; Hogshooter limestone; Nellie Bly formation; Dewey limestone; and the Ochelata formation, including the Avant limestone about 200 feet above its base. These formations extend across the county irregularly in a northeast-southwest direction, the oldest occurring in the area south of the city of Broken Arrow. Reference to the accompanying areal map (No. 1) will show this relationship in detail.

In that part of the county north of the Arkansas River there are more limestones than south of the river. South of the river shales and sandstones predominate over the limestones, the whole area for the most part being covered by the Wewoka formation and the Nowata shale. However, the writer maintains that the information published to date on that part of the county south of the river is in error in several respects, and that a more detailed survey and reconnaissance will show the surface geology to be more differentiated than that mapped and published at present.

CHEROKEE SHALE

The Cherokee shale, is exposed in the southeast part of the county south of Broken Arrow and in the vicinity of Leonard. The shales vary in color from light gray to almost black, and are interbedded with limestones and several dominant sandstones, the following of which have produced oil in commercial quantities in this area: Red Fork, Bartlesville (Glenn), Tanaha, Tucker, and Dutcher sands. The top of the Cherokee includes the equivalent of the Calvin, and according to Miser, some lower Wetumka beds. Bloesch' correlates the top of the Cherokee with the base of the Wetumka.

The shales and sandstones vary both vertically and laterally, and often grade into each other within comparatively short distances. The sandstones of this group are usually dull red and muddy brown in color.

The total thickness of the Cherokee shales in this part of the county is over 1,200 feet. However, only the top part of the formation is exposed in Tulsa County.

FORT SCOTT (OSWEGO) LIMESTONE

The Fort Scott limestone, which is known to the oil fraternity as the “Oswego” lime, lies immediately above the Cherokee shales. A long, narrow ledge is exposed in the southeastern part of the county in the vicinity of Leonard and Broken Arrow, and extends northeastward through T. 17 N., R. 14 E., Tps. 18 and 19 N., R. 14 E., into Rogers County where it attains a thickness of about 100 feet. In Tulsa County it is only about 38 feet thick, consisting of an upper limestone member 20 feet thick, a dark shale parting 8 to 10 feet thick, and lower limestone member about 10 feet thick. From the vicinity of Leonard southward the limestone disappears and the formation grades into the Wetumka shale.

WEWOKA FORMATION

This formation covers a large portion of the surface of the southern part of the county, including Tps. 16, 17, and 18 N., and Rs. 13 and 14 E. It is about 350 to 400 feet thick, and is composed mostly of sandstone with shale between the upper and lower sandstone members. The upper part is cross-bedded and shaly, but the middle part contains a hard, massive and persistent sandstone member. The lower part is composed of a thin but hard, medium- to coarse-grained sandstone. The color of the sandstone members is predominately brown, but the shales vary from gray to blue in color.

LABETTE SHALE

Most of this formation as exposed in Tulsa County is found in the east half of T. 19 N., R. 14 E. It lies upon the Ft. Scott (Oswego) limestone, and is overlain by the Oolohag limestone. These shales vary from blue to pale green, and are known to contain appreciable amounts of brownish shaly sandstones in places. Their thickness is about 60 to 75 feet in this area.

OOLOHAG LIMESTONE

This formation has been popularly called the “Big” lime. In the northern part of the State and in southern Kansas it has been divided into the Pawnee limestone, the Bandera shale, and the Altamont limestone. However, northeast of Tulsa County in the northern part of Rogers County, the Altamont limestone joins the Pawnee limestone. From there southward the collective name of Oolohag limestone is applied. It is characteristically hard, massive, and cherty, and is usually bluish-gray in color when freshly broken.

There is a general opinion among several reputable geologists located in Tulsa that the geologic map of Oklahoma as compiled by H. D. Miser of the United States Geological Survey is in error as to the exact location and extent of the so-called “Oolohag” limestone. Instead of thinning-out and striking-off in the west half of T. 19 N., R. 14 E. in a southeastern direction toward the city of Broken Arrow, where it has been customarily purported to merge into the Nowata shale above and the Labette shale below to form the Broken Arrow formation, it apparently trends southwestward from the north central part of T. 18 N., R. 14 E., crossing the Arkansas River northwest of the town of Bixby. From this locality it is traceable southwestward through T. 17 N., R. 13 E., into T. 16 N., where it grades into the Wewoka formation or the Holdenville shale.

TULSA COUNTY

NOWATA SHALE

This formation overlies the Oolohag formation, and is widespread in Tulsa County. It enters the county at the northeast corner, in T. 22 N., R. 14 E., and follows a southwestward trend across the county to the Arkansas River near Jenks where it is covered and made obscure by the river and dune sand deposits in that area. The Nowata shales consist of a series of shales and a few interstratified sandstones and limestones being mostly sandy in the upper part and clayey in the lower part. The Dawson coal is found near the top of the formation. In the area east of the city of Tulsa these shales are 550 to 600 feet thick.

COFFEYVILLE FORMATION

This formation is very widespread in Tulsa County, especially in the northern and western parts. The approximate thickness in this area is 275 to 325 feet. The upper portion is sandy in many localities, but the lower part is composed largely of homogeneous clay shales, which are bluish- to greenish-gray in color. Near the base of this formation the Checkerboard limestone is located. These strata continue southwestward into Creek and Okmulgee counties, and northeastward into Washington and Nowata counties.

The Checkerboard limestone member has an irregular southwest trend from the northeastern corner of T. 22 N., R. 13 E., to the southwest corner of the county in the vicinity of Glenn pool. In T. 20 N., R. 12 E., its trend is southward along the east side of the township, thence it passes through the city of Tulsa southwestward past Red Fork then swings westward over into Creek County, passing on southwestward through Tps. 18 and 17 N. along the western boundary of Tulsa County. This thin but persistent limestone is fine-grained, and usually contains an appreciable amount of fossils. It is usually bluish-white in color, and is characteristically only about three feet thick.

HOGSHOOTER LIMESTONE

This is the so-called “Lost City” limestone. It is characteristically a massive limestone and is, for the most part only a few feet thick outside of Tulsa County. The Hogshooter lies conformably upon the
Coffeyville formation. While this limestone can be traced northeast-southwest for many miles in northeastern Oklahoma, it is well exposed in many places in Tulsa County. In T. 19 N., R. 11 E., it is more massive and about 40 feet thick.

**NELLIE BLY FORMATION**

The Nellie Bly formation is exposed in the vicinity of Skiatook, and covers a large part of T. 19 N., R. 11 E., where it is approximately 125 feet thick. It lies upon the Hogshooter limestone, and is overlain by the Dewey limestone. This formation is composed of alternating bluish-gray shales and gray sandstones. In the north part of T. 19 N., R. 11 E., it is made somewhat obscure locally by the terrace and dune sands of the Arkansas River.

**DEWEY LIMESTONE**

The Dewey limestone lies upon the Nellie Bly formation, and is overlain by the Ochelata formation. It occurs as a narrow outcrop extending north to south along the east side of T. 19 N., R. 10 E., being only about 6 to 10 feet thick in this area. This limestone is characteristically a shaly blue-gray in color, and is usually quite fossiliferous.

**OCHELATA FORMATION**

This formation covers almost all of T. 19 N., R. 10 E., where it is approximately 450 to 500 feet thick. It is composed mostly of variegated shales, but it also includes several sandstone and limestone members, the most prominent of which is the Avant limestone located about 150 to 200 feet above the base of the formation. The Avant member is usually bluish-gray in color, and contains an appreciable amount of ferruginous material, which upon weathering causes the limestone to have a reddish-brown color. Due to its persistence the Avant is a good key bed in this area, being noticeable as low cliffs and terraces along the hillsides and wooded slopes.

**Subsurface Formations**

**PRE-CAMBRIAN**

For the most part the exact location and lateral extent of the buried granite hills and ridges of Tulsa County are only partially known. However, to date approximately ten wells have been reported as having encountered granite in this area. Through the courtesy of Frank C. Greene, the writer is able to submit the following wells which encountered granite, together with their location and depth. Not all of these are in Tulsa County, however.

It is possible that igneous rocks other than granite underlie the county. However, our knowledge of this is rather meager at the present time, as only comparatively few wells have been drilled into igneous rocks. Our present data indicate that the granite surface is very uneven. It also appears that there are many isolated granite peaks and possibly ridges around which the sedimentary rocks were deposited. Wells drilled on structure usually encounter 400 to 500 feet of Arbuckle limestone before drilling into the granite; whereas, wells drilled off structure may penetrate 1,000 to 1,500 feet of Arbuckle limestone before the granite is reached. This probably means that not all of the granite floor was submerged and that granite islands existed during the deposition of sediments in the early Arbuckle sea.

**Table I. List of wells penetrating granite in and near Tulsa County.**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>COMPANY</th>
<th>FARM</th>
<th>Depth To Granite Feet</th>
<th>TOTAL DEPTH Feet</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW 27-17-14</td>
<td>Wilcox Co.</td>
<td>Hulputta</td>
<td>2242</td>
<td>2435</td>
<td>Top of red formation, 3300'</td>
</tr>
<tr>
<td>SE 22-19-10</td>
<td>Sweeney Co.</td>
<td>Winters</td>
<td>2687</td>
<td>3071</td>
<td>Red Granite</td>
</tr>
<tr>
<td>SW 1-19-15</td>
<td>Winters</td>
<td>Billy</td>
<td>2700</td>
<td>2704</td>
<td>Wagoner Co.</td>
</tr>
<tr>
<td>NE 8-20-12</td>
<td>Grimes and Gillespie</td>
<td>?</td>
<td>3215</td>
<td>3217</td>
<td>Osage County</td>
</tr>
<tr>
<td>SW 3-20-8</td>
<td>Tidal</td>
<td>Arnold</td>
<td>3158</td>
<td>3158</td>
<td>Dark Red</td>
</tr>
<tr>
<td>NW 9-20-12</td>
<td>Barnsdall</td>
<td>Cox</td>
<td>2424</td>
<td>2435</td>
<td>&quot;Sand&quot; 3300'</td>
</tr>
<tr>
<td>SE 23-20-14</td>
<td>J. W. Irwin</td>
<td>No. 1 Blakemore</td>
<td>3195</td>
<td>3360</td>
<td>Osage County</td>
</tr>
<tr>
<td>SE 28-21-13</td>
<td>Superior</td>
<td>No. 2 Blakemore</td>
<td>1365</td>
<td>1462</td>
<td>Rogers County</td>
</tr>
<tr>
<td>SE 31-22-15</td>
<td>Duequesne</td>
<td>Doublehead</td>
<td>1566</td>
<td>1589</td>
<td>Red Granite</td>
</tr>
<tr>
<td>NE 32-22-10</td>
<td>Tidal-Osage</td>
<td>?</td>
<td>1785</td>
<td>2785</td>
<td>Rogers County</td>
</tr>
<tr>
<td>NE 32-22-10</td>
<td>?</td>
<td>?</td>
<td>2217</td>
<td>2222</td>
<td>Pinkish red</td>
</tr>
<tr>
<td>NE 32-22-10</td>
<td>Tidal-Osage</td>
<td>?</td>
<td>2240</td>
<td>2290</td>
<td></td>
</tr>
</tbody>
</table>

**CAMBRO-ORDOVICIAN ARBUCKLE LIMESTONE**

Examination of well logs and drill cuttings taken from various areas of Tulsa County indicate that the Arbuckle limestone underlies the entire county. Its upper surface is unconformable to all overlying formations. While the maximum thickness of this formation is unknown in this region, it probably varies from several hundred feet over the buried granite ridges to possibly 1,000 to 1,500 feet in the structural valleys. However, in a well drilled directly over a granite hill the drill evidently passed out of the Chattanooga formation into the granite.

For the most part the Arbuckle limestone is characteristically a siliceous, crystalline, medium-grained dolomitic limestone, occasionally containing some quartz. The color varies from almost white to brown, and the magnesium content varies from 20 to 40 per cent.

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2. F. C. Greene, Geologist, Shell Petroleum Corporation.

SILICEOUS LIME OR TURKEY MOUNTAIN SAND

The logs of many wells drilled in Tulsa County usually record either one or the other of these terms before recording the Arbuckle limestone. Reference to the two geologic cross-sections accompanying this report will show some of the wells in which this horizon has been identified and recorded. The horizon that has been called the Turkey Mountain is the weathered top of the Arbuckle except in a few places where due to poor samples or lack of fossils, it may be Simpson. Regarding the age, character, and correlation of these formations the reader is referred to the work of White.

ORDOVICIAN
BURGEN ("HOMINY") SAND

The "Burgen" sand, which is thought by some to be equivalent to the St. Peter sandstone, was first called the "Hominy" sand because it was thought to be the principal source of deep production in the vicinity of Hominy, Oklahoma. It lies upon the weathered surface of the Arbuckle limestone, and varies in thickness from 10 to 75 feet in Tulsa County. This is a hard, massive sandstone composed of rounded and angular grains of various sizes. The color varies from light gray to yellowish brown.

Until recently the Burgen sandstone was not differentiated from the overlying Tyner formation, and the "Wilcox" sand above was correlated with the Tyner. This correlation was erroneous, as in almost all the deep wells drilled a hundred feet or more of green sandy shales (Tyner formation) are encountered, after which 30 to 50 feet of sandstone ("Burgen") is penetrated before reaching the Arbuckle limestone.

TYNER FORMATION

This formation lies beneath the Wilcox sand. Apparently it ranges in thickness from 40 to more than 200 feet in Tulsa County. In the central, northern, and eastern parts of the county, where the Wilcox sand is absent, the Tyner lies directly beneath the Chattanooga shale. It consists of clay shale and sandy shale, and is easily recognized by its light green color. In many wells two distinct sandy horizons have been recognized in the Tyner. The upper Tyner sand which may vary 10 to 40 feet in thickness is separated from the lower sand by green shales of variable thickness.

WILCOX SAND

The Wilcox sand, the Tyner formation, and the Burgen sandstone of northeastern Oklahoma seem to be the northern equivalents of the Simpson formation of the Arbuckle Mountain section of southern Oklahoma. The Wilcox is separate and distinct from the underlying Tyner.
OIL AND GAS IN OKLAHOMA

formation, and should not be correlated with it. The sandstone is composed of both angular and rounded fine-grained white quartz, usually loosely cemented.

MISSISSIPPIAN CHATTANOOGA SHALE

In Tulsa County this formation lies unconformably above the Tyner formation and the Wilcox sand where the latter is present. It is characteristically brown to black, slaty, bituminous shale of uniform texture. It is remarkably persistent in both lithologic character and thickness in Tulsa County as well as in adjoining counties, being usually about 30 to 60 feet thick.

Regarding the age and correlation of the Chattanooga Ulrich5 says:

The Bois d'Arc is succeeded by the more or less cherty shales of the Woodford formation which I correlate with the widely distributed Ohio and Chattanooga shales and classify as earliest Mississippian. Black shales regarded as strictly contemporaneous occur in northeastern Oklahoma, Arkansas, Missouri, Illinois, Indiana, Michigan, central Tennessee, and in the Appalachian Valley from Alabama to well into southeastern Virginia. In the late State they pinch out northwardly from a maximum thickness of 500 feet and rest with an intervening break on much thicker often sandy, late Devonian shales that pinch out southwardly in northeast Tennessee.

"MISSISSIPPI LIME" (BOONE-MAYES-PITKIN-MORROW)

This series of limestone beds underlies all of Tulsa County. It is still debatable as to whether the upper part is the equivalent of the Pitkin or the Morrow group, but the middle and lower members have been definitely correlated as being Boone and Mayes equivalents. Regarding this correlation of the members of the "Mississippi lime" to the east of Tulsa County Bush says:

The faunas of the Pitkin and Morrow groups are very similar, the Pitkin being classified as Chester in age, and the Morrow as lowermost Pennsylvanian. It must be noted, though, that the latter group has a decided Mississippian facies, together with the Pennsylvanian. The Pennsylvanian elements of this fauna are termed proemial and the Mississippian residual by Mathur6 who has made a careful study of them. Then on the basis of lithology and faunas also, the Morrow and Pitkin limestones are not rapidly distinguishable, and where the stratigraphic position of each may be clear in Arkansas, it is not in Oklahoma. The fact that the Morrow is resting directly on the Mayes formation in this well, suggests that the Pitkin-Fayetteville formations may be absent entirely in this area, and that what has often been mistaken for Pitkin in both well records and outcrop is part of the Morrow.


The limestones and shale beds composing the "Mississippi Lime" vary somewhat in thickness over Tulsa County. They seem to be thinnest in the southern and extreme western parts, being about 215 feet thick in T. 16 N., R. 13 E., and about 220 feet thick in T. 16 N. In the northern part of the county, in T. 22 N., R. 13 E., the apparent thickness is 250 to 300 feet; whereas, in the eastern part, in T. 19 N., R. 14 E., these beds average 350 to 400 feet thick. In the vicinity of Tulsa they are quite thick also, being about 350 feet.

The "Mississippi lime" is characteristically a grayish to brown to almost black cherty limestone with occasional shale partings. The upper member, which is usually about 60 to 80 feet thick, is gray limestone and chert, coarsely crystalline, platy, granular, and locally micaceous. This is the Morrow-Pitkin(?) member. The middle member consists of dark gray to black finely granular, platy, siliceous, argillaceous limestone, locally separated by thin beds of black shale. This middle member is the Mayes formation. The lower part consists of 40 to 50 feet of light gray massive chert and finely crystalline buff limestone, which is the Boone limestone member.

PENNSYLVANIAN CHEROKEE SHALE

The upper part of the Cherokee shales, including the Senora formation and the Stuart shale, is exposed at the surface in southeastern parts of Tulsa County. The stratigraphic interval composing the Cherokee shales includes all the shales and interbedded coal seams and sandstones lying unconformably above the Morrow-Pitkin group up to the base of the Fort Scott limestone. Within this group of rocks commercial production of oil and gas has been obtained from the Prue (Squirrel), Red Fork, Bartlesville (Glenn), Taneha (Tucker), and Dutcher sands.

Reference to the two cross-sections shows that the Cherokee shales are approximately 900 feet thick and are encountered at about 400 feet in depth in eastern Tulsa County; that is, in SE 1/4 sec. 16 T. 19 N. R. 14 E. In SW 1/4 sec. 17, T. 19 N. R. 10 E., the thickness is 625 feet found at a depth of 1,800 feet. This shows a thinning toward the west, as well as a dip of approximately 45 to 55 feet to the mile. In the northern part of the county, in sec. 8, T. 21 N. R. 13 E., these shales are encountered at 700 to 725 feet, and are about 650 to 700 feet thick; whereas, in the southern part of the county, in sec. 16, T. 16 N. R. 13 E., the thickness is 1,300 feet, and the average depth is 550 to 600 feet. This shows an appreciable thickening toward the south.

FT. SCOTT (OSWEGO) LIMESTONE

This formation lies above the Cherokee shales. The outcrop can be traced southwestward from the northeast corner of T. 18 N., R. 14 E., into the Quaternary deposits near the Arkansas River northwest of TULSA COUNTY.
the town of Leonard. The upper and lower limestone members are usually called the upper and lower “Oswego” limes. The upper member is found about 1,650 feet deep in sec. 17, T. 19 N., R. 10 E., and 600 feet deep in sec. 8, T. 21 N., R. 13 E. The thickness varies throughout the county, but reaches a maximum of about 100 feet.

**LABETTE SHALE**

Above the Fort Scott (Oswego) limestone the drill may encounter from 20 to 250 feet of brown and blue to greenish sandy, clay shales, known collectively as the Labette shale. They are exposed at the surface in the east half of T. 19 N., R. 14 E., but dip rather rapidly westward until in T. 19 N., R. 10 E., they lie about 1,600 feet below the surface. In this area these shales are only 30-50 feet thick; whereas, they obtain a thickness of 250 feet in sec. 16, T. 19 N., R. 14 E. These beds are thinnest in the extreme northwest part of the county.

**OOGAH ("BIG") LIME**

Oologah or “Big lime” is the name applied to the hard, massive, cherty limestone formed by the merging of the Pawnee and Atalmon limestones. It is exposed in Tps. 18, 19, and 20 N., R. 14 E., according to the geologic map compiled by Miser, and becomes thicker and more shaly to the south. There is a gentle westward dip from the outcrops mentioned until in sec. 18, T. 19 N., R. 10 E., it is encountered at an average depth of 1,575 feet. In this area the limestone has thinned to approximately 12 feet. The Oologah is thickest in T. 20 N., R. 13 E., where it is about 135 feet thick.

In the northern part of the county the Oologah has an average thickness of 105 feet, and thickens toward the north. In T. 21 N., R. 13 E., it is encountered at depths ranging from 250 to 475 feet. This formation thins out and becomes more and more shaly toward the south until from sec. 6, T. 18 N., R. 13 E., southward it is logged as either shale, sandy shale, or very thin limestone.

**NOWATA SHALE**

Lying above the “Big lime” is a series of shales and a few inter-stratified sandstones which attain a thickness of 425 to 475 feet in T. 19 N., R. 10 E., and are encountered at an average depth of 925 feet. This group of rocks is known as the Nowata Shale. The Cleveland sand is found in this formation. The Nowata thickens toward the east, and has a widespread outcrop in the central and northeastern parts of Tulsa County.

**COFFEYVILLE FORMATION**

The interval from the top of the Nowata shale to the base of the Hogshooter (Lost City) limestone is known as the Coffeyville formation. In T. 19 N., R. 10 E. these beds are about 375 feet thick, and

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**GENERALIZED GEOLOGIC SECTION OF TULSA COUNTY**

<table>
<thead>
<tr>
<th>Ochelata Fm</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>Dewey Limestone</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Nellie Bly Fm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hogshooter (Lost City)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffeyville Fm</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Checkerboard Ls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleveland Sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nowata Shale</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Oologah (Big) Limestone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fort Scott (Oswego) Limestone</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Figure 129.
are encountered at an average depth of 450 to 500 feet. It has been concluded by geologists in the past that the Checkerboard limestone belongs near the base of the Coffeyville formation.

**HOGSHOOTER (LOST CITY) LIMESTONE**

This thin but persistent limestone is encountered in wells only in the western part of Tulsa County, in T. 19 N., R. 10 and 11 E. It dips to the west at the rate of 60 feet to the mile, and in wells in the west part of T. 19 N., R. 19 E. it is about 740 feet below the surface.

Figure 129 is a generalized geologic section of the central part of Tulsa County.

---

**TULSA COUNTY**

**STRUCTURE**

The strata exposed at the surface in Tulsa County have a northeast-southwest strike. The geologic map accompanying this report shows the position and direction of strike of these formations. The surface structure for the most part is a portion of the large monocline which is well known in this section of the State. This monocline dips toward the northwest.

The westward dip of the surface formations is traceable with depth down to and including the Mississippi lime. The formations below the Mississippi lime are also monoclinic except where interrupted by folding, but the general regional dip is toward the southwest. The cross-sections (Map Nos. XLVIII and XLIX) show the regional structure of the county.

The productive structures in the Pennsylvanian sediments are usually reflected at the surface in this county, but where the oil and gas have accumulated in sandstone lenses this is not generally true. Structures which have been mapped on subsurface strata as anticlines and domes are often reflected at the surface in this area as small noses and terraces.

Various theories have been advanced as to the origin of the structures that have proved productive in Tulsa County as well as in the adjoining counties in this area. Some geologists maintain that tangential compression accompanying the Ozark uplift was the major cause; whereas, others believe that differential condensation and compaction of the various sediments themselves was the principal cause. Vertical thrust resulting from the intrusion of the granite ridges has also been advocated as the cause, and rotational stresses transmitted to overlying sediments by shearing in the basement rocks has also been advanced as a possible cause.

It is quite probable that no one of the above theories can be interpreted as being applicable to the cause of all the types of structures found in Tulsa County.

**OIL AND GAS DEVELOPMENT**

**History**

The first oil produced in Tulsa County was at Red Fork on June 15, 1901 by Dr. F. S. Clinton and associates on the Bland allotment in sec. 22, T. 19 N., R. 11 E. This well had an initial production of approximately 100 barrels from the Big lime at about 600 feet in depth and is still producing. The Red Fork pool was responsible for the first commercial production of Oklahoma. Oil has been found in other places previous to 1901, but it had not been developed commercially.

The oil found above the Mississippi lime in Tulsa County possibly had its source in the thick Cherokee black shales. The production obtained from the Siliceous ( Arbuckle) lime, Burgen (Hominy) sand, Tyner formation, and the Wilcox sand may have originated in the Chattanooga shale.
Figure 131. Bruner pool, contoured on the top of the Oswego lime.

Figure 132. Bruner Pool, contoured on the top of the "Turkey Mountain lime." 
Table II. Productive Horizons of Tulsa County

<table>
<thead>
<tr>
<th>NAME</th>
<th>AGE</th>
<th>AVERAGE THICKNESS Feet</th>
<th>DESCRIPTION</th>
<th>AREAS WHERE PRODUCTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Lime</td>
<td>Penn.</td>
<td>12</td>
<td>Coarse-grained, comparatively soft, porous, fairly uniform in texture and porosity.</td>
<td>Red Fork.</td>
</tr>
<tr>
<td>Oswego</td>
<td>Penn.</td>
<td>32</td>
<td>Has upper and lower limestone members; coarse, brownish</td>
<td>Red Fork, Owasso, Bird Creek, Collinsville.</td>
</tr>
<tr>
<td>Perryman (Prue-Squirrel)</td>
<td>L. Penn.</td>
<td>28</td>
<td>Very fine-grained, muddy brown in color, shaly in places.</td>
<td>Tulsa, Jenks.</td>
</tr>
<tr>
<td>Bartlesville (Glenn)</td>
<td>L. Penn.</td>
<td>45</td>
<td>Light muddy brown color, angular grains, fine to coarse-grained, contains some shale. Porosity 12 to 39 per cent.</td>
<td>Tulsa, Sperry, Glenn Pool, Owasso, Leonard, Bixby, Flat Rock, Bird Creek, Dawson, Collinsville.</td>
</tr>
<tr>
<td>Taneha (Tucker) Booch</td>
<td>L. Penn.</td>
<td>28</td>
<td>Medium- to fine-grained, mostly well-rounded but some angular grains. Pale yellowish white with some dark micaceous material. Traces of iron oxide.</td>
<td>Dawson, Owasso, Sperry, Glenn Pool, Bixby, Fisher, Sand Springs, Broken Arrow, Taneha, Flat Rock, and Jenks.</td>
</tr>
<tr>
<td>Burgess</td>
<td>Penn.</td>
<td>26</td>
<td></td>
<td>Sand Springs, Broken Arrow, Dawson, Sperry, Owasso, Bruner-Vern, Bird Creek, Fisher, Collinsville, and Flat Rock.</td>
</tr>
</tbody>
</table>

Table II., Cont'd.

<table>
<thead>
<tr>
<th>NAME</th>
<th>AGE</th>
<th>Feet THICKNESS</th>
<th>DESCRIPTION</th>
<th>PRODUCTIVE AREAS WHERE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mississippi Lime</td>
<td>Miss.</td>
<td>5‡</td>
<td>Mostly limestones with thin shale beds, grayish to brown, cherty, plati, granular, micaceous locally. Produced mostly gas.</td>
<td>Bixby, Jenks, Dawson, Sperry, Owasso.</td>
</tr>
</tbody>
</table>
Producing Horizons

Table II shows the producing horizons of Tulsa County arranged in stratigraphic order, the youngest at the top, together with a brief description and the average thickness of each.

Most of the producing horizons have a wide range in quantity of oil and gas, but the Tanha (Tucker), Burgess, Mississippi lime, have produced mostly gas.

**Table III. Analysis of Crude Oils**

<table>
<thead>
<tr>
<th></th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. P. I. Gravity</td>
<td>32.4</td>
<td>31.3</td>
<td>34.5</td>
<td>34.1</td>
</tr>
<tr>
<td>Per cent sulphur</td>
<td>0.30</td>
<td>0.23</td>
<td>0.27</td>
<td>0.19</td>
</tr>
<tr>
<td>Saybolt Universal Viscosity at 700 F</td>
<td>70.2</td>
<td>83.4</td>
<td>54.8</td>
<td>58.4</td>
</tr>
<tr>
<td>Per cent water</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline and naphtha</td>
<td>24.8</td>
<td>20.3</td>
<td>26.9</td>
<td>26.2</td>
</tr>
<tr>
<td>Kerosene</td>
<td>17.4</td>
<td>18.5</td>
<td>18.8</td>
<td>17.8</td>
</tr>
<tr>
<td>Gas oil</td>
<td>12.5</td>
<td>6.4</td>
<td>12.6</td>
<td>10.9</td>
</tr>
<tr>
<td>Light lubricating distillate</td>
<td>5.2</td>
<td>12.6</td>
<td>5.9</td>
<td>11.5</td>
</tr>
<tr>
<td>Medium lubricating distillate</td>
<td>11.5</td>
<td>13.8</td>
<td>11.1</td>
<td>5.2</td>
</tr>
<tr>
<td>Carbon residue</td>
<td>9.3</td>
<td>7.5</td>
<td>7.5</td>
<td>6.2</td>
</tr>
</tbody>
</table>


Productive Areas

Table IV shows the names of the various commercial oil and gas fields of Tulsa County, together with their location and date of opening.

Previous to the discovery of the Wilcox sand near Bixby by H. F. Wilcox in April, 1914, most of the production in Tulsa County had been obtained from the Bartlesville, Red Fork. The initial production in the Bartlesville sand has ranged from 10 to 2,000 barrels per day; but the Red Fork sand was not so prolific, the wells ranging from 3 to 200 barrels initial. Average initial daily production in the Big lime was only about 10 barrels, but many wells have produced from this horizon.

Some widely scattered production as high as 200 barrels per day has been reported from the Dutcher sand. Commercial production in the Burgess sand has ranged from about 5 to 500 barrels per day. The Mississippi lime production has been as high as 40 to 50 barrels.

The most prolific wells in Tulsa County have been discovered in the Wilcox and Turkey Mountain (Siliceous lime) sands, ranging as high as 2,000 to 2,500 barrels daily in the former, and as high as 3,000 barrels in the latter. Initial production from the Tyner series has been as high as 500 barrels per day in the field near Sperry and at Bruner-Vern.
It is quite possible that there are still some undeveloped structures in Tulsa County, but it is probable that the area has been quite extensively prospected. The present method of repressuring has proved too slowly to predict any highly productive areas of repressuring. The method used by both operators has been very small and insufficient to complete the profitable wells. Also, operators cannot be expected to complete commercial wells by this method. It is likely that the area is adiabatic to a large extent, as has been shown in the past, but since the productive areas of northeastern Oklahoma are adaptable to the water flooding, the possibility of producing them at a profit has not been discovered until the oil is repressured. It has been repressured to its economic limit.

### Table IV. Oil and Gas Fields in Tulsa County

<table>
<thead>
<tr>
<th>FIELD</th>
<th>LOCATION</th>
<th>DATE OF OPENING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tulsa</td>
<td>T. 19 N., R. 13 E.</td>
<td>1901</td>
<td>Small oil and gas wells.</td>
</tr>
<tr>
<td>Jenks</td>
<td>T. 18 N., R. 13 E.</td>
<td>1901</td>
<td>Produces both oil and gas.</td>
</tr>
<tr>
<td>Bird Creek</td>
<td>T. 18 N., R. 12-13 E.</td>
<td>1906</td>
<td>Good oil wells.</td>
</tr>
<tr>
<td>Glenn Pool</td>
<td>T. 21 N., R. 12 E.</td>
<td>1906</td>
<td>Oil and gas; good deep production.</td>
</tr>
<tr>
<td>Sperry</td>
<td>T. 21 N., R. 12 E.</td>
<td>1909</td>
<td>Much oil and wet gas.</td>
</tr>
<tr>
<td>Collinsville</td>
<td>T. 22 N., R. 14 E.</td>
<td>1911</td>
<td>Both oil and gas.</td>
</tr>
<tr>
<td>Owasso</td>
<td>T. 21 N., R. 14 E.</td>
<td>1913</td>
<td>Many large gas wells; not much oil.</td>
</tr>
<tr>
<td>Broken Arrow</td>
<td>T. 18 N., R. 12 E.</td>
<td>1913</td>
<td>Mostly gas; some oil wells.</td>
</tr>
<tr>
<td>Lost City</td>
<td>T. 18 N., R. 12 E.</td>
<td>1913</td>
<td>Small oil and gas wells.</td>
</tr>
<tr>
<td>Bixby</td>
<td>T. 16-17 N., R. 13 E.</td>
<td>1914</td>
<td>Production from Tanahe and Burgess.</td>
</tr>
<tr>
<td>Leonard</td>
<td>T. 17 N., R. 14 E.</td>
<td>1916</td>
<td>Small gas and oil wells; good deep production.</td>
</tr>
<tr>
<td>Tanahe</td>
<td>T. 19 N., R. 11-12 E.</td>
<td>1916</td>
<td>Small oil wells; good gas wells.</td>
</tr>
<tr>
<td>Tuskegee</td>
<td>T. 19 N., R. 11 E.</td>
<td>1918</td>
<td>Small oil and gas production.</td>
</tr>
<tr>
<td>Turkey Mountain</td>
<td>T. 18 N., R. 12 E.</td>
<td>1922</td>
<td>Small oil and gas wells; good deep production.</td>
</tr>
<tr>
<td>Bruner-Vernard</td>
<td>T. 19 N., R. 12 E.</td>
<td>1912-1923</td>
<td>Small oil and gas wells in upper sands; deep production.</td>
</tr>
<tr>
<td>Inscho</td>
<td>T. 19 N., R. 11 E.</td>
<td>1925</td>
<td>Good production in Turkey Mountain sand.</td>
</tr>
</tbody>
</table>
The oil sands above the Mississippi lime have been quite extensively tested in Tulsa County, but apparently there are still several areas in which the Wilcox, Tyner, Burgen, and Turkey Mountain sands should prove productive. The Wilcox is found below only a portion of the county.

dipping monocline, interrupted at intervals by noses, terraces, anticlines and synclines, and (2), those sedimentary rocks lying below the Mississippi lime which form a southwestward dipping monocline except where interrupted by anticlinal folds and terraces.

Oil and gas development began actively at Red Fork in 1901, and has continued more or less intensively and extensively until the present time.

Commercial production has been obtained from the Big lime, Cleveland, Oswego (?), Perryman (Prue), Red Fork, Barlesville, (Tucker) Tanha, Dutcher, Burgess, Mississippi lime, Wilcox, Tyner, Burgen (?), and Turkey Mountain (Siliceous lime) sands at depths ranging from 400 to 2,800 feet. The majority of the wells were small producers initially, but they have been usually long lived. Many of the earlier wells drilled in this county are still being pumped.

SUMMARY

The rocks outcropping at the surface are composed of the Cherokee shales and younger deposits of Pennsylvanian age. The rocks penetrated in drilling belong to the Pennsylvanian, Mississippian, Ordovician, and Cambrian systems. In a few areas pre-Cambrian granite has been encountered.

The general structure of Tulsa County is similar to that of other counties in this region, and can be divided roughly into two classes: (1) that of the Mississippi lime and younger rocks, generally a westward
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