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OIL AND GAS IN OKLAHOMA

GEOLOGY OF OSAGE COUNTY

By

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CONTENTS

ILLUSTRATIONS

FOREWORD

In 1917 the Oklahoma Geological Survey issued Bulletin 19 part 2 entitled, "Petroleum and Natural Gas in Oklahoma." This volume was so popular that the supply was soon exhausted, and for several years copies have not been obtainable.

The present director has seen the need of a revision of this bulletin. On account of lack of appropriations he has not been able to employ sufficient help to compile the data, and has called on some twenty representative geologists throughout the state to aid in the preparation of reports on separate counties. These gentlemen, all busy men, have contributed freely of their time and information in the preparation of these reports.

It will be understood that the facts as set forth in the various reports represent the observation and opinion of the different men. The Oklahoma Geological Survey has every confidence in judgment of the various authors, but at the same time the Survey does not stand sponsor for all statements made or for all conclusions drawn. Reports of this kind are, at best, progress reports, representing the best information obtainable as of the date issued and doubtless new data will cause many changes in our present ideas.

Mr. H. T. Beckwith, who has prepared the chapter on Osage County, has had several years experience in this part of the State. Osage County has been producing oil longer than almost any other area in Oklahoma and, contains more separate fields than any other county. It is impossible to deal in minute detail with each of the thirty-five or more producing oil and gas fields in the county in a report of this character. Mr. Beckwith has called to his aid the assistance of a number of other workers, and by the combined information obtained by these various men, has given us a comprehensive picture of conditions as represented by some of the most typical oil fields. The map accompanying this report is believed to be the most complete map of the county ever published. It shows, in some detail, the surface outcrops of the various geological formations.

CHAS. N. GOULD
Director

February, 1928.

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. F. 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

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.

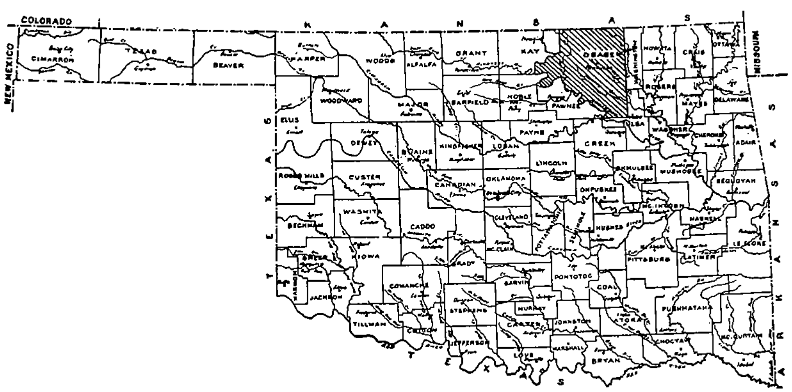


Figure 1.—Map of Oklahoma showing location of Osage County.

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.

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 paralleling 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 dendritic 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.

GEOLOGY

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.[1] 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 Chattanooge 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 (Cambro-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.[2]

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.

1. Gould, Chas. N., Index to the stratigraphy of Oklahoma: Oklahoma Geol. Survey, Bull 35, p. 81, 1925.

2. White, L. H., Subsurface distribution and correlation of the pre-Chattanooga ("Wilcox" sand) series of northeastern Oklahoma: Oklahoma Geol. Survey, Bull. 40-B, p. 9, 1926.

The surface formations, as previously mentioned, are of Permian and Pennsylvanian age. (See geologic map, Plate I.) 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[3] 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 Permian 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 Vilas 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, limestone, 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

3. Beede, J. W., The Neva limestone in northern Oklahoma: Oklahoma Geol. Survey, Bull. 21, p. 21, 1914.

least, were deposited in shallow waters such as tidal flats, or flood-plains 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 species 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 upper 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.[4]

MARION FORMATION

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.

Herington Limestone Member

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.

Winfield Limestone Member

Character: This limestone lies at the top of th: 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-

4. Gould, Chas. N., op. cit.

laceous 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[5] 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.[6]

Section of Neva Limestone, 4½ miles south of Grainola.

	Ft.	In.
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. **Schwagerinae** Chert.	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.

5. Beede, J. W., Oklahoma Geol. Survey, Bull. 21, p. 7, 1914.
6. Beede, J. W., op. cit., p. 17.

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.

SAND CREEK FORMATION

This formation is described by Gould[7] 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. Overlies the Buck Creek formation and underlies Elmdale formation. Includes at base the Grayhorse limestone member.

Correlation: The formation is equivalent to the middle part of the Wabaunsee group of the Kansas section.

Foraker Limestone Member

Character: This limestone or series of limestones, sandstones, and shales make up fully half of 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, slabby 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, slabby 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.

7. Gould, Chas. N., op. cit., p. 79.

Grayhorse Limestone Member

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 south 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.

8. Bowen, C. F., Roundy, P. V., Ross, C. S. and Reeves, Frank, Structure and oil and gas resources of the Osage Reservation, Oklahoma: U. S. Geol. Survey, Bull. 686, p. 282, 1922.

Cryptozoan-Bearing Limestone Member

Character: The *Cryptozoon*-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 Cryptozoa, 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 segment 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 *Cryptozoon*-bearing and the underlying Bird Creek limestones.

Bird Creek Limestone Member

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, *Enteletes 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 lime" in the northern part of the county and from 40 to 60 feet above 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 best distinguished 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.

9. Heald, K. C., Structure and oil and gas resources of the Osage reservation, Oklahoma: U. S. Geol. Survey, Bull. 686, p. 215, 1922.

10. Heald, K. C., and Mather, K. F., Structure and oil and gas resources of the Osage reservation Oklahoma: U. S. Geol. Survey, Bull. 686, p. 226, 1922.

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 Okey 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 lime" 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 impure conglomeratic limestone 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-

11. Heald, K. C., op. cit., p. 217.

12. Heald, K. C., and Mather, K. F., Structure and oil and gas resources of the Osage reservation, Oklahoma: U. S. Geol. Survey, Bull. 686, p. 152, 1922.

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 correlated as Lecompton (?) limestone by Bowen, et al[13] 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 sparingly 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

13. Bowen, C. F., Roundy, P. V., Ross, C. S., and Reeves, Frank, op. cit., p. 280.

in some places. According to Heald[14] 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.

Okey Limestone (Lentil) 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 lentils. Most of these shale lentils are vari-colored, 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 shaly 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 lentil 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.

14. Heald, K. C., U. S. Geol. Survey, Bull. 691-C, p. 68, 1919.

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 lime outcrops as a thin-bedded, gray, ledge-forming limestone from 6 to 8 feet thick. Its outcrop on Artillery Mountain in the SW.¼ 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 muddly yellow color and breaks up into wedge shaped slabs. Other than lots of *Fusulina* 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 distinctive 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 Labadie 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[15]:

> 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 Bigheart sandstone, but it differs from the Bigheart in not being conglomeratic. It is also immediately underlain by gray shale, 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 lens 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.¼ T. 23 N., R. 9 E., where it is split up into two or more beds by intervening shale wedges. Some short lentils 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.

Cochahee Sandstone Member

Character: A dark colored, hard, massive sandstone, locally fossiliferous 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.

15. Bowen, C. F., U. S. Geol. Survey, Bull. 686, pp. 19-20, 1922.

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. 10-11 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.[16] 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 thins 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.[17] 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 Hominy 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

16. Goldman, M. I., and Robinson, H. M., U. S. Geol. Survey, Bull. 686, p. 362, 1922.

17. Wood, R. H., Personal communication.

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[18] who describes it as follows:

> The Iatan (?) limestone, which lies from 100 to 180 feet below the top of the Jonesburg 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 sandstone (**Cheshewalla**). * * *This variation in thickness is characteristic of Iatan (?) limestone * * *. **Fusulina** is the most characteristic and easily recognizable fossil in the limestone * * *

18. Goldman, M. I., Structure and oil and gas resources of the Osage reservation, Oklahoma: U. S. Geol. Survey, Bull. 686, p. 331, 1922.

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 all 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 *Fusulina*-bearing Iatan (?) 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 that 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 a 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 lentils 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 south of Bird 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 northern 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 lentils 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 slabby sandstones. In most places, at least to the south of the type locality which is west of the town of Barnsdall (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 separated 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.¼, 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 its most 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.

A very good description of its occurrence in T. 20 N., R. 11 E., is that given by Lloyd and Mather[19] 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 brownish 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[20] as follows:

> The beds here designated Clem Creek sandstone embrace a series of massive medium-grained sandstones and thin lenticular shales aggregating 60 to 65 feet in thickness and are exposed along Clem Creek in the northwestern 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 giver 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 2[illegible] 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-

19. Lloyd, E. R. and Mather, K. F., Structure and oil and gas resources of the Osage reservation, Oklahoma: U. S. Geol. Survey, Bull. 686, p. 121, 1922.
20. Emery, W. B., U. S. Geol. Survey, Bull. 686, p. 3, 1922.

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.

Okesa 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 Okesa member is from that of Clark.[21]

> In the vicinity of Okesa 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 13 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 50 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 50 feet or so below the Okesa sandstones. Tracing it south into 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 Okesa sandstone into one group of soft 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 (Lentil) 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]

21. Clark, F. R., U. S. Geol. Survey, Bull. 686, p. 95, 1922.
22. Hopkins, O. B. and Powers, Sidney, Structure and oil and gas resources of the Osage reservation, Oklahoma: U. S. Geol. Survey, Bull. 686, p. 240, 1922.

> 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 grades 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 Okesa 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 this 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.¼, T. 24 N., R. 10 E.

Red Limestone (Lentil) 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 is the base of another limestone which because of its 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 as such 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 **Productus** 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

23. Hopkins, O. B. and Powers, Sidney, op. cit. p. 239.
24. Hopkins, O. B. and Powers, Sidney, Idem. p. 238.
25. Hopkins, O. B. and Powers, Sidney, Idem. p. 238.
26. Goldman, M. I., op. cit., p. 355.

and is a hard slabby sandstone 3 to 5 feet thick. It is overlain and underlain by shale and usually shows many casts of *Fusulina*.

Occurrence: This limestone as a mappable units 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 lentil 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[27] 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 massive flaggy 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[28] 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 flaggy, the lower part massive. The topmost bench, which is 12 to 15 feet below the top of the Dewey limestone, caps 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.

27. Roundy, P. V., Heald, K. C., and Richardson, G. R., U. S. Geol. Survey, Bull. 686, pp. 396-398, 1922.
28. Lloyd, E. R. and Mather, K. F., op. cit., pp. 121-122.

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[29] 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 190 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.

HOGSHOOTER LIMESTONE

Character: A thin bedded, argillaceous limestone, blue on fresh fracture and weathers 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.

29. Ross, C. S., U. S. Geol. Survey, Bull. 686, p. 172, 1922.

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 thicknesses of the principal formations here given will in all possibility 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 western side of the county from the base of the Permian to the top of the Mississippian, 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 another 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 Lime" group of the driller; the Peru 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

30. Gould, C. N., Idem.

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 to dark brown, almost black limestone. In some places 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 Mississippi 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 White[31] 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, dolomitic, 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. White[32] states: "Samples of Arbuckle limestone from widely separated wells resemble each other so much that it is difficult to distinguish between them." Clark and Cooper[33] describe the Arbuckle limestone as found in drill cuttings, as follows:

31. White, Luther H., op. cit.
32. White, Luther H., Idem.
33. Clark, G. C., and Cooper, C. L., Oil and gas geology of Kay, Grant, Garfield and Noble counties: Oklahoma Geol. Survey, Bull. 40-H, p. 19, March, 1927.

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-Arbuckle folding has taken place and the upper surface has been truncated. What is generally referred to as the Turkey Mountain sand or Siliceous lime 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 37) show that is 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. (See Plate II). 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 sticks up into the overlying formations from several hundred to perhaps a thousand feet or more. As 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[34]

Carter Oil Co., No. 1, Johnson NW. Cor. sec. 9, T. 26 N., R. 6 E., granite 4,230-41.

Tidal-Osage, No. 8, A. A. Arnold, NE.¼ SE.¼ SW.¼ sec. 3 T. 20 N., R. 8 E., granite 3,215-17.

Redbank Oil Co., No. 2, cen. S. line NW.¼ sec. 3, T. 22 N., R. 8 E., granite 3,422-29.

Prairie Oil and Gas Co., No. 12, SW.¼ NE.¼ SE.¼ sec. 25, T. 23 N., R. 8 E., granite 2,545-3,937.

Marland, No. 1, SE.¼ SE.¼ NE.¼ sec. 16, T. 24 N., R. 8 E., granite 2,526-86.

Gled Oil Co., No. 3, cen. SE.¼ NE.¼ NE.¼ sec. 16, T. 24 N., R. 8 E., granite 2,708-20.

Gypsy Oil Co., No. 8, E[illegible]hel Bryant, NE.¼ SE.¼ sec. 18, T. 27 N., R. 8 E., granite 3,36[illegible]-3,444.

Gled Oil Co., No. 2, ce[illegible] SE.¼ sec. 9, T. 21 N., R. 9 E., granite 2,576-2,667.

Foster and Davis and Finance, No. 1, SW. corner SE.¼ sec. 19, T. 21 N., R. 9 E., granite 3,200-3,202.

Tidal-Osage Oil Co., No. 18, cen. W. line E.½ NE.¼ sec. 32, T. 22 N., R. 10 E., granite 2,217-22.

Tidal-Osage Oil Co., No. 20, SW.¼ SE.¼ NE.¼ sec. 32, T. 22 N., R. 10 E., granite 2,267-90.

Barnsdall Oil Co., No. 17, SE.¼ NW.¼ NW.¼ sec. 12, T. 24 N., R., 10 E., granite 2,980-2,961.

Amerada Petr. Corp. et. al. No. 1, NW. ¼ NW.¼ SE.¼ sec. 7, T. 23 N., R. 11 E., granite 2,359-84.

Homaokla Oil Co., No. 8, NE.¼ SE.¼ SE.¼ sec. 30, T. 24 N., R. 11 E., granite 2,359-84.

Barnsdall Oil Co., No. 23, cen. W. line W.½ NW.¼ sec. 9, T. 20 N., R. 12 E., granite 2,424-35.

Granite wells near Osage County

Empire Gas and Fuel Co, No. 3, McElmore, sec. 25, T. 25 N., R. 12 E., granite 2,340-68.

Superior Oil Corp. No. 1, Blakemore, 50 ft. E. of W. line and 875 ft. N. of S. line, sec. 26, T. 21 N., R. 13 E., granite 1,365-1,462.

(Continued on page 38)

34. The list of wells that have been drilled into granite in Osage County was kindly furnished the writer by Frank C. Greene, chief geologist of the Skelly Oil Company. It is not complete, but is believed to include nearly all of those wells upon which reliable data are available.

Superior Oil Corp. No. 2, Blakemore, 1,163 ft. N. of S. line and 369 ft. E. of W. line, sec. 26, T. 21 N., R. 13 E., granite 1,566-86.

Barnsdall Oil Co., No. 7, Wm. Rigdon, cen. SW.1/4 sec. 30, T. 28 N., R. 13 E., granite 2,548-60.

Marland Oil Co., No. 1, Joynson, cen. NE.1/4 SE.1/4 sec. 18, T. 28 N., R. 3 E., Comp. 7-22-19, granite 4,800-26.

The deposition of the first sediments laid down on this uneven granite floor occurred from late Cambrian into probably middle Ordovician times. They include an unknown thickness of massive Arbuckle limestone which was apparently deposited in an advancing sea so that there is a progressive overlapping of the higher points in the granite floor. At the close of Arbuckle time there was a period of slight uplift during which the Arbuckle limestone appears to have been tilted slightly in a southwesterly direction. Immediately following the tilting of the Arbuckle the Simpson formation, and probably the Viola, Sylvan, and Hunton formations of Silurian-Ordovician age, were laid down unconformably upon the Arbuckle limestone. This second period of deposition was followed by a period of tilting and erosion during which the Viola, Sylvan, and Hunton formations were entirely removed, if they were ever deposited. A large part of the Simpson was also removed. Over the northeastern part of the county all of the Simpson appears to have been eroded. Further developments in this area may show the presence of some small outliers of early Simpson age. Following or perhaps during this period of erosion the next structural movement took place and as a result of this movement the formations were again tilted to the southwest, such tilting probably being caused, in part at least, by some movements in the Ozark uplift. During or immediately following this period of structural movement the folds in these formations were eroded and in most places truncated, leaving the remains of the Simpson and the underlying Arbuckle as a nearly level surface which, in places, was covered with a thin mantle of residual material.

Following this last described period of folding and erosion the Chattanooga black shale was laid down over a wide area as a mantle of variable thickness. This in turn was followed conformably by the entire thickness of the Mississippian limestone. At the close of Mississippian time there was another period of emergence accompanied by some folding and possibly some faulting, and an undetermined amount of erosion. The extent of this structural movement at the close of Mississippian times is not definitely known. There is no doubt as to the erosion of a part of the upper Mississippian in certain areas, and it is quite probable that there was some folding at the same time.

After this hiatus, or time gap, there was a period of deposition during which all of the Pennsylvanian and Permian sediments were laid down. Sedimentation was probably interrupted during the early part of this period and in Cherokee times, but such interruptions were short and did not include any known structural movements. The variations in the thickness of the early Cherokee sediments are more than likely due to the uneven surface of the pre-Pennsylvanian floor. This uneven floor 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 o 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.

OIL 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[35] 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 Plate III).

Most of the pools that are producing from formations of Mississippian age show the same general charactertistics 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-Q 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[36]

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 66c 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.

36. Leech, Chas. F., Personal communication.

The Phoenix Oil Co. was organized as the "operating company" and on June 20, 1896, commenced drilling the first well, located about the cen. NE.¼ 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 NW.¼ 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 NE.¼ 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 SW.¼ 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 SE.¼ 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.

Oil and Gas Fields of Osage County

FIELD	LOCATION	FIELD	LOCATION
Atlantic	T. 25 N., R. 8 E.	Nelagoney,	T. 25 N., R. 10 E.
Avant,	T. 23 N., R. 11-12 E.	Osage Junction,	T. 21 N., R. 8-9 E.
Barnsdall,	T. 24 N., R. 11-12 E.	Okesa,	T. 26 N., R. 11 E.
Bird Creek, Flat Rock,	T. 27 N., R. 7 E.	Pawhuska,	T. 25 N., R. 9 E.
Boston,	T. 21-22 N., R. 7-8 E.	Personia,	T. 27 N., R. 8 E.
Bowring,	T. 28 N., R. 11 E.	Pershing,	T. 24 N., R. 10 E.
Buck Creek,	T. 28-29 N., R. 9 E.	Pettit,	T. 23 N., R. 8 E.
Burbank,	T. 26-27 N., R. 5-6 E.	Pond Creek,	T. 28-29 N., R. 10 E.
Domes,	T. 27 N., R. 11 E.	Prue,	T. 21 N., R. 10 E.
Fairfax,	T. 25 N., R. 6 E.	Quapaw,	T. 25 N., R. 11 E.
Foraker,	T. 28 N., R. 7 E.	Skiatook,	T. 22 N., R. 12 E.
Frankfort,	T. 29 N., R. 6 E.	South Elgin,	T. 29 N., R. 9 E.
Gilliland.	T. 23 N., R. 7 E.	Sperry,	T. 21-22 N., R. 12 E.
Hickory Creek,	T. 29 N., R. 11 E.	Twenty-One Eleven	T. 21 N., R. 11 E.
Hominy	T. 22 N., R. 8 E.	Wildhorse,	T. 22 N., R. 10 E.
Landon,	T. 28 N., R. 9 E.	Wiser,	T. 27 N., R. 12 E.
Madalene,	T. 21 N., R. 10 E.	Wynona,	T. 24 N., R. 9-10 E.
Manion,	T. 23 N., R. 9 E.	X-686,	T. 20 N., R. 10 E.
Myers Dome,	T. 26 N., R. 8 E.	Y-686,	T. 28 N., R. 10 E.
		Z-686,	T. 26 N., R. 12 E.

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.¼ 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)

FIELD	LOCATION	FIELD	LOCATION
1901	10,536	1915	7,257,788
1902	10,522	1916	9,805,477
1903	52,217	1917	9,943,919
1904	90,806	1918	10,906,376
1905	1,868,260	1919	12,138,086
1906	4,514,004	1920	17,077,348
1907	5,547,167	1921	20,621,614
1908	4,775,289	1922	28,941,934
1909	4,816,462	1923	41,810,178
1910	5,091,424	1924	37,577,900
1911	9,418,769	1925	33,662,179
1912	9,445,669	1926	25,682,848
1913	7,787,030	Total	319,945,593
1914	11,091,791		

Burbank Field[37]

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 sales of 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 $1,990,000 for the 160 acres in NW.¼, 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.

37. Sands, J. Melville, Amer. Assoc. Pet. Geol., Abst. of article in Symposium on influence of structure on the accumulation and concentration of oil.

Production of the Burbank Field, by fiscal years

1920	134,408
1921	4,986,340
1922	24,230,563
1923	26,206,741
1924	21,994,479
1925	15,800,470
1926	13,352,917
Total	106,705,918

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 Mississippi lime by 40 to 70 feet of blue Cherokee shales. Granite was encountered at 4,240 feet in a well belonging to the Carter Oil Company, located in the NW. cor. NW.¼ sec. 9, 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 12½ per cent to 20 per cent by volume. The thickness of the sand varies, and in some places there is a stratum of blue 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 2 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.¼, 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 35 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-

tions of the field for oil production are in the northwest part, several miles from the highest point structurally, and from 100 to 150 feet below it. The production of wells changes in a few hundred feet from

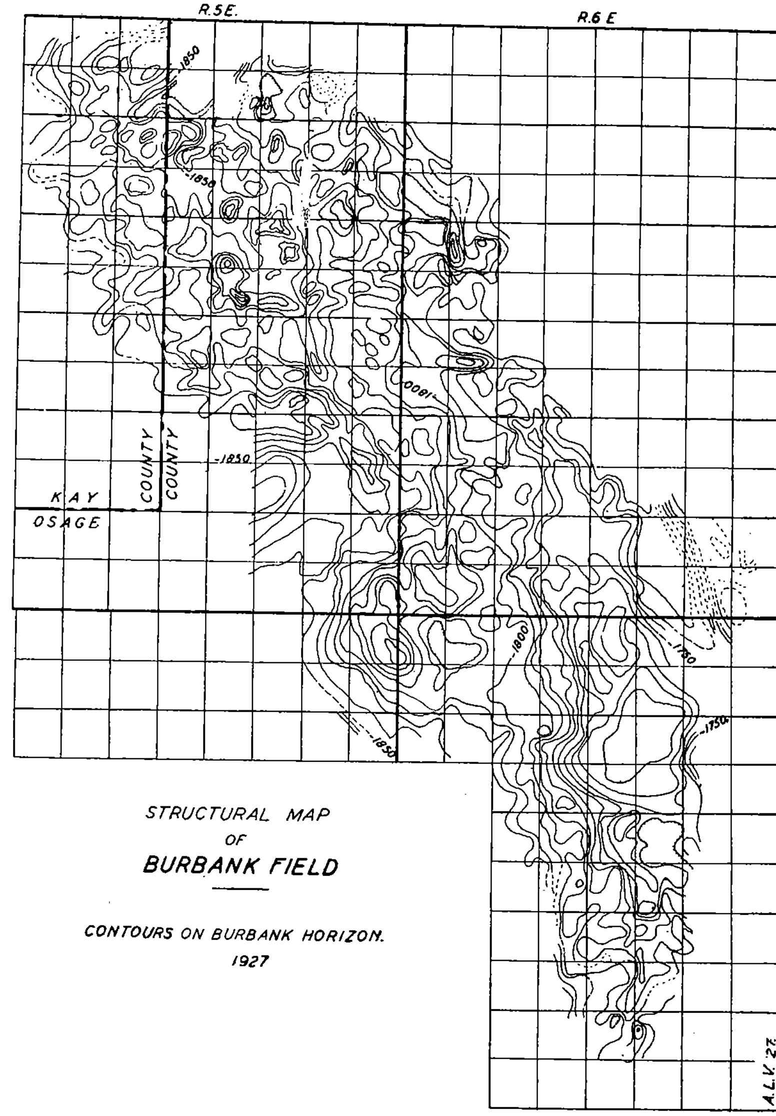
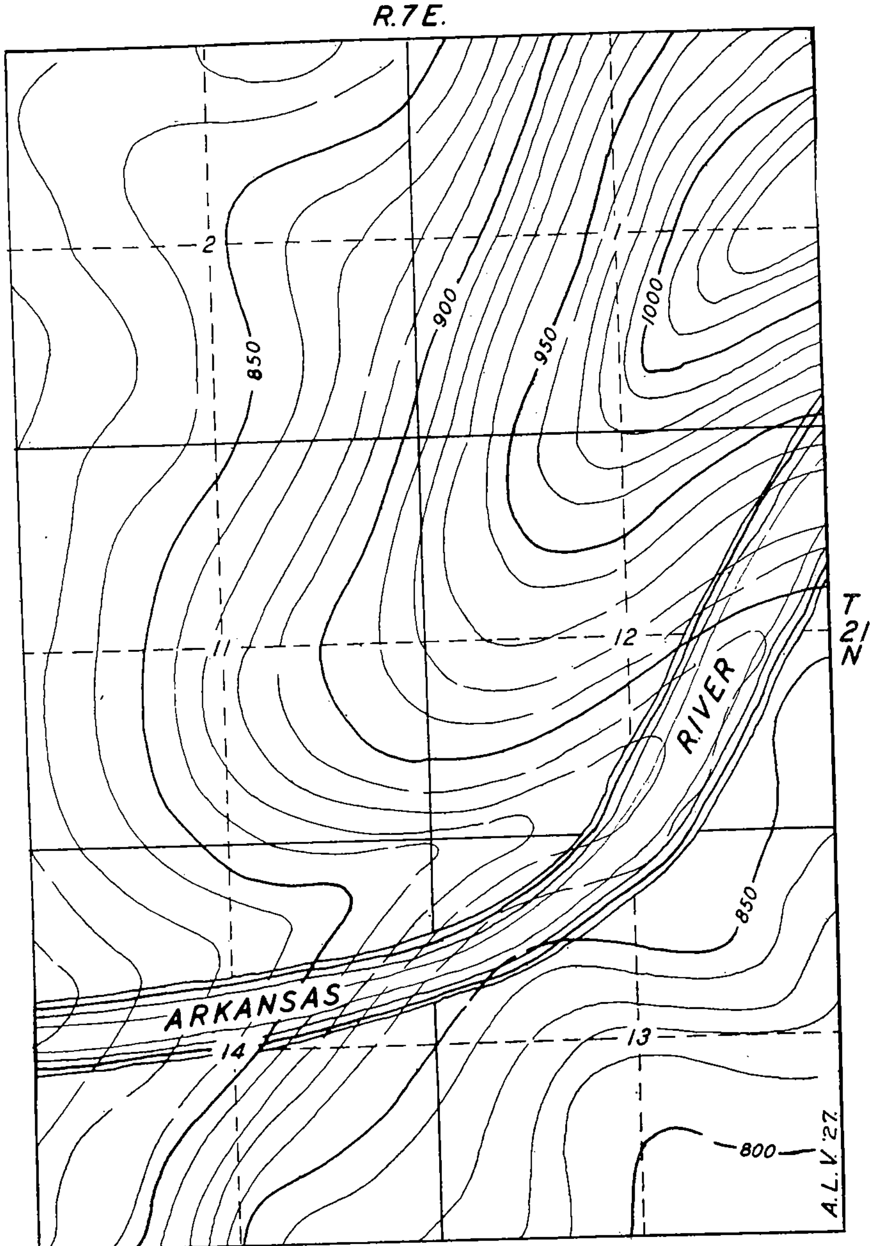


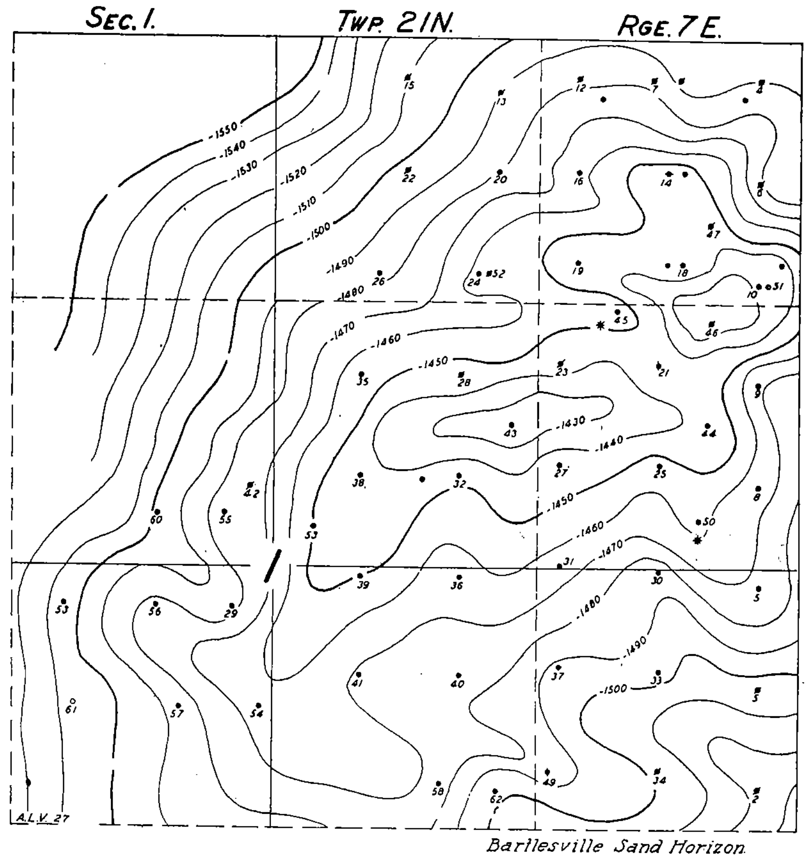
Figure 2.



SURFACE STRUCTURE OF BOSTON POOL

Figure 3.

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 porous portions of the sand seem to be in irregular patches, mostly disconnected 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.



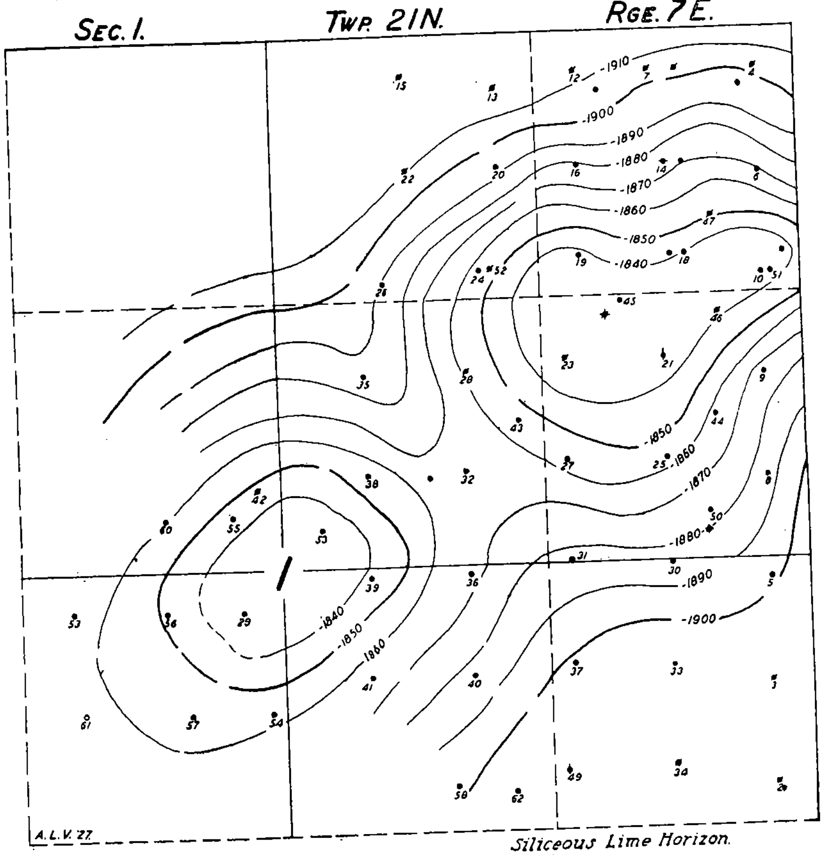
BOSTON POOL

Figure 4.

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[38]

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



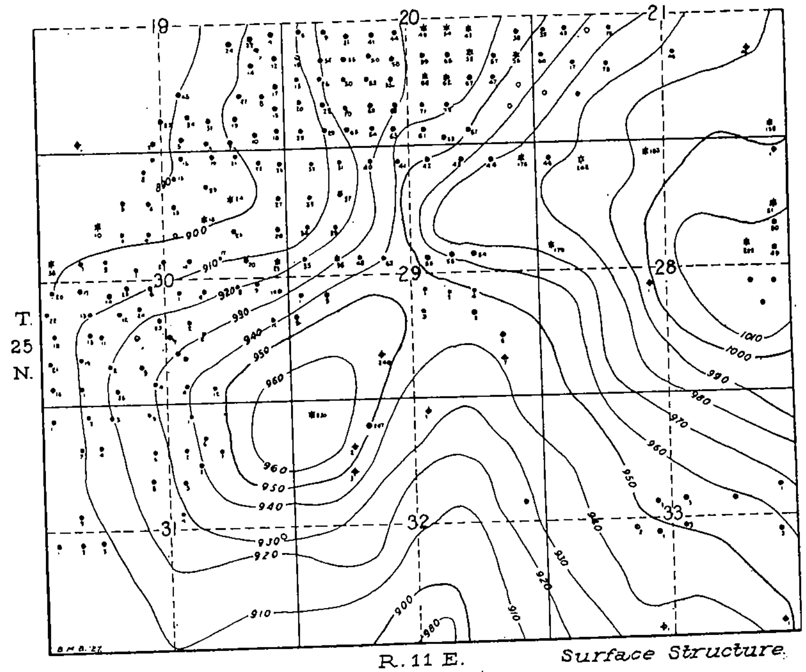
BOSTON POOL

Figure 5.

38. Bernard, H. E., Personal communication.

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 be-



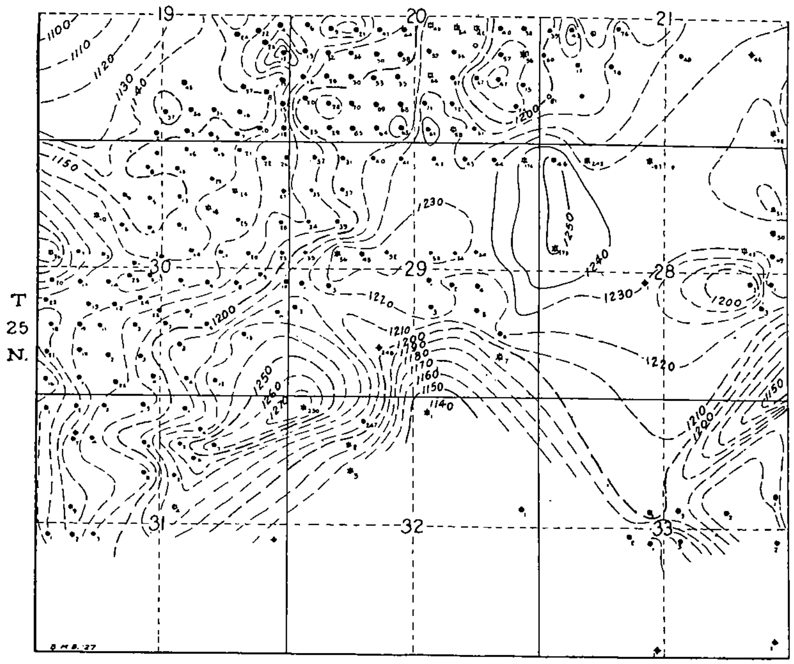
QUAPAW POOL

Figure 6.

cause 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. 3, 4 and 5, and the cross-section, Plate IV.

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-



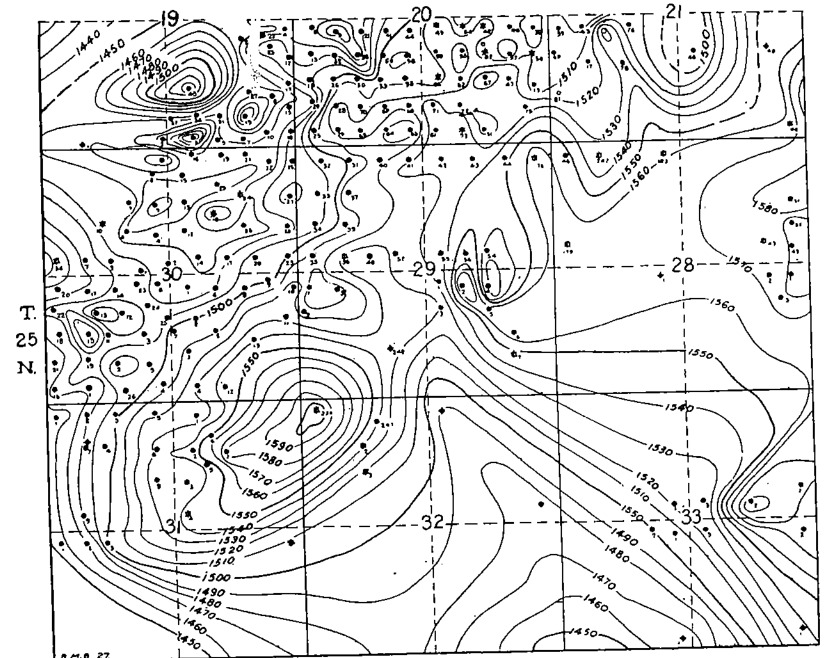
Datum 2000 feet below sea level. R. 11 E. *Contours on Top of Bartlesville sand.*

QUAPAW POOL

Figure 7.

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.



Datum 2000 feet below sea level. R. 11 E. *Contours on Top of Oswego lime.*

QUAPAW POOL

Figure 8.

Pettit Pool[39]

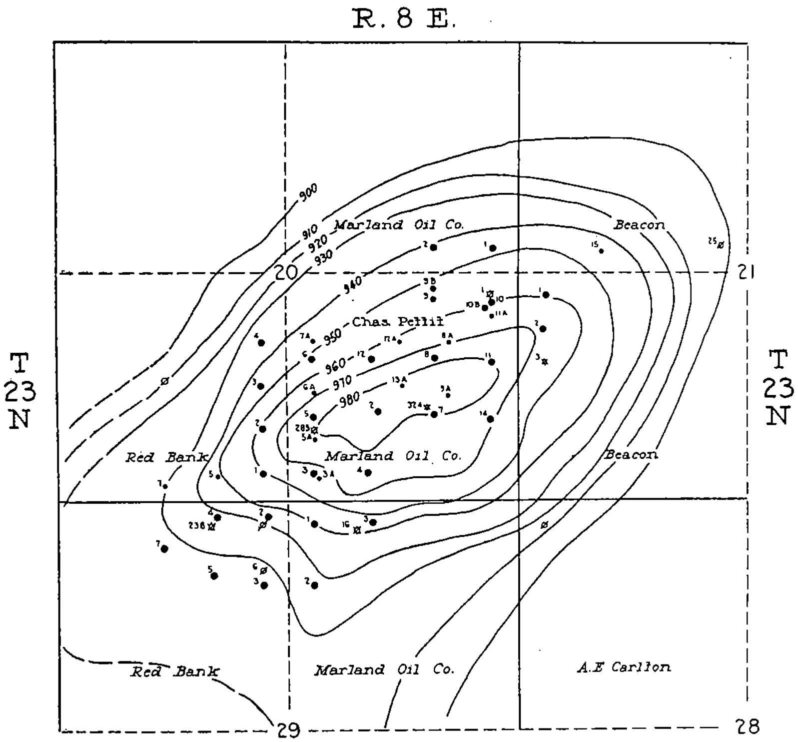
The Pettit pool is located in sections 20, 21, and 29, T. 23 N., R. 8 E. During 1920 two wells were drilled in an attempt to test the Wilcox sand. Pettit No. 1, NE. cor. SE.¼ section 20, was completed in June, 1920, and produced 5½ million cubic feet of gas from the Mississippi lime at a depth of 2,470 feet. Gra-Tah-Me-Tsa-Ha No. 16, NE.¼ NW.¼ NW.¼ 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.¼ 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:

39. Clark, G. C., Personal Communication.

Big lime—1,800 feet;
Oswego lime—1,950 feet;
Mississippi lime—2,400 feet;
Burgen sand—2,600 feet;
Siliceous lime—2,650 feet.

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. ¼ section 20, were drilled to this horizon and had initial productions averaging from ten to fifteen barrels. This sand may be correlated with the Bigheart sandstone of the Osage section and with the Tonkawa or Stalnaker sand of Kay County. The Bartlesville sand is present locally in the northeastern part of the SE. ¼ 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.



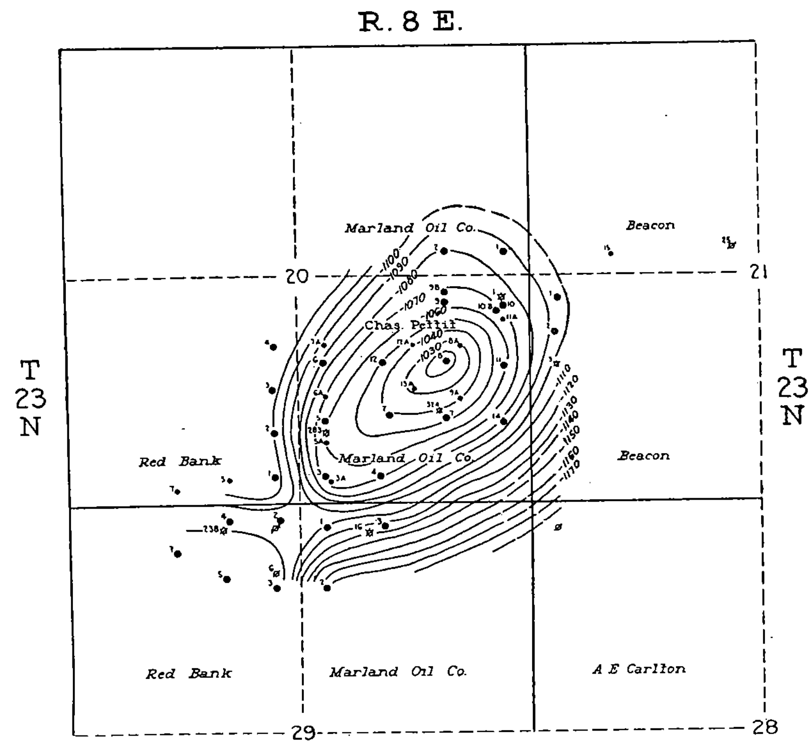
Surface Structure.
Wells shown by small circles produce from 800' Horizon.

PETTIT POOL

Figure 9.

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 6⅝ inch casing was set in many wells in the lower part of the Mississippi



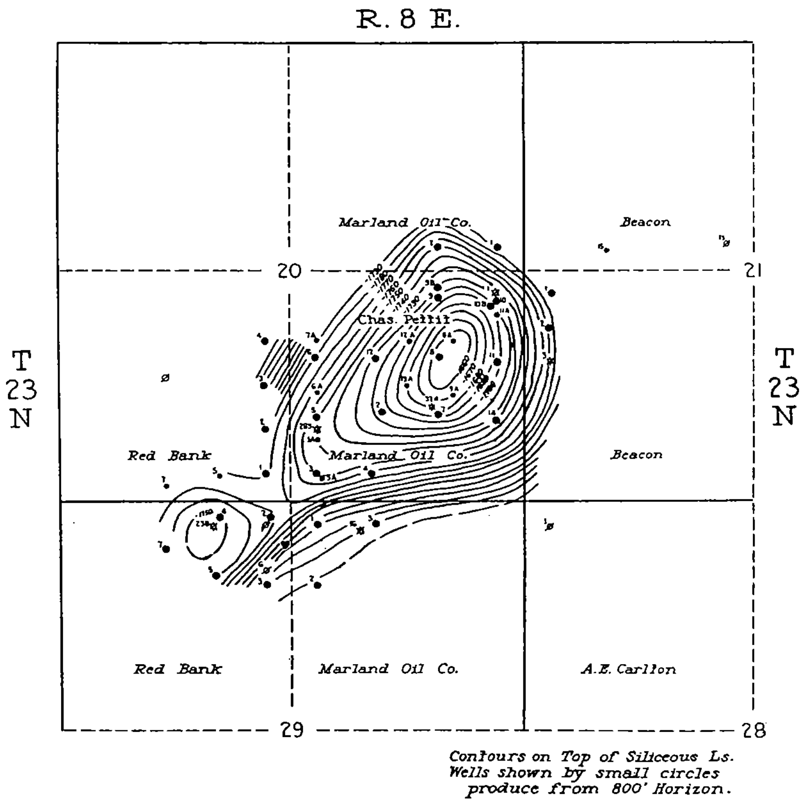
Contours on Base of Oswego Ls.
Wells shown by small circles produce from 800' Horizon.

PETTIT POOL

Figure 10.

lime to shut off gas found through the upper 150 feet of this formation. the 5 3⁄16 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.¼ 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 POOL

Figure 11.

Pettit No. 2, the discovery well, had produced, at the above date, over 900,000 barrels.

Wildhorse Pool[40]

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-

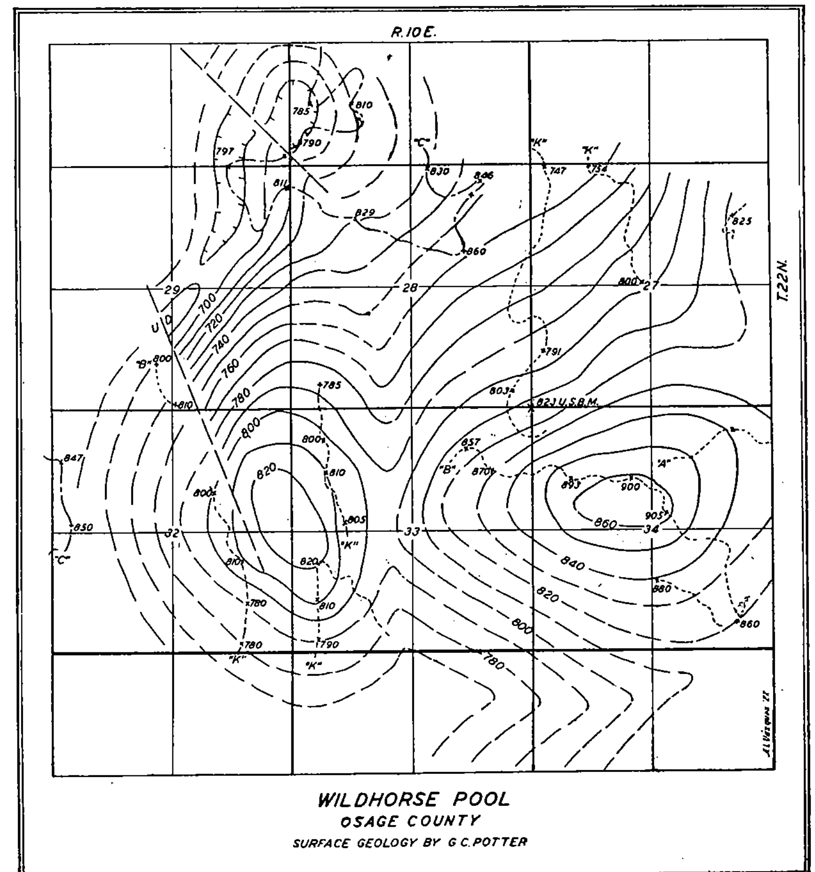


Figure 12.

40. By G. C. Potter: By permission of the Tidal Oil Company.

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. 12, was mapped on a sandstone ledge of the Bigheart 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.

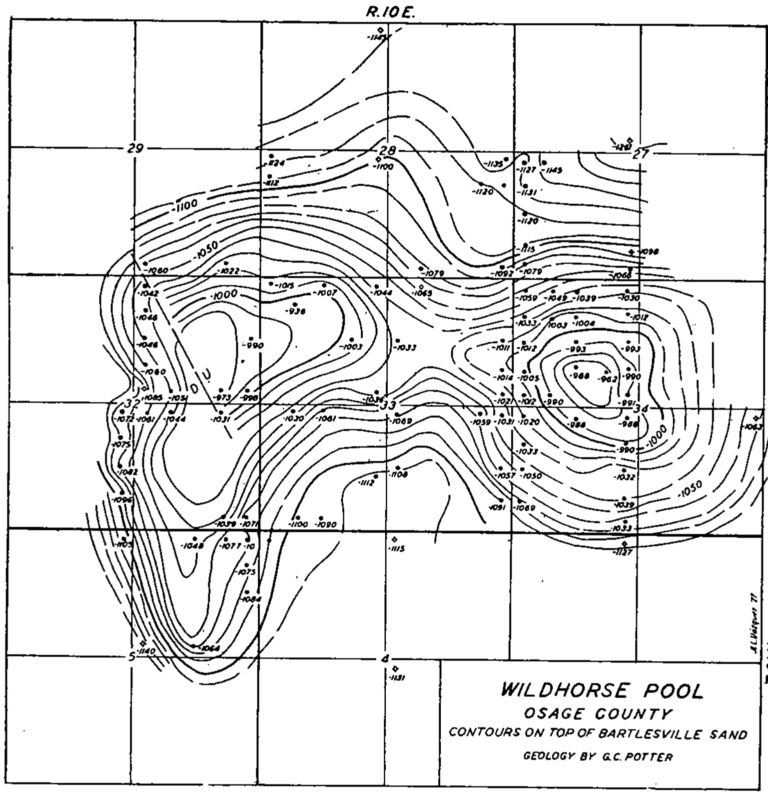


Figure 13.

Subsurface Geology

The most commonly known formations penetrated by the drill in this pool are as follows: the Avant line, which is found at a depth of approximately four hundred and fifty feet; Cleveland sand, Big lime, Peru sand, Oswego lime, Skinner sand, Bartlesville sand, Burgess sand, Mississippi lime, Tyner formation, Siliceous lime, and granite. It will be noted in the cross-section, Fig. 14, that granite was encountered in the Tidal-Osage Oil Company's well No. 18, located in the NE.¼ sec. 32, T. 22 N., R. 10 E., at 2,217 feet.

The subsurface geology, (Fig. 13) as mapped on the Bartlesville sand, conforms very well with the surface geology, except that the dip is considerably steeper on the subsurface. There are two separate, distinct, domes, with the top of one in section 34, with a saddle in section 33, and a dome in section 32. The dome in section 32 has a subsurface fault with a maximum throw of about 50 feet, the downthrow being on the west side, while the surface fault has the downthrow on the east side. This dome is underlain by granite encountered at 2,217 feet in the Tidal-Osage Oil Company's well No. 18, in the NE.¼ section 32,

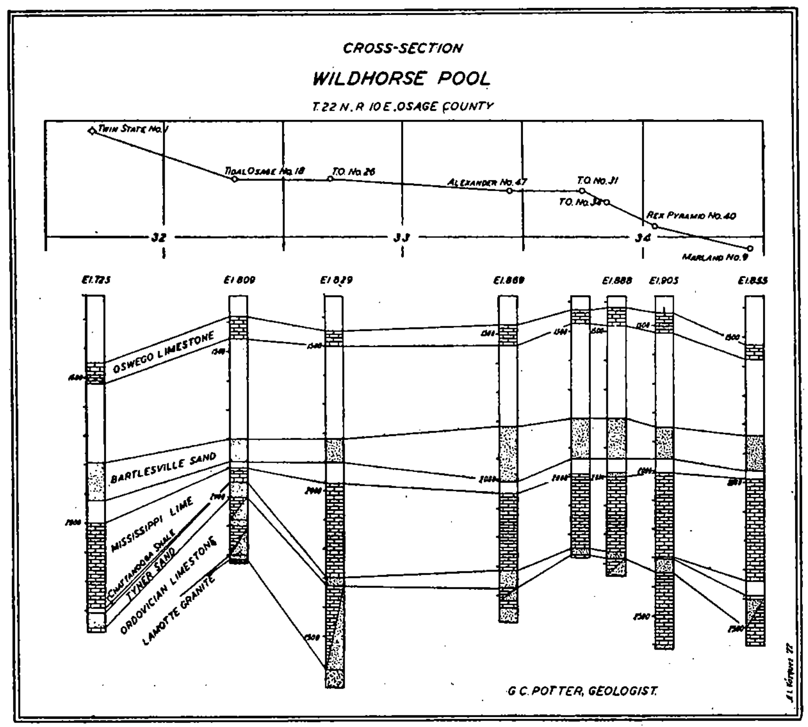


Figure 14.

and at 2,600 feet in the same company's well No. 26 in the NE.¼ of section 32, about one-half mile distant.

It will be noted by referring to cross-section (Fig. 14) 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 structure. 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.¼ of section 32. About thirty feet of Chattanooga shale was logged in the Marland Oil Company's well No. 9, in the NE.¼ SE.¼ 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.¼ NE.¼ 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 level, represented by the dashed contour line in Fig. 13. 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 coning 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).

LOCATION	Init. Prod. Date	Total Gross Prod.	No. of Wells	Actual Prod. Acres	Av. Actual Prod. Per Acre	Av. Prod. Per Acre Total
NE. 32-22-10	1918	399,988	18	120	3,333	2,500
SW. 32-22-10	1918	122,818	5	40	3,070	768
NE. 33-22-10	1918	512,706	24	125	4,102	3,204
SW. 27-22-10	1919	429,750	21	120	3,581	2,686
NW. 34-22-10	1919	1,489,974	44	160	9,312	9,321
SW. 34-22-10	1919	474,457	22	120	3,954	2,965

Total gross production ---------------------------3,429,810
Total number of wells ------------------------------------134
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

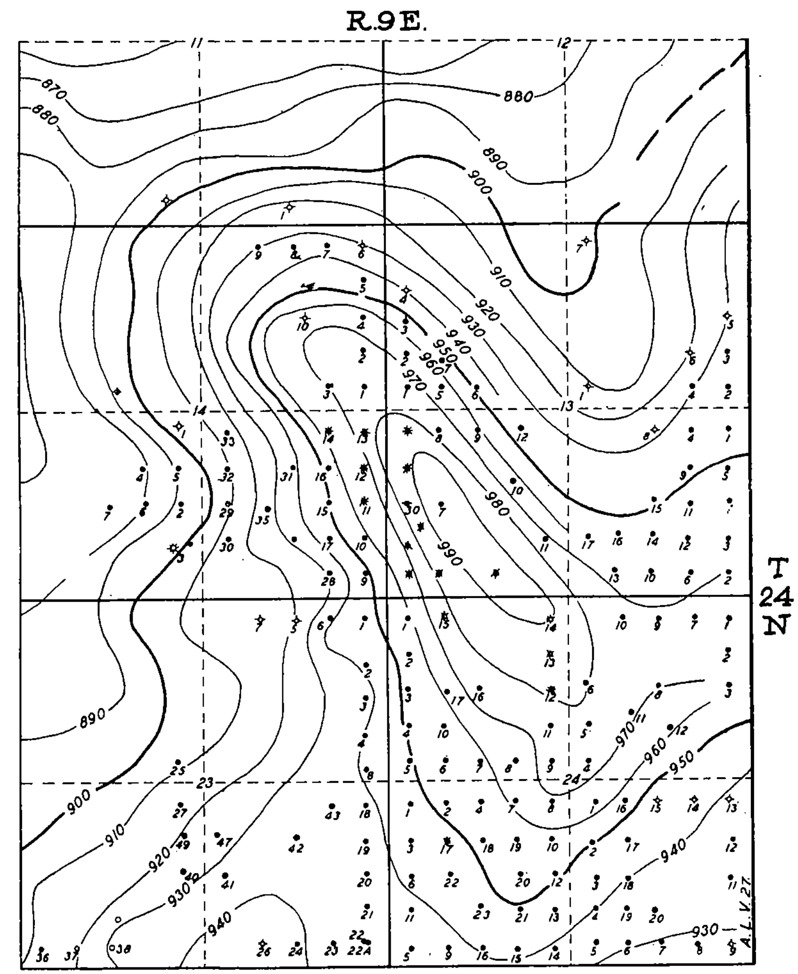
There seems to be a definite relation between topography, surface geology, and subsurface geology in the Wildhorse pool. Surface geology was very difficult to work due to the lack of good exposures, so that an accurate geologic section was almost impossible to obtain. Surface faulting carries down through 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.

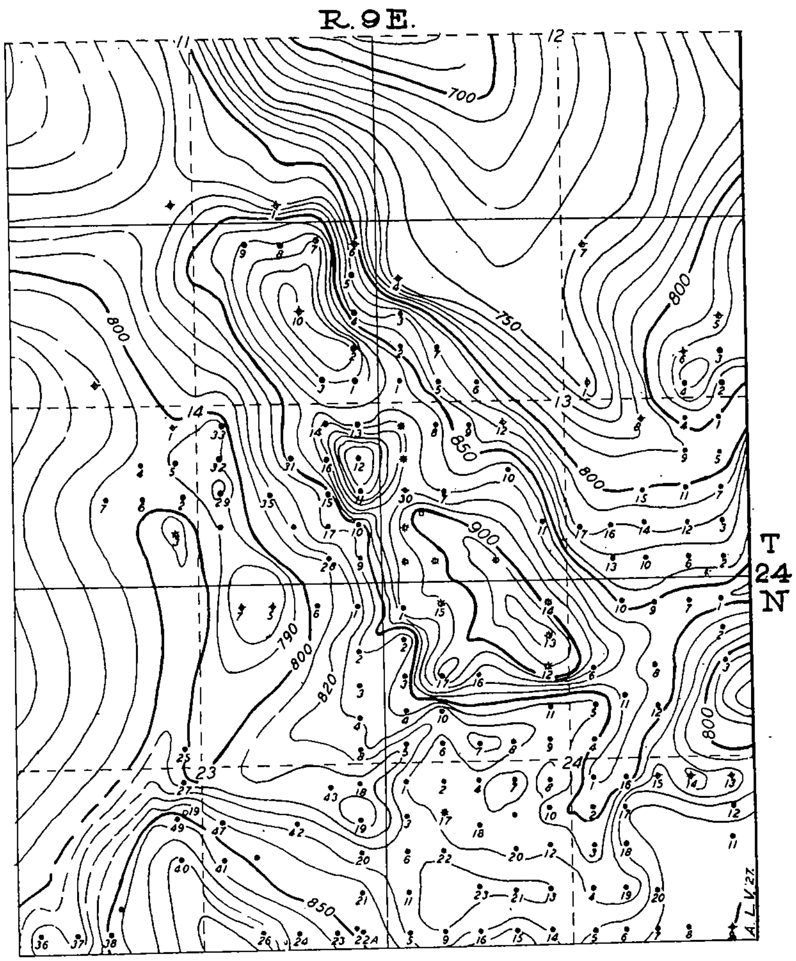
Most of the pools that are producing from formations of Mississippian age show the same general characteristics as those producing from Pennsylvanian sediments, at least as far as the oil production is concerned. In several places, notably in the northeastern part of the county, some very productive 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.



Surface Structure

WYNONA POOL

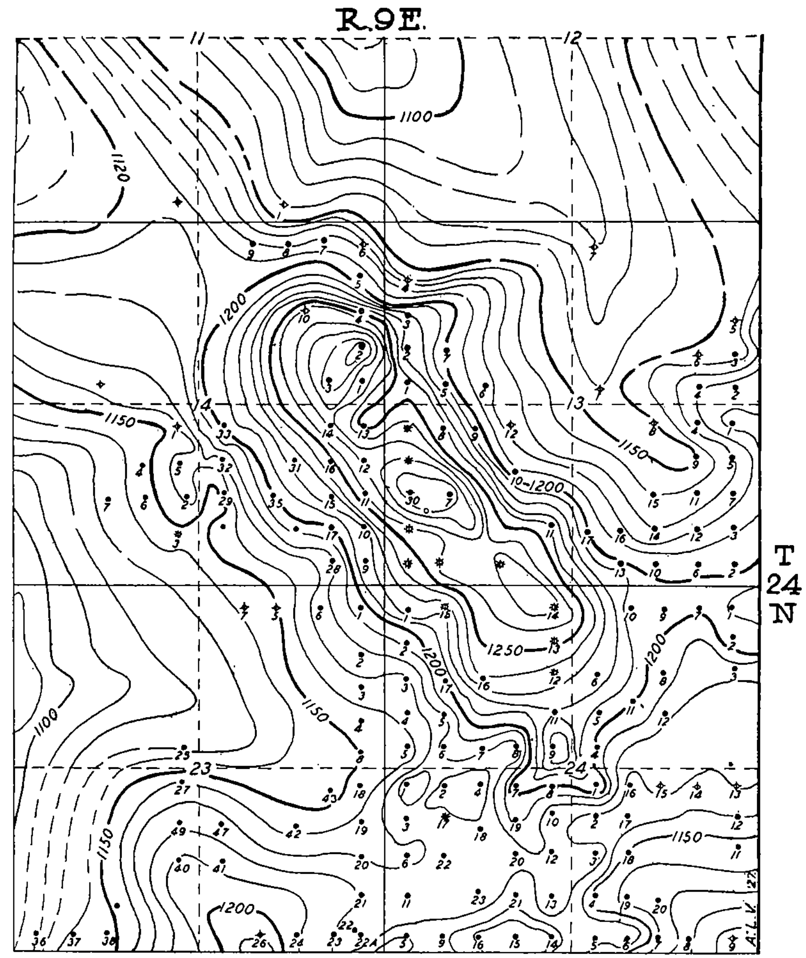
Figure 15.



Contours on Top Bartlesville Sand.

WYNONA POOL

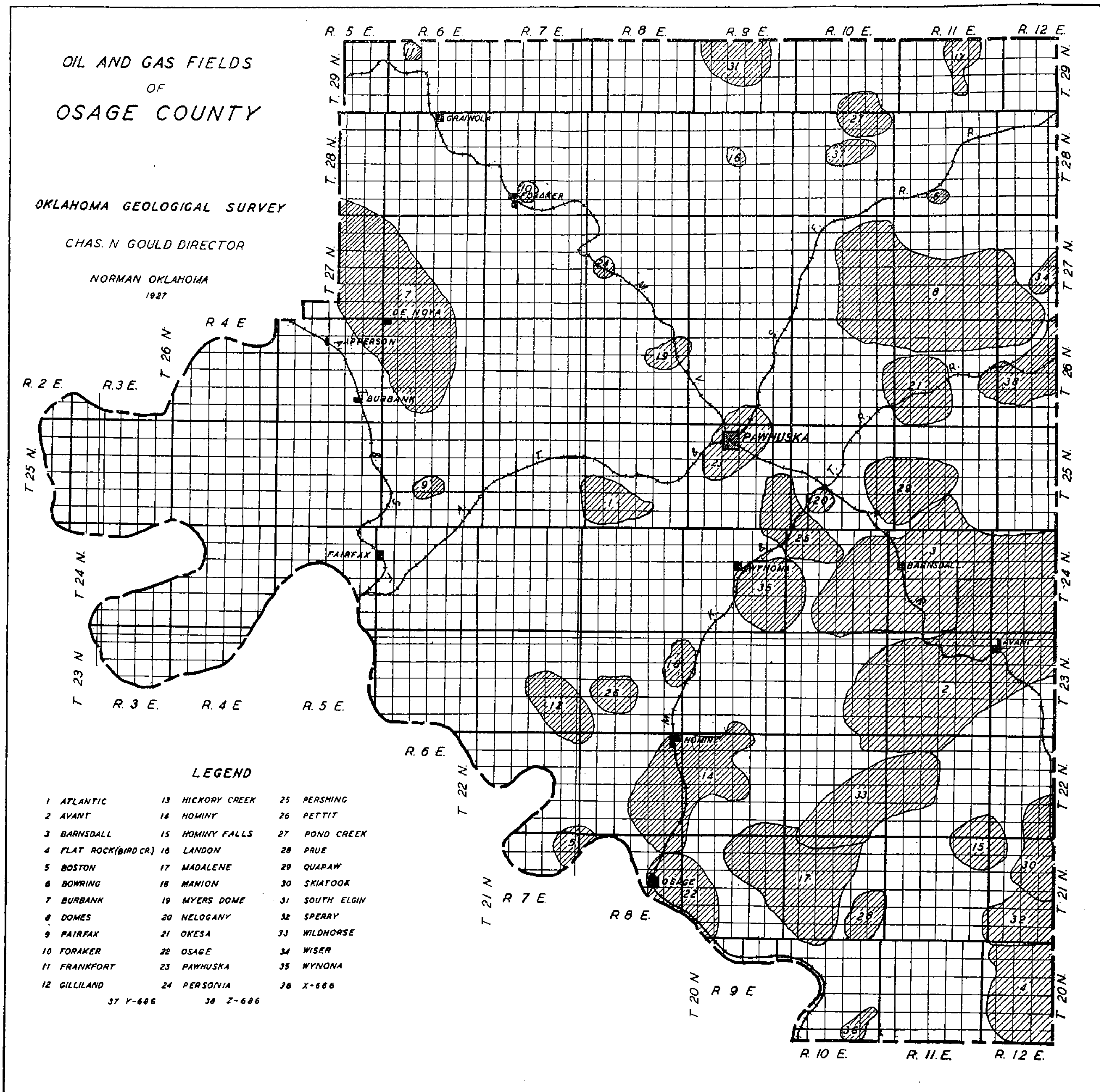
Figure 16.



Contours on top of Oswego Lime

WYNONA POOL

Figure 17.


OIL AND GAS FIELDS
OF
OSAGE COUNTY
OKLAHOMA GEOLOGICAL SURVEY
CHAS. N GOULD DIRECTOR
NORMAN OKLAHOMA
1927
LEGEND
1 ATLANTIC
2 AVANT
3 BARNSDALL
4 FLAT ROCK (BIRD CR.)
5 BOSTON
6 BOWRING
7 BURBANK
8 DOMES
9 FAIRFAX
10 FORAKER
11 FRANKFORT
12 GILLILAND
13 HICKORY CREEK
14 HOMINY
15 HOMINY FALLS
16 LANDON
17 MAGALENE
18 MANION
19 MYERS DOME
20 NELOGANY
21 OKESA
22 OSAGE
23 PAWHUSKA
24 PERSONIA
25 PERSHING
26 PETTIT
27 POND CREEK
28 PRUE
29 QUAPAW
30 SKIATOOK
31 SOUTH ELGIN
32 SPERRY
33 WILDHORSE
34 WISER
35 WYNONA
36 X-686
37 Y-686
38 Z-686
GRAINOLA
FORAKER
DE NOYA
APPERSON
BURBANK
FAIRFAX
PAWHUSKA
WYNONA
BARNSDALL
AVANT
HOMINY
OSAGE
R. 2 E.
R. 3 E.
R. 4 E
R. 5 E.
R. 6 E.
R. 7 E.
R. 8 E.
R. 9 E.
R. 10 E.
R. 11 E.
R. 12 E.
T. 29 N.
T. 28 N.
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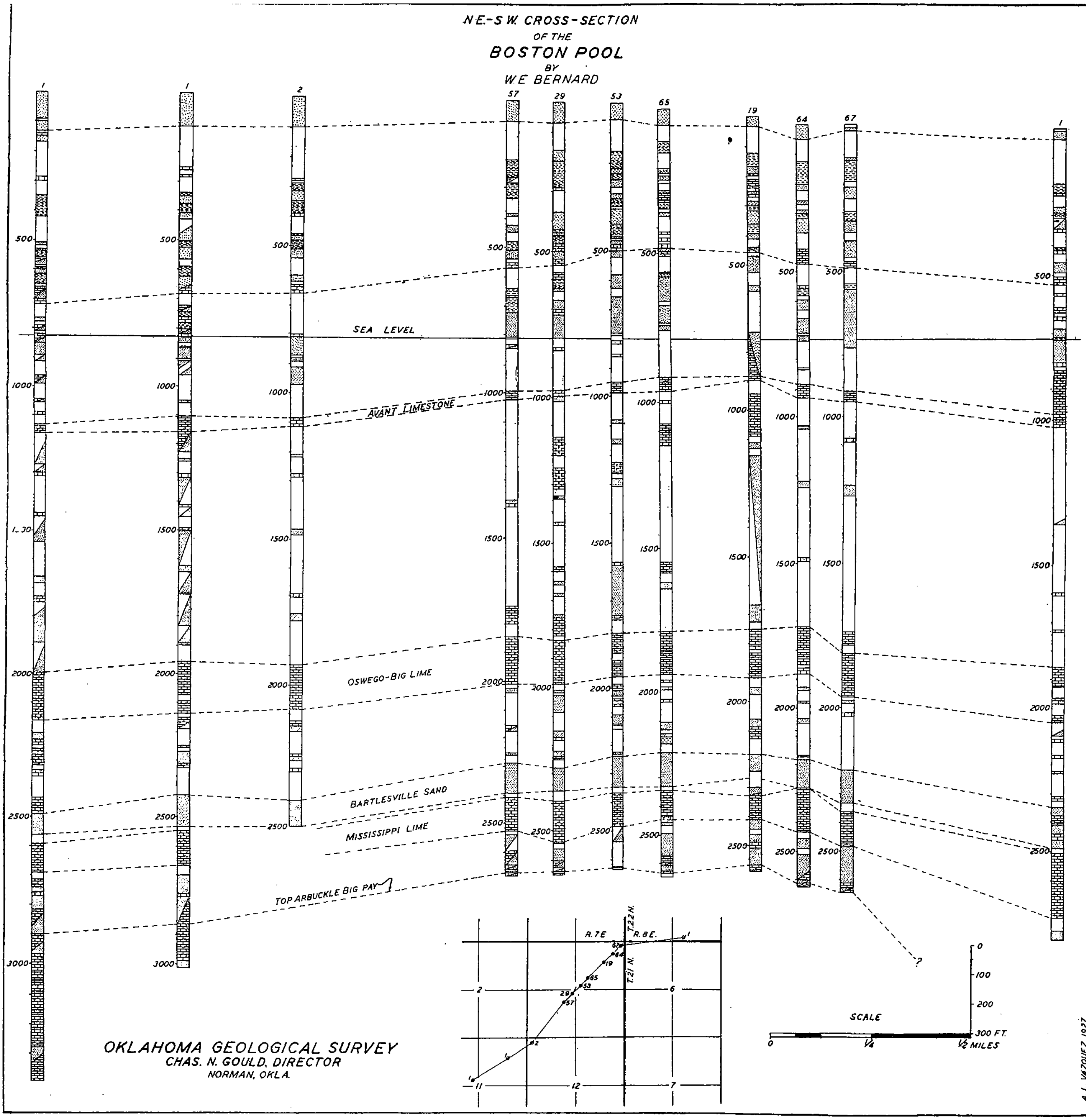
T. 20 N.


N.E.-S.W. CROSS-SECTION
OF THE
BOSTON POOL
BY
W.E. BERNARD
SEA LEVEL
AVANT LIMESTONE
OSWEGO-BIG LIME
BARTLESVILLE SAND
MISSISSIPPI LIME
TOP ARBUCKLE BIG PAY
R.7E
R.8E.
T.22 N.
T.21 N.
SCALE
0
1/4
1/2 MILES
300 FT.
OKLAHOMA GEOLOGICAL SURVEY
CHAS. N. GOULD, DIRECTOR
NORMAN, OKLA.
A. L. VAZQUEZ, 1927.