ANTICLINAL STRUCTURE OF THE ROCKS OF THE OIL AND GAS REGIONS OF OKLAHOMA.

A Thesis

presented for the

Degree of Bachelor of Arts

by

Robert Richard Severin

University of Oklahoma

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ANTICLINAL STRUCTURE OF THE ROCKS OF THE OIL AND GAS REGIONS OF OKLAHOMA.

INTRODUCTION.

Location and Area

The most important oil and gas region of Oklahoma is situated in the eastern part of the State. In general it occupies an area two hundred miles in length, north and south, and fifty miles in width; bounded on the north by the oil fields of Kansas, on the south by the Choctaw Fault and Cretaceous over-lap*, on the east by the Ozark uplift and the Arkansas line, and on the west by the Red-Beds.** The center of the field lies approximately along the 96th meridian. The most productive oil and gas wells at the present time are near Bartlesville, Copan, Coody's Bluff, Alluwe, Skiatook, Tulsa, Glenn Pool, Muskogee and

* See Geological map
** Geology of Water Resources of Oklahoma Bulletin No 148 Map page 12.

Cleveland. The location of these fields is shown on the map of the Productive Area.

Source of Data

The work which forms the basis of this paper was accomplished during the years 1906 and 1907. In the summer of 1906 the writer was a member of the field party of the Oklahoma Geological Survey, which spent about ten weeks in the northeastern part of Oklahoma investigating conditions in the principal oil and gas fields. In addition to this general work several short trips have been made to various parts of the oil region and considerable valuable data has b en secured. The theoretical parts of the discussion were obtained from various sources, chiefly State Geological Survey reports.

The writer desires to express his thanks to Professor C. N. Gould and Mr. L. L. Hutchison for the assistance rendered in writ-

ing this paper. Professor Gould directed the work of the field party during the summer of 1906. Mr. Hutchison, a member of the same party, has materially aided in the determination of the geological structure of the rocks in the different oil and gas fields.

ORIGIN OF OIL AND GAS.

In this brief discussion the greater part of the data has been secured from the following State Reports, viz: Ohio Report on Oil and Gas, 4th Ser. Bull. 1 by J. A. Bownocker, pp 307, 318. Illinois State Geological Survey, Bull. 2 by W. S. Blatchley, pp 23-25. Kentucky Geological Survey on Petroleum and Natural Gas, etc. by Edward Orton, pp 27-61.

It is a well known fact that there is an intimate relationship existing between petroleum or rock oil and natural gas. Wherever oil is found there gas is usually present also. It is due in a large measure at least to the expansive force of gas that flowing wells exist. With the escape of the gas the force of a gusher or flowing well gradually becomes less until it finally ceases to flow. On account of the intimate association of oil and gas in nature, and from their close chemical relation, it seems certain that both products have been derived from the same ultimate source and probably in the same general manner. For these reasons it is thought best to consider the two substances together.

One of the latest and perhaps most comprehensive discussions on the origin of oil and gas is that of Professor Bownocker referred to above in the Ohio Report, in which he says, "Of the theories propounded that have received serious considerations two classes may be recognized." The first class of theories advanced chiefly by chemists, assigns to these products an inorganic origin. The chemists usually maintain that the oil and gas have been produced within the earth by the reaction of inorganic substance, usually under the influence of heat. The second class of theories assigns to oil and gas an organic origin. That is, the exponents of theories of this class believe that oil and gas have been formed in some manner from organic substances, either animals or plants, or both. Theories of this latter class have been most strongly advocated by geologists, although a few chemists have given them favorable consideration also. The theories which assign an organic origin to oil and gas are generally known as geological theories while those of the other class are known as chemical theories. These two classes will be considered separately and somewhat in detail.

Inorganic or Chemical Theories.

Professor Bownocker* in his discussion

* Ohio Report on Oil and Gas 4th Series Bulletin 1, page 308

enumerates three theories of this class.

1. In 1866, Bertholet, a distinguished French chemist, attempted to prove that petroleum was produced by the chemical action of water containing carbonic acid on alkali metals deeply buried in the earth, and hence, highly heated. He found by experiment that when carbonic acid acts on hot alkali metals acetylides are formed, and that these bodies, when treated with water, produce hydrocarbons resembling petroleum.

2. In 1871, Byasson presented a theory attempting to prove the fact that petroleum has resulted from the action on each other of water, vapor, carbonic acid, sulphuretted hydrogen and hot iron.

3. Another theory which greatly strengthened the inorganic theories was advanced by the eminent Russian chemist Mendelejeff in 1877. He assumed that the interior

of the earth contains metallic carbides--that is, metals, especially iron, combined with carbon. This being true, water coming in contact with these highly heated carbides would, he claimed, produce hydrocarbons, and convert these metals into oxides. This theory is supported by actual laboratory experiment.

These various chemical theories may satisfy the chemist in that under favorable conditions substances resembling petroleum may be produced in the laboratory, but they do not meet the demands of the practical geologist. They have all been developed without due regard for the geological conditions under which oil and gas are actually found. All the chemical theories appear to require one factor in common, viz: great heat. It is generally believed by geologists and physicists that heat can be produced, so far as it is necessary in the formation of oil and gas, in but two ways: First , by the materials which produce these products originating at great depths below the earth's surface; and second, by intrusions of some molten material. The first hypothesis may be rejected in toto, for all geological evidence points to the fact that it is impossible that the vast amounts of petroleum known to exist in various parts of the earth could have been produced through the agency of heat derived from intrusions of highly heated material.

The other alternative, that of great heat being obtained at extreme depths, seems also inadmissable. One reason is that many important oil deposits have been found at depths ranging from 100 to 500 feet, beneath the surface, and in regions that show no evidence where erosion has removed any considerable amount of surface material. It is apparent that the temperature at such places is but very little in excess of that on the surface and there is no evidence that it was ever greater than now. Heat is one of the principal factors of rock metamorphism and if any such temperatures occured such as are necessary, under the chemical theories, to produce oil and gas, the rocks themselves would furnish unmistakable evidence of the fact. In Oklahoma, for instance, in many of the wells which have been drilled to a depth of 1500 feet or more, no rocks have been found showing any indications of high temperatures. On the other hand fragments brought up from the deepest wells drilled on the plains showed no more evidence of the action of heat than rocks from a depth of only a few feet, or even, those from the surface. From these various lines of testimony it seems very probable that many, probably most, of the rocks which now contain the oil and gas have never been lightly heated.

There remains, then, but one other explanation to account for the chemical theory, and that is, that the oil and gas were produced at great depths, and have slowly risen through the rocks to the place they now occupy. To the mind of the writer this explanation seems very unsatisfactory be- cuase of the fact that there are usually great thicknesses of compact shales and other impervious rocks, which would not permit the passage of oil or gas, lying between these deep seated, and hence highly heated rocks, and the beds now containing the oil. It is no uncommon occurence for the drill to pene- trate in the same well several oil bearing strata one above another separated by appar- ently impervious beds. If the oil at such places had a deep-seated origin it is improbable that two oil-bearing sands would exist.

Granting that the chemical theory is true, it would be very reasonable to expect petroleum and natural gas in igneous rocks, since these rocks have been highly heated and hence are in a condition favorable for the production of these substances. As far as the writer knows, no oil or gas has ever been found in igneous rocks.

Organic or Geological Theories.

"These theories have only one point in common: all assign organic matter as the origin of petroleum and natural gas."* Some authorities contend that these products have been derived wholly from animal matter, others consider them derived entirely from vegetable matter, while still others look to both plants and animals as the source of supply.

* Bownocker, Ohio Report 4th Series, Bulletin 1, page 311

If it be true that oil and gas have originated from organic matter, then it might be expected that these products, or others closely related to them, should produced artificially in the laboratory. This has actually been done in the laboratory by Daubree, who treated wood with super-heated steam and obtained a product having the odor of petroleum. In 1897 Sadtler distilled linseed oil under pressure and obtained an oil resembling petroleum with a paraffine base.

Prof. Edward Orton,* who has carefully studied the subject has given an extensive discussion of the organic origin of oil and gas. He cites among others, three main theories: 1st, Prof. J.S.Newberry's; 2nd, Dr T S Hunt's; and Third, Peckham's.

1. Prof. J.S.Newberry, former State Geologist of Ohio, believed that the oil and

* Ken. G. S. On Pet and Nat Gas, etc. page 34 et seq.

gas in the Appalachian field including eastern Ohio, and adjacent states comes from the great beds of deeply buried bituminous shales, such as the Huron, Genesee, and Utica shales.* He reasoned that the animal and plant remains in these shales had undergone, through a very long period of time, a kind of distillation or secondary decomposition, resulting in petroleum, which by hydrostatic pressure, has been carried to the rock strata in which it is found. This theory appears to hold good only in parts of the Appalachian field. It does not account for the oil and gas that is found in limestone stratas.

2. Dr T Sterry Hunt, at one time assistant state geologist of Pennsylvania, after having investigated the subject at length gave it as his opinion that petroleum has been formed from the remains of animals and plants buried in the same rock strata now qielding the oil;

* Geology of Ohio, Vol XII page

the decomposition having taken place under such conditions that the organisms passed directly into petroleum which has since remained in the rocks where it is now found. Among other proofs of his theory Dr. Hunt stated that in several cases petroleum is found filling cavities of large fossil shells. Dr. Hunt's theory therefore, accounts for the presence of oil and gas in limestone strata as well as in porous sandstones and conglomerates.

3. Prof. S. F. Peckham believes that petroleum has been produced by the distillation of animal and plant remains at comparatively low temperatures. Any heat necessary, he thinks might have been caused as the result of friction produced by the elevation of the Appalachian mountains. This would only apply to the oil of such states as Pennsylvania, New York, West Virginia, and

eastern Ohio. Other oils, especially those found in shales of California, he classed as strictly animal in origin.

From what has preceded it will be obvious that the various organic theories seem to be the most plausible in view of the facts that they attempt to account for the origin of oil by assuming that it came from the remains of plants and animals, and that it was produced not by heat, but by a slow and long continued process of distillation or fermentation. Organic theories also account for the position now occupied by the oil and gas by two possible hypotheses, viz: it either rose by hydrostatic pressure, or it originated in the same strata in which it is now found. It is believed that one or the other of these hypotheses will explain all known existing conditions.

GEOLOGICAL CONDITIONS UNDER WHICH OIL AND GAS ARE FOUND.

According to a popular but erroneous belief both petroleum and natural gas occur in immense caverns or hollow spaces in the rocks beneath the surface of the earth. It is often believed also that great lakes or underground cavities or open spaces occur in the rocks. It is true that all rocks are slightly porous, even shale of the closest grain will hold a small amount of liquid in its minute cavities, but large cavities are not necessary for retaining these products. Oil and gas sands are simply porous rocks in which the oil and gas exist, like water in a sandstone. The larger the pores of the rock the greater will be the supply of oil or gas contained in a given area.

The following four conditions essential to the presence of oil and gas have been strongly advocated by geologists who have studied the question.

1. A source of supply,

2. A porous rock to contain the oil or gas, or reservoir,

3. An impervious cover, or cap-rock,

4. Such a geological structure of the rocks as to permit the accumulation of the oil and gas from relatively large areas into smaller ones.

1. It is very obvious that a source of supply is essential. Without it no matter what other conditions might exist no oil or gas would ever be formed in rocks. As has been shown above it is believed that the ultimate source of supply is from buried plants and animals, and that the oil has been formed by a slow and long continued distillation of these substances.

2. The necessity of reservoir rock

to contain the oil and gas is also admitted. The essential quality of this rock is that it be porous. Sandstone is the most common reservoir rock, although limestones, conglomerates and even porous shales sometimes contain oil. The oil sands of Oklahoma, for instance, consist almost wholly of coarse grained sandstone. In Texas the oil is sometimes found ina calcareous limestone and sometimes in sandstone. In Ohio, Pennsylvania and West Virginia it occurs in sandstone and congomerates. Shales are usually not important carriers of either oil or gas, although small quantities are sometimes found in them.

5. In order that the accumulated petroleum be retained it is necessary that the porous rock or reservoir be entirely covered by an impervious stratum, i e, one through which neither oil nor gas can pass.

This impervious cover may be either a shale clay or a fine grained limestone; usually it is the former. If the oil and gas can penetrate the caprock it is obvious that it has escaped as fast as it has been formed. There are many places where small quantities of gas escape from shallow wells or from crevices in the rock. No practical geologist would think of finding a permanent supply of gas under such conditions.

4. The fourth condition that is essential for the accumulation of large quantities of oil and gas is the structure of the rocks. Experience in many regions has shown that oil and gas are most often found under an arch, or as it is known to geologists, an anticline. The surface of an oil-bearing sand is usually not level, but often exhibits a series of alternating wave-like arches and depressions, or geol-

A = GAS B = OIL C = SALT WATER D = CAPROCK

SECTION of ANTICLINAL FOLDS SHOWING ACCUMULATION of OIL & GAS ogically speaking, synclines and anticlines. These arches and depressions usually extend to the surface and the geologist by studying the dips of the rocks is often able to determine the locality of an anticline. The structure of an anticline and the method of the accumulation of o il and gas may be best understood from the plate showing accumulation of oil and gas.

Prof. I. C. White, director of the West Virginia Geological Survey, who has spent a number of years in practical work on the subject, has outlined carefully the existing relations between anticlines and oil and gas pools. Professor White says: "After visiting all the great gas wells that have been struck in western Pennsylvania and West Virginia, and carefully examining the geological surroundings of each, I found that every one of them was situated directly on or near the crown of an anticlinal axis, while wells that had been bored in the synclines on either side furnished little or no gas, but in many cases large quantities of salt water. Further obervation showed that the gas wells were confined to a narrow belt, only one fourth to one mile wide, along the crests of anticlinal folds. These facts seem to connect gas territory unmistakably with the disturbances in the rocks caused by their upheaval into arches, but the crucial test was yet to be made in the actual location of good gas territory on this theory. During the last two years, I have submitted it to all manner of tests, both in locating and in condemning gas territory, and the general result has been to confirm the anticlinal theory beyond a reasonable doubt."*

During long ages the oil has been transformed into gas and the gas being lighter than the oil, rose to the top of the anticline. Now if a well is drilled to the oil and gas bearing stratum along one of these lines where all three substances, oil, gas and salt water are located in close proximity to each other, it is plain to be seen that any one of these three substances, oil, gas or salt water, may be yielded to the drill according to the location of the drill hole. If the drill penetrates a syncline it is very probable that salt water will follow the drill as soon as the reservoir is reached. But if the drill descends into the oil space on the sides of the anticline, an oil well will result. If the drill goes down on the

* Taken from Kentucky Geological Survey, Petroleum and Natural Gas, etc., p 79.

axis of the anticline a flow of gas will usually be found. The logical arrangement of these three substances, oil, gas and salt water, is governed by their specific gravity. (See drawing.)

Pressure behind the Oil.

When the drill pierces a stratum of porous rock containing oil, the latter is often pushed upward by the so-called "rock pressure" behind it. Often this pressure is so great that when the oil stratum is first encountered the oil escapes in a fountain sometimes rising high above the derrick, and consequently much of it is lost before the flow can be controlled. In most wells the pressure steadily diminishes until after a time the well ceases to flow and the oil must be pumped. Several different theories have been proposed to to account for the rock pressure. Mr. W. S. Blatchley, state geologist of Indiana, in summing up the evidence says: "It is now almost universally admitted that the rock pressure in most oil fields is nothing more nor less than water pressure."* Prof. I. C. White, however, concedes that "In such cases like that of New York we are forced back upon the 'expansion hypothesis' advocated long ago by Prof. Lesley as the only theory consistent with the facts concerning the high pressures in the deep or Gourdon group of oil sands in West Virginia, since nowhere in Monogalia, Marion, Wetzel, Marshall, Tyler, or Harrison counties has any water been found."** Geologists have not yet reached a unanimity of opinion on this subject and in the light of present data both the expansive force of gas and

* Illinois State Geol Survey Bul No 2.
** West Va. Geol Survey Vol 1.

LEGEND

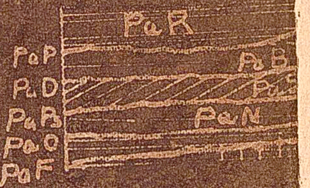
- Kc Comanche Cretaceous.
- Pc Chase Formation. (Shales, Sandstone, limestone)
- PW Wreford Limestone.
- PaR Ralston Series. (Limestone, sandstone, shale, coal.)
- PaP Pawhuska Limestone.
- PaB Bird Creek Series. (limestone, sandstone, shale, coal)
- PaD Drum Limestone.
- PaSs Skiatook Shales. (limestone, sandstone, shale, coal)
- PaPs Parsons Limestone.
- PaN Nowata Shales. (Sandstone, shales, coal.)
- PaO Oologah Limestone.
- PaB Bandera (Sandston
- PuLVi Lower Oo
- PaL Labette (Sandstone,
- PaF Fort Sco
- PaV Vinita (Sandstone
- PaB Boggy (Sands
- PaS Savan
- PaMc McAles
- PaW Winslow (Sandston
- Mi Mississi
- Ouachi (Sands

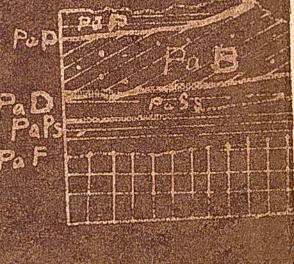
CROSS SECTIONS ALONG LINES A-B & C-D

(Anticlines Exaggerated)

LEGEND

PaR Ralston Series.
PaP Pawhuska Limestone.
PaB. Bird Creek Series.
PaD Drum Limestone.
PaSs Skiatook Shales.
PaPs Parsons Limestone.
PaN Nowata Shales.
PaC Oologah Limestone.
PaL Labett Shales.
PaF Ft Scott Limestone.
PaV Vinita Series.
Mi Mississippian Series.





hydrostatic pressure of the water, are, by different authorities, considered causes of this rock pressure.

GEOLOGY OF THE OKLAHOMA FIELDS.

Mississippian Limestones.

The floor upon which the Coal Measures of Oklahoma rest is the Mississippian limestones.* Rocks of Mississippian age cover a considerable part of the Ozark uplift,** and occupy a small area in northeastern Oklahoma, east of the Grand River and north of the Arkansas River. The rocks of the region have a gradual dip of from 20 to 30 feet per mile to the west. They are covered in the west by the overlap of the sandstone and shales of the Coal Measures in which the oil and gas occurs. The unvarying character of the Mississippian formations and their generally uniform

* Tahlequah Folio No 122, Muskogee Folio No 132.
** See geological map, part marked mi.

structure beneath the overlying Pennsylvanian shales and sandstones render them a valuable datum in prospecting for oil and gas. The Mississippian rocks as exposed in this region consist largely of white or gray cherty limestones, with occasional sandstones and shales. In the vicinity of Joplin, Missouri, and in northwestern Arkansas where the entire thickness of the formation is exposed, the Boone Chert, the most important formation of this series, has a thickness of from 325 to 400 feet.

These various Mississippian formations have been encountered in all the wells in the oil and gas regions which have been drilled to a sufficient depth to pass through the Pennsylvanian rocks. In only one instance, namely at Muskogee, has oil or gas been reported in the Mississippian rocks, and the exact geological location of the Muskogee oil is still a question of doubt. These formations are habitually known to the driller as the "Mississippi lime" or "flint rock," and it is the universal experience that when this rock is encountered it is useless to go deeper.

Pennsylvanian Series.

Vinita Formation.

The basal beds of the Coal Measures in Oklahoma consist of a series of shales and sandstones which average 450 feet on the Kansas line, but thicken rapidly to the south. The name, "Vinita Shales,"* has been proposed by Mr Hutchison for these rocks on account of the good exposures of the series at the town of Vinita. The Vinita formation is approximately the stratographic equivalent of the Cherokee

* Stratigraphy of the Northern part of Okla by L L Hutchison. Ms unpublished.
**

shales of Kansas.* The normal dip of the rocks of the Vinita formation is 20 to 50 or more feet per mile to the west.

In the region south of the Canadian River the rocks corresponding to the Vinita formation which include a thickness of between 10,000 and 15,000 feet, have been subdivided by Mr Taff** into the following formations: Thurman, Stewart Senora, Boggy, Savanna, McAlester, Hartshorne, and Atoka. In this paper the term Boggy, the stratigraphic equivalent of the upper part of the Vinita shales, includes the Senora formation 140 to 400 feet thick, Stuart shale 90 to 280 feet thick, the Thurman sandstone, 80 to 250 feet thick, and the Boggy 2000 to 2600 feet thick. The Winslow formation the equivalent of the lower part of the Vinita Series as described by Mr. Taff in

* Kan Geol. Report, Vol 1 Bul No 184, p 211 of U S G S.
** Coalgate Folio, No 74

the Muskogee Folio includes the McAlester formation, 2,000 feet thick, the Hartshorne sandstone, 150 to 200 feet thick, the Atoka formation, 3,000 to [illegible],000 feet thick, and the Morrow formation. These extreme thicknesses would indicate either that there is a great thickening of the rocks of the Vinita series toward the south or that the contact of the Coal Measures with the Mississippian in this region is one of overlap. Mr Adams is inclined to the opinion that the latter is the case.

In character the Vinita formation varies greatly both vertically and in areal extent. In general, however, it consists of shales which vary in color from a jet black or light gray to a brownish red, interbedded with a number of ledges of sandstone from 10 to 50 or more feet thick. The rocks of this series are rich in coal, and including the areas in the Choctaw County which are the stratigraphic equivalent of the Vinita, produce at the present time about nine-tenths of the annual output of the Territory. The most important oil sands are found in these shales also. So far as known all the oil produced is Oklahoma except that in the Cleveland field comes from the various sandstone members ff the Vinita series."

Ft. Scott Limestone.

Above the Vinita formation lies the Fort Scott limestone. As exposed in Oklahoma this formation consists of two ledges of limestone from 0 to 20 feet of shale. The outcrop of the surface of this formation extends from Fort Scott, Kansas, south past Oswego and into Oklahoma, passing near Kinnison, Chelsea, Claremore, Catoosa and

* Kansas Geol. Survey Vol III.

and Broken Arrow as far as the Arkansas River at Wealaka. At Wealaka the limestone is thin and its place has been taken by a sandstone ledge. This sandstone ledge continues on south past Morris and Henryetta towards Weleetka and Holdenville, and it may prove to be the equivalent of the Calvin sandstone described in the Coalgate Folio by Mr Taff.

The writer secured the following section of this formation west of Chelsea:

Limestone,	10 ft.
Black shale with sandstone near the top,	20 ft.
Limestone, hard, massive, fossilliferous,	12 ft.
Total - -	42 ft.

This formation is remarkably regular in character and is very persistent. It has the normal dip of 25 to 30 feet per mile to the west. Its outcrop can easily be followed in the field thus rendering it a convenient horizon of reference. The sandstone which takes the place of the limestone to the south is not so readily followed. This limestone is known to the drillers as the Oswego or Ft. Scott lime. Except in the Cleveland field as stated above, oil and gas is encountered, if at all, below this limestone.

Labette Shales.*

Above the Fort Scott limestone is a shales formation tanging in thickness from 80 feet in the northern part to 350 feet in the southern part. The shales are composed of blue, gray, black members irregularly interbedded with lentils of limestone and sandstone and occasional beds of

* Bul No 184 p 211 U S G S.

coal. These shales dip west at low but regular angles.

Oologah Limestone.*

Immediately above the Labette shales lies a heavy limestone formation, the "Big Lime" of the drillers, separated by an interval of shale. Northward this shale thickens and is the equivalent of the Sanders shales of Kansas.** To the south it gradually thins out until it finally disappears between the upper and lower limestone in the vicinity of Talala. In discussing these rocks Doctor Adams says: "The upper members of the limestone was determined by Mr. Bennett to be the equivalent of the lower member of the Parson's formation (of Kansas) as mapped and defined by Mr Adams. The equivalency of the lower

*Kansas Geol Survey Vol III
** Kansas Geol Survey Vol III

member of the OOlogah has not been definitely determined. It is not impossible that it may prove to be a continuation of the Pawnee.** This formation, consisting of about 100 feet of limestone at OOlogah gradually decreased in thickness southward. It crossed the Arkansas River below Tulsa, and finally disappears in the vicinity of Mounds. Its outcrop is conspicuous along the Verdigris River where it forms steep bluffs of a hard, massive, gray limestone of uneven texture locally containing gray chert nodules. (See Geological Map) The formation dips west.

Nowata Shales.

Just above the OOlogah limestone is a series of rocks designated as the Nowata shales by Mr. Hutchison**from typical exposures near the town of Nowata. The

* Bul No 211 U S G S page 62.
** Strat. of N Okla, Bachelor's Thesis '07 Was unpublished.

formation consists of varying strata of gray, black, and slaty shales interbedded with coal and several ledges of friable sandstone. The thickness of the formation averages from 150 to 300 feet. The dip is to the west.

Parsons Limestone.

Above the Nowata shales lies a ledge of limestone known as the Parsons limestone* which gradually thins out southward. It has been traced as far south as Nowata. There is a ledge of limestone averaging four feet in thickness at Tulsa and Mounds which has all the lithological characteristics of the Parsons Limestone and occupies the same stratigraphic position. This ledge is provisionally known as the Tulsa limestone. It is the writer's opinion that future study in the region between Nowata

* Kansas Geol. Survey Vol III.

and Tulsa will demonstrate that the Parsons limestone extends farther south than is at present known and that it will eventually be shown to be the same as the ledge found at Tulsa and Mounds.

Skiatook Shales.

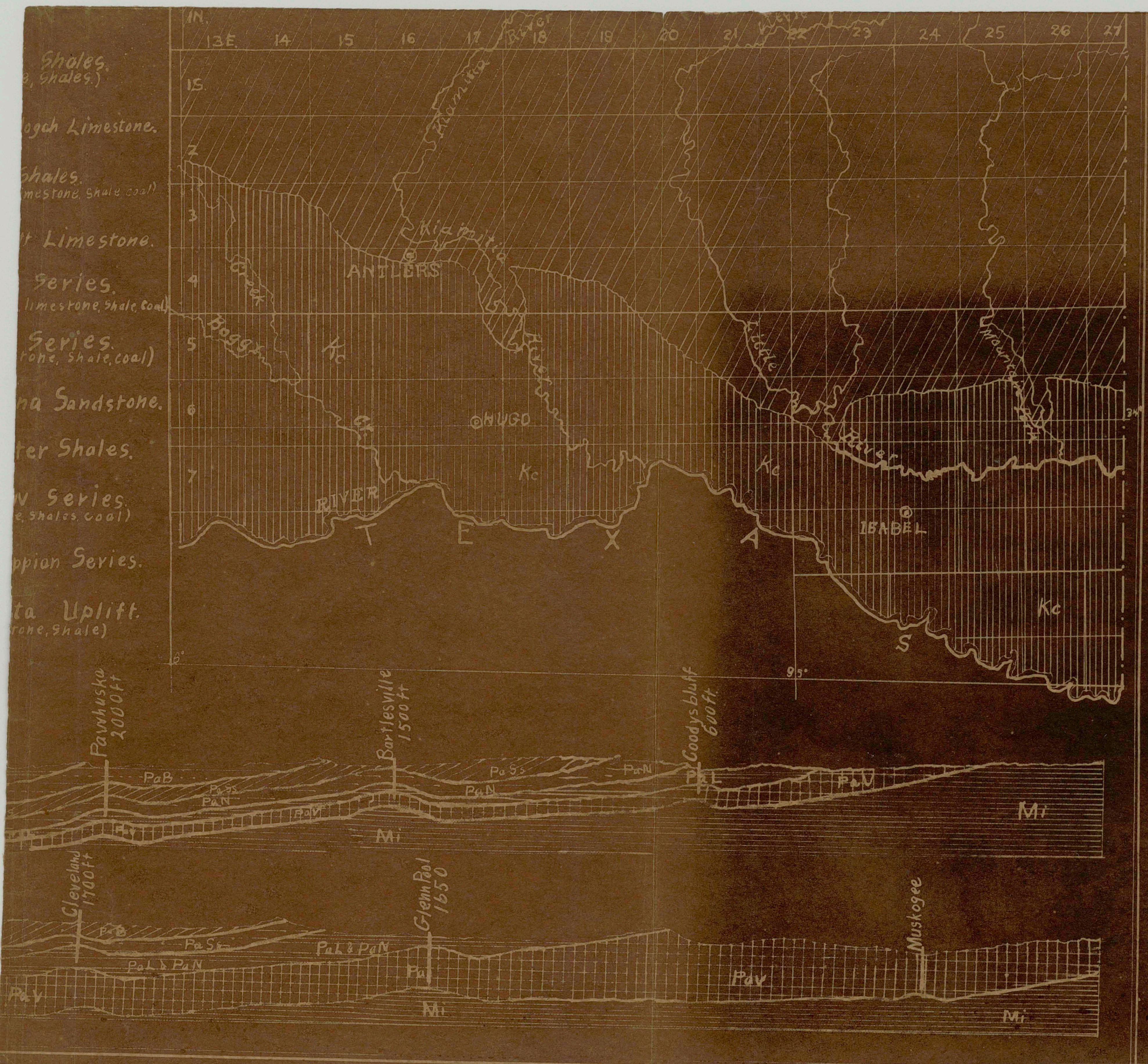
Above the Parsons and Tulsa limestone is a series of alternating strata of shales and sandstones with several interbedded limestone lentils. Mr. Hutchison* has proposed for the series the name "Skiatook shales" from exposures at Skiatook. The shales vary in color from a blue-gray to a yellow, the sandstones are usually light red. Logs of wells show that the average thickness of these shales is about 550 feet.

Drum Limestone.**

* Strat. of N Okla by L L Hutchison mss unub.
** Kan Geol Survey Vol III Bul No 211, p 184 U S G S.

Above the Skiatook shales occurs a ledge of heavy massive limestone which extends from near Independence, Kansas, south past Bartlesville and Ramona to a point southwest of Sapulpa, the southern point at which it has been located. It is a massive ledge 30 to 50 feet in thickness, interbedded with clay and sand. It weathers irregularly, white in some places and reddish brown in others and breaks into large rectangular blocks. The famous "Lost City" near Red Fork is composed of these blocks. The dip of the Drum is 20 to 50 feet per mile west. (See Geological map).

The formations above the Drum limestone consist of alternating layers of sandstones and shales with several ledges of limestone, all dipping west. These different members have not as yet been accurately mapped and for that reason the writer



Shales.
(... Shales.)
...ogah Limestone.
Shales.
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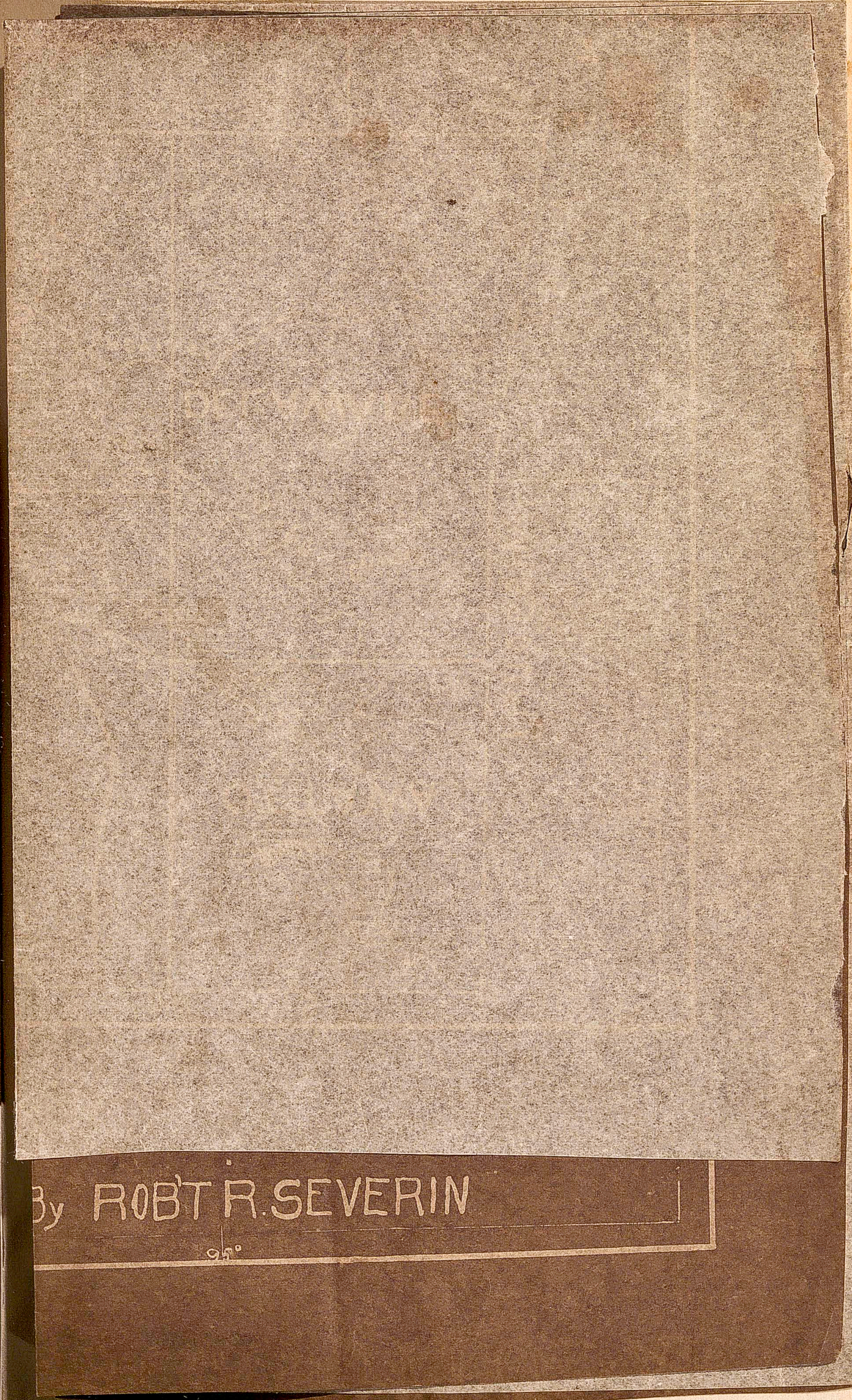
4
5
6
7
River
Kiamitia
ANTLERS
Boggy
Creek
Kc
HUGO
RIVER
Little
River
Mountain Fk
ISABEL
T E X A S
34°
95°
Pawhuska 2000 ft
Bartlesville 1500 ft
Goodysbluff 600 ft
PaB
PaSs
PaN
PaL
PaV
Mi
Cleveland 1700 ft
Glenn Pool 1650
Muskogee
PaL & PaN
Pav


By ROB'T R. SEVERIN
95°


MAP of the OIL & GAS DEVELOPE-
MENTS of OKLAHOMA
1907
OIL POOLS
+ GAS WELLS
FT. SCOTT Ls.
MISSISSIPPIAN Lss
By ROBT R. SEVERIN
KANSAS
MISSOURI
ARKANSAS
OSAGE NATION
WASHINGTON
NOWATA
CRAIG
OTTAWA
DELAWARE
MAYES
ROGERS
PAWNEE
TULSA
CREEK
WAGONER
CHEROKEE
ADAIR
OKMULGEE
MUSKOGEE
SEQUOYAH
OKFUSKEE
McINTOSH
SEMINOLE
HUGHES
Pawhuska
Bartlesville
Dewey
Copan
Nowata
Coodys bluff
Alluwe
Vinita
Miami
Grove
Chelsea
Bigheart
Ramona
Oolagah
Hominy
Pawnee
Cleveland
Claremore
Pryor Creek
Tulsa
Turley
Red Fork
Sapulpa
Mounds
Coweta
Wagoner
Westville
Tahlequah
Muskogee
Beggs
Okmulgee
Morris
Chandler
Okemah
Eufaula
Sallisaw
Tecumseh
Wewoka
Holdenville
CIMARRON RIVER
ARKANSAS RIVER
CANADIAN
GRAND
Spavinaw Creek
North Fork
Canadian
Verdigris River
97°
96°
95°
37°
36°
35°

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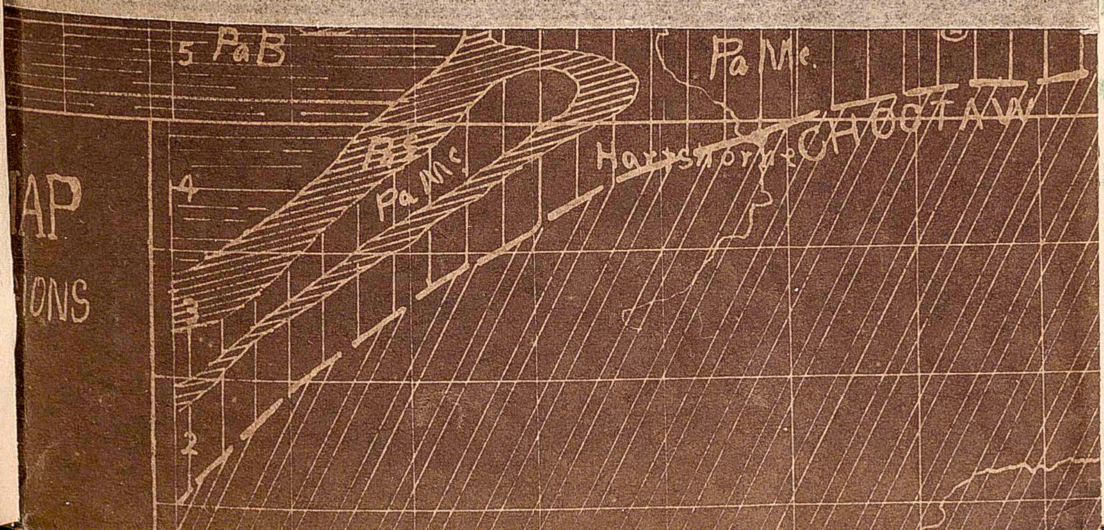


PRELIMINARY GEOLOGICAL MAP
of the PRODUCTIVE OIL & GAS REGIONS
OF OKLAHOMA
1907
By Rob't R. Severin
K A N S A S
MISSOURI
ARKANSAS
A
B
C
D
PAWHUSKA
BARTLESVILLE
Copan
Dewey
NOWATA
VINITA
MIAMI
Grove
PAWNEE
Hominy
CLEVELAND
Bigheart
CLAREMORE
PRYORCREEK
Tulsa
SAPULPA
Mounds
MUSKOGEE
TAHLEQUAH
Westvill
CHANDLER
OKMULGEE
OKEMAH
SALLISAW
EUFAULA
STIGLER
WEWOKA
Crowder
McALESTER
WILBURTON
POTEAU
CHOCTAW
FAULT
Canadian
Cimarron
Grand
Verdigris
Arkansas River
North Fork
Deep Fork
Little River
PaR
PaB
PaSs
PaN
PaL
PaV
PaBs
Mi
Pc
PaMc
Pas
Alluvium

thinks best not to attempt to describe them in detail. Mr. Hutchison has included these rocks under the series which he calls the Bird Creek series.

PRESENT OIL AND GAS FIELDS:

With the exception of the oil found at Muskogee practically all the oil development of Oklahoma has been along three lines of anticlines. First and most important, is the line running north and south near the 96th meridian. Along this line occur the following productive fields: Copan, Dewey, Bartlesville, Ramona, Skiatook, Turley, Tulsa, Redford, Sapulpa, and the Glenn Pool. It is believed that this anticline, which has been definitely traced from the Kansas line south as far as the Glenn Pool, extends for a number of miles south of Boggs and

and Okmulgee and possibly as far as the vicinity as Weleetka or Holdenville. A second line of development is a region along the Verdigris River which contains the oil fields at Coody's Bluff, Alluwe and west of Cehlsea. The location of the southern extension of this anticline is not now definitely known, but recent field work by Messrs. Gould and Hutchison seems to indicate that an expression of this fold occurs a few miles east of Claremore and possibly as far south as the Verdigris River south of Inola. The third productive region extends north and south through Cleveland, Oklahoma. This anticline has been traced as far south as the northern line of the Creek Nation southwest of Terolton.

So far as known all the oil and gas found along these three main lines of development occurs in anticlines. In no place of which we have any knowledge has any oil or gas been found in a syncline in Oklahoma. The extent of these anticlines hasmnot yet been traced nor mapped accurately, but they have all been studied sufficiently to warrant the assertion that the greater part of the oil or gas now being produced in Oklahoma is found along anticlinal folds. We shall consider in detail a few of the more important oil fields:

Muskogee Field.

The Muskogee field is the only field of importance in Oklahoma that is not located on one of the three lines of development referred to above. Some of the first producing oil and gas wells discovered in the state were at Muskogee. The field which had been developed previous to April

1907, comprised only a very small area in the southeastern part of the city, being approximately a mile in length by a quarter mile in width. The first well, which was drilled to a depth of 665 feet, yielded 12 barrels of oil a day. Over 40 wells in all have been drilled in this region and the greater number to a depth of 1,100 feet where an oil sand was encountered. Many of the wells at one time produced from 5 to 60 barrels per day. At the present there are only a few producing wells in this oil field and their output is steadily decreasing.

The oil is dark green in color, appearing cherry red when held to the light. It is of a much higher grade than any other oil now produced in Oklahoma, having a gravity of 42 degrees Baume! Other oils range usually from 28 to 32 degrees Baumé. The Muskogee Oil is superior to most other oils found in Oklahoma in that it has a paraffine base while others have an asphaltum base.

Mr. Taff, who studied the Muskogee field, says: "The structure of the Mississippian rocks and of the strata both above and below them in eastern Cherokee Nation, is complicated. A survey of the region between Muskogee and the Arkansas-Indian Territory line supports the following statements, which may have bearing upon the occurence of oil: 1. There is an unconformity between the Mississippian limestone and the overlying Pennsylvanian deposists. 2. There are indication that folds were developed in the Mississippian rocks before and probably during the earlier part of the deposition of the Pennsylvanian.

3. The Mississippian limestone lies across the folded and eroded surface of the Silurian and Ordovician limestone, sandstone and shales."*

A study of the structure of the rocks east of Grand and Arkansas Rivers reveals the fact that instead of having the even westerly dips seen in most parts of the oil fields, these formations have been thrown into a series of low anticlines and synclines with which faults are usually associated. The faults do not extend far westward but gradually disappear while the associated folds extend for a considerable distance farther west before finally flattening out. Mr. Taff, further says, " It is presumed that if oil occurs in the region south and southeast of Muskogee its collection into pools would be influenced by

* Bul No 260, page 444.

the location of the upward folds. There are several anticlines south of Muskogee and these should prove to become, if prospected, good oil fields."* True to Mr. Taff's prediction during April, 1 07, a prospect well which was drilled about 5 miles southwest of Muskogee, secured a flow reported to be 500 barrels a day. The old oil field in the city of Muskogee is possibly upon the western limb of an anticline which is plainly shown along the west bank of the Arkansas River 4 mil s east of Muskogee at the point where it is crossed by the St. Louis and San Francisco Railroad.

Bartlesville Field.

This, the first important field developed in Oklahoma, is situated in

* Bulletin No 260, page 445.

in the northern part of the State, being located along the 96th meridian anticline. The developments of Oklahoma oil fields date from 1903 at which time there had been completed 54 wells in Section 12, T. 26N R 13 E, Bartlesville townsite, and 90 wells in the Osage reservation west of Bartlesville. During that year the shipments of crude oil from Bartlesville in tank cars was about 1,000 barrels a day. When the pipe line was completed to Bartlesville in July of that year, the runs averaged about 4,000 barrels per day. At the present time the field is producing about 25,000 barrels daily. The oil is a heavy dark liquid with an asphaltum base. The productive wells at Bartlesville start on the Drum* limestone or the Skiatook* shales, descending to a depth of from 1,200

* See Geological Map.

feet to 1,500 feet for the oil and gas-bearing sand, the depth depending upon the elevation. This oil-bearing sand, which is known to the drillers as the "Bartlesville sand" is one of the sandstone members of the Vinita shales.

The following log of a well near Bartlesville gives a fairly accurate record of the different formations penetrated with their character and approximate thickness.

Log of well five miles southeast of Bartlesville:

Limestone (Drum)		26 ft	26 ft
Shale dark (Skiatook)		214 "	240 "
Limestone, white, hard, (Parsons)		40 "	280 "
Watersand	)	15 "	295 "
Shale dark	(Nowata	250 "	545 "
Sandstone, showing oil	) (Shales	20 "	565 "
Shale	(	85 "	640 "
Limestone (Oologah)		90 "	730 "
Shale dark	) Coblet	10 "	740 "
Sandstone	(Shale	40 "	780 "
Shale	)	120 "	900 "
Limestone (Oswego)		85 "	985 "
Shale	) Vinita	310 "	1295 "
Oil sand	(	8 "	1303 "
Shale to bottom	) Shales	26	1329 "

From this log it is evident that the oil-bearing sand is some 300 feet below the top of the Vinita formation.

Practically all the producing oil wells in this field are situated along the 96th meridian anticline. This fold is plainly shown by the outcrops of the Drum limestone, which, in the vicinity of Bartlesville, dips to the east while farther west it dips to the west. The width of the fold varies but in general it is from 3 to 6 miles wide.

Tulsa field.

This field is located along the 96th meridian anticline also, and also all productive wells are situated upon this fold. The following log is a record of a dry hole drilled off the anticline, given here to show the different formation and the depth of the Mississipian limestones.

Dry hole four miles Southeast of

Tulsa, Polly Sango, Well No. 1.

Surface soil	42 ft	42 ft
Sandstone	8 "	50 "
Shale	24 "	74 "
Sandstone white	18 "	92 "
Shale dark	78 "	170 "
Shale	170 "	340 "
Limestone (Oologah)	13	353 "
Shale	180	533 "
Limestone (Ft Scott)	18 "	551""
Shale	16 "	567 "
Limestone	8 "	575 "
Slate (Black shale)	119	694 "
Limestone	10 "	704 "
Shale 140	140 "	844 "
Limestone	12 "	856 "
Shale	120 "	976 "
Shale Black	20 "	996 "
Shale	39	1075 "
Oil sand	3 "	1078 "
Shale	87 "	1165 "
Sandstone	14	1179 "
Shale	123	1302 "
Slate (Black shale"	10 "	1312 "
Shale	108 "	1420 "
Limestone dark to white		
Mississippian limestone	397 "	1817 "
Black shale	24 "	1841 "
Sandstone	24 "	1902 "

Saltwater at 1902.

Sapulpa Glenn Pool Field.

The present southern development of

the 96th meridian anticline is the Sapulpa-Glenn Pool field. Since the Humble Pool was struck in Texas three years ago, nothing has appeared upon the oil horizon to attract the attention that centers about the Glenn Pool and the Sapulpa field. The pioneer well is this field was drilled in December of 1905, but it was not in good producing shape until March, 190[illegible]. A second well on the same property was drilled in April 1906 which produced 700 barrels per day. Another well was drilled on an adjoining lease about the same time, the well producing 75 barrels per day. The third well drilled on the original property started at 1,200 barrels per day, and from that time many wells have been drilled in this field, some of them producing as much as 1,600 barrels per day. Many large gas wells have also been found, the largest of which is estimated to register 60,000,000 cubic feet per day. The present oil output of the Glenn Pool is reported to be about 75,000 barrels every 24 Hours, and not all of the wells are flowing their full capacity. It is estimated that not one fifth of the pool has as yet been developed. The present area of the field is about 3 by 5 miles.

The surface rocks of the Sapulpa-Glenn Pool field consist of the parsons limestone and the Nowata shales. The following log of one of the wells will give the different formations passed through and the average depth of the oil bearing sand.

Well No 3, Sec. 3, Tp 17 N, R 12 E

Holston farm.

Soil	20 ft	20 ft
Blue shale or doby	45 "	65 "
Limestone	5 "	70 "

Sandstone-water	5 ft	75 ft
Sandy shale	20 "	95 "
Blue shale or doby	50 "	145 "
Sandy shale	40 "	185 "
Blue shale or doby	60 "	245 "
Sandstone	30 "	275 "
Blue sandstone and shells	50 "	325 "
Limestone	12 "	337 "
Blue shale and shells	70 "	407 "
Blue shale	263 "	670 "
Black shale	185 "	855 "
Limestone	45 "	900 "

At 889½ ft a small amount of gas was encountered.

Sandstone	21½"	921½"
Blue shale	33½"	955 "
Limestone and water	15 "	970 "
Sandy shale	20 "	990 "
Sandstone	6 "	996 "
Black shale	50	1046 "
Blue shale	100 "	1146 "
Black shale	68	1214 "
Black shale	68 "	
Sandy limestone	8 "	1222 "
Blue shale	80 "	1302 "
Black shale	48 "	1350 "
Sandstone and shells	18 "	1368 "
Sandy shale	40 "	1408 "
Blue shale	8 "	1416 "
Sandy shale	80 "	1496 "
Gas at 1500 ft		1500 "
Oil sand at		1610 "
Bottom of well at		1612 "

Well producing from 175 to 200 barrels per day.

So far as known all the producing

oil and gas wells of this field are situated along an anticline, which, as has already been said, is the southern expression of the 96th meridian fold. This fold is probably not continuous as might be supposed, but it seems to be influenced by minor transverse folds. It also seems to contain occasional level areas where no evidence of a fold can be distinguished.

The fold at the Glenn Pool was first discovered by Mr. Hutchison and the writer at a point northeast of the city of Mounds along a branch of Duck Creek. It was found that along this creek the rocks dipped both east and west, thus indicating an arch or anticline. The dips at this place were very gentle ranging from 1/4 degree to 1 degree, or 25 to 100 feet per mile. From Duck Creek the anticline was traced to a point several miles southwest of Mounds and north to a point east of the city of Sapulpa. The width of the anticline varies, averaging about three miles. The location of the gas wells of this field substantiates the theory of the accumulation of oil and gas under anticlines, the greater part of them being situated directly along the axis of the fold.

Coody's Bluff- Alluwe Field.

This field lies east of the Verdigris River comprising the eastern line of oil developments in Oklahoma. The surface formations of this field are the Oologah limestone and the Labette* shales. The rocks of this region, especially the Oologah limestone, show plainly the folding that has taken place. At Coody's Bluff post-office this limestone dips from 1 to 5

* See Geological Map.

degrees to the east. Further west across the Verdigris River, which has here cut its channel along the axis of the anticline the limestone dips from 1 to 2 degrees to the west.

Mr. Hutchison and the writer traced this anticline from a point five miles north of Coody's Bluff postoffice to a region about five miles south of Alluwe. How much further south this fold extends is not known but it is very probable that it will be found east of Claremore and possibly as far south as Coweta. The width of the fold varies from 1 to 3 miles.

The oil and gas is secured from a depth of 500 to 600 feet. On account of the oil sand being so shallow the oil is not of an extra high grade, being a heavy black liquid with a strong asphaltum base.

The following log will give a good

idea of the character of the geological formations which are penetrated in drilling for oil in this field, below Oologah limestone. Sec 7 NE corner of SW quarter Tp 26 N, R 16 E.

Soil	)	10 ft	10 ft
Sandy shale	(Labette	36 "	46 "
Shale	)	44	90 "
Limestone	(Shale.	10 "	100 "
Shale	)	15	115 "
Limestone (Ft Scott)		40 "	155 "
Shale	(	40	195 "
Limestone	)	10	205 "
Shale	(Vinita	5	210 "
Limestone	)	2	212 "
Shale light gray		277	489 "
Gas Sand	(Shales	17	506 "
Oil sand	)	12	518 "

From this record it will be seen that the oil sand is approximately 315 feet below the top of the Vinita formation. Remembering that the oil sand at Bartlesville was found to be about [illegible]00 feet below the top of the Vinita shales, we conclude that the oil producing sand of Bartlesville and Coody's Bluff is probably the same ledge.

Cleveland Oil Field.

The third region of extensive oil developments in Oklahoma is at Cleveland in eastern Pawnee County. Three years ago this was the most prolific oil field in Oklahoma and Indian Territory. There are three so-called pools in this region, one in the city of Cleveland, one called the Kelso Pool south of Cleveland, and the third, the Sayton Pool three miles west of the city. The two latter are smaller than the Cleveland Pool, occupying only a section or two. The Kelso Pool produces the largest amount of gas.

In the city of Cleveland practically all the wells started out as "gushers" or flowing wells with a capacity of from 200 to 500 barrels per day. The field was "over drilled", however, and at present, with a well on practically every 25 foot lot, the oil has been exhausted to such an extent that nearly all the wells are not being pumped. The average daily production is now perhaps 10 barrels per well.

The surface rocks at Cleveland are formations which lie stratigraphically above the Drum limestone. The oil is encountered at a depth ranging from 1,500 to 1,700 feet, depending upon the surface elevation, coming probably from the horizon of the Labette shales. This is the only oil producing sand, so far as the writer knows that is situated above the Fort Scott limestone. All other oil sands are encountered in the Vinita shales.

The following log will give an idea of the geological formations that are encountered in drilling, with their thicknesses and character. This was the first well drilled in Cleveland. Uncle Bill No 1.

Red shales	180 ft	180 ft
White sandstone	25 "	205 "
Red shales	35	240 "
White sandstone	25 "	265 "
Red shales	195 "	460 "
Limestone (Drum)	25 "	485 "
White sandstone	10 "	495 "
Red Shales	39 "	534 "
Limestone and shales	8 "	542 "
Red Shales	28 "	570 "
White sandstone	25	595 "
Red shales	5 "	600 "
White sandstone	100 "	700 "
Black shales	100 "	800 "
White sandstone	20 "	820 "
Black shale	200 "	1020 "
Gray sand	195 "	1215 "
Black shale	125 "	1340 "
Gray sand	15 "	1355 "
Black slate	215 "	1570 "
Oil sand	20 "	1590 "
Gray sand	15	1605 "
Second oil sand	10 "	1615 "

The Cleveland Pool seems to be situated upon a low and inconspicuous dome-shaped anticline with its axis extending north and south. It is about two miles in length by 1/4 miles in width. The limit of the producing field is very sharply marked, possibly on account of the small size of the fold. The structure of the rocks of the Kelso Pool and the Sayton Pool have not as yet been investigated thoroughly. The Kelso Pool seems to be situated on a small dome which is in line with the Cleveland fold. The Sayton Pool is apparently a small pool having no connection with the others.

PROSPECTIVE OIL AND GAS FIELDS.*

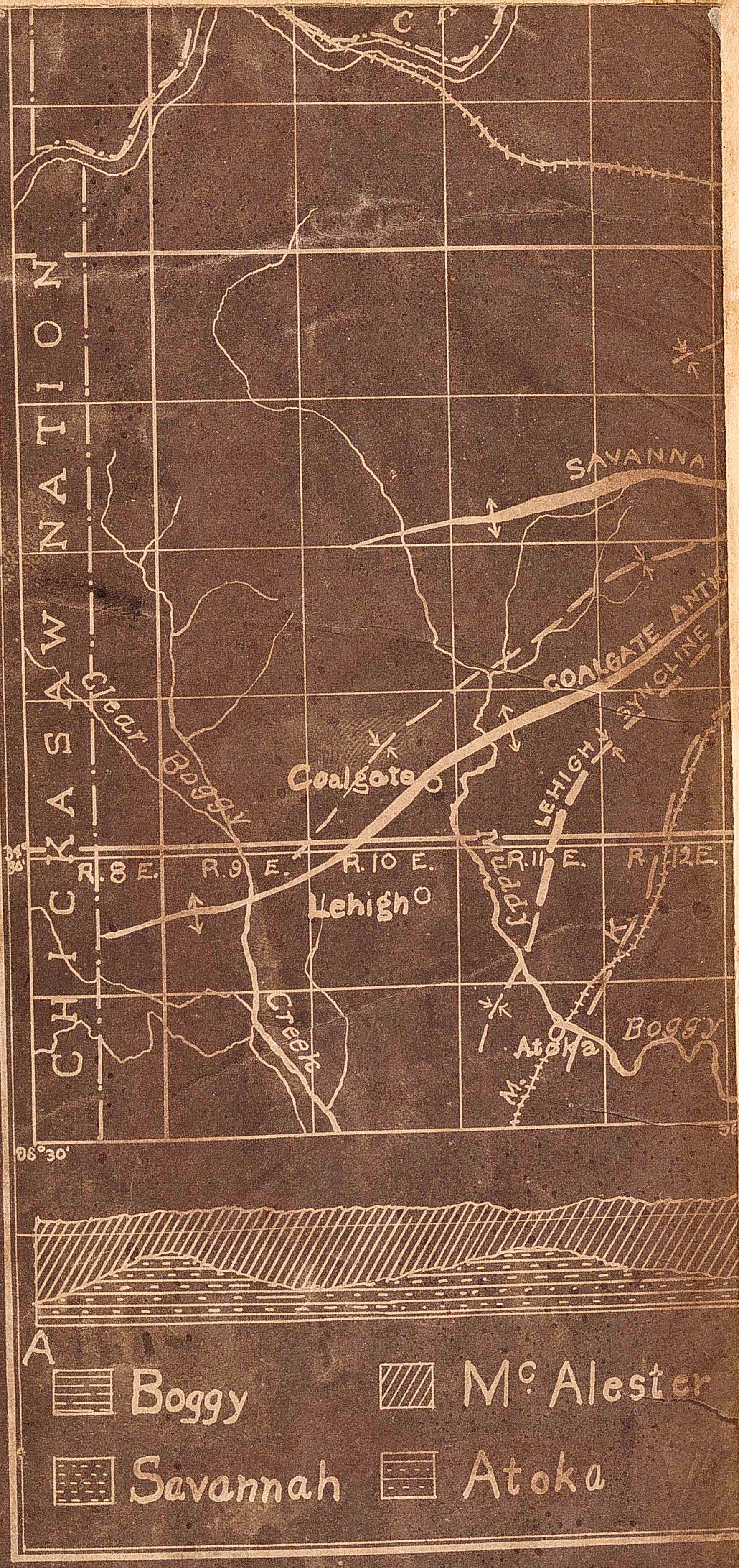
Thus far only those oil and gas fields that are known to be productive have been considered. The intimate relation existing between the prolific fields and anticlines have also been considered. It may not be ill advised to consider some-

* See map showing prospective fields.

what briefly certain regions which, because anticlines are known to be present, should eventually become productive oil and gas territory.

Mr. Taff, in conducting his investigation of the coal fields of the Choctaw Nation,* found it necessary to study somewhat carefully the structure of the rocks, and particularly the location of the anticlines and synclines which are present in that region. He prepared a map showing the most important folds. His map forms the basis of the map presented herewith illustrating the general structural condition of the region south of the South Canadian River. The following are the most important folds: McAlester, Savanna, Coalgate, Howe, Brazil and Canadian anticlines; and Krebs, Sansbois, Kiowa, Lehigh, Cavanal

* 21st Annual Report of U S G S Part 2.


CHICKASAW NATION
SAVANNA
COALGATE ANTIC
SYNCLINE
LEHIGH
Clear
Boggy
Creek
Coalgate
Lehigh
Muddy
Atoka
Boggy
R. 8 E.
R. 9 E.
R. 10 E.
R. 11 E.
R. 12 E.
96°30'
A
Boggy
Mc Alester
Savannah
Atoka

and Poteau synclines. The synclines, as they are not indicative of either oil or gas need not be discussed here, but the more prominent anticlines will be e xamined somewhat in detail. These anticlines are shown on the map of prospective oil fields. It must be understood that on a map of this size only the approximate location of the most conspicuous folds can be shown.

The McAlester Anticline.

This fold which is one of the most important in the region extends from the northeast corner of Tp 4 N, R 12 E in a northeastlery direction to a point a few miles east of the city of McAlester, where the fold divides; the northern branch known as the Richville anticline extends on northeast as far as Tp 6 N, R 17 E. The southern branch or main McAlester anticline continues in an easterly direction cutting across the Sanbois syncline past Anderson and Dwight nearly to Wilburton, where it again divides, one branch going northeast and the other southeast.

The Savvanna Anticline.

This fold extends from Tp 3 N, R 10 E in an easterly direction nearly to the town of Kiowa, then northeast past Savanna to Alderson, at which place it joins the McAlester anticline.

Coalgate Anticline.

This fold extends in a north-eastern and southwestern direction through the town of Coal gate which is about located on the axis of the anticline.

McCurtain Anticline.

This fold extends from Tp 7 N, R 16 E east near the towns of Blocker, Featherstone, McCurtain and Bokoshe as far as the

Arkansas River. This is one of the most extensive folds in the Choctaw Nation.

Brazil Anticline.

This fold extends from about the 5th Guide Meridian in Tp 6 N, east and northeast along Brazil Creek to the Fort Smith and Western Railroad where the fold turns east and continues past Panama and Farmers.

Howe Anticline.

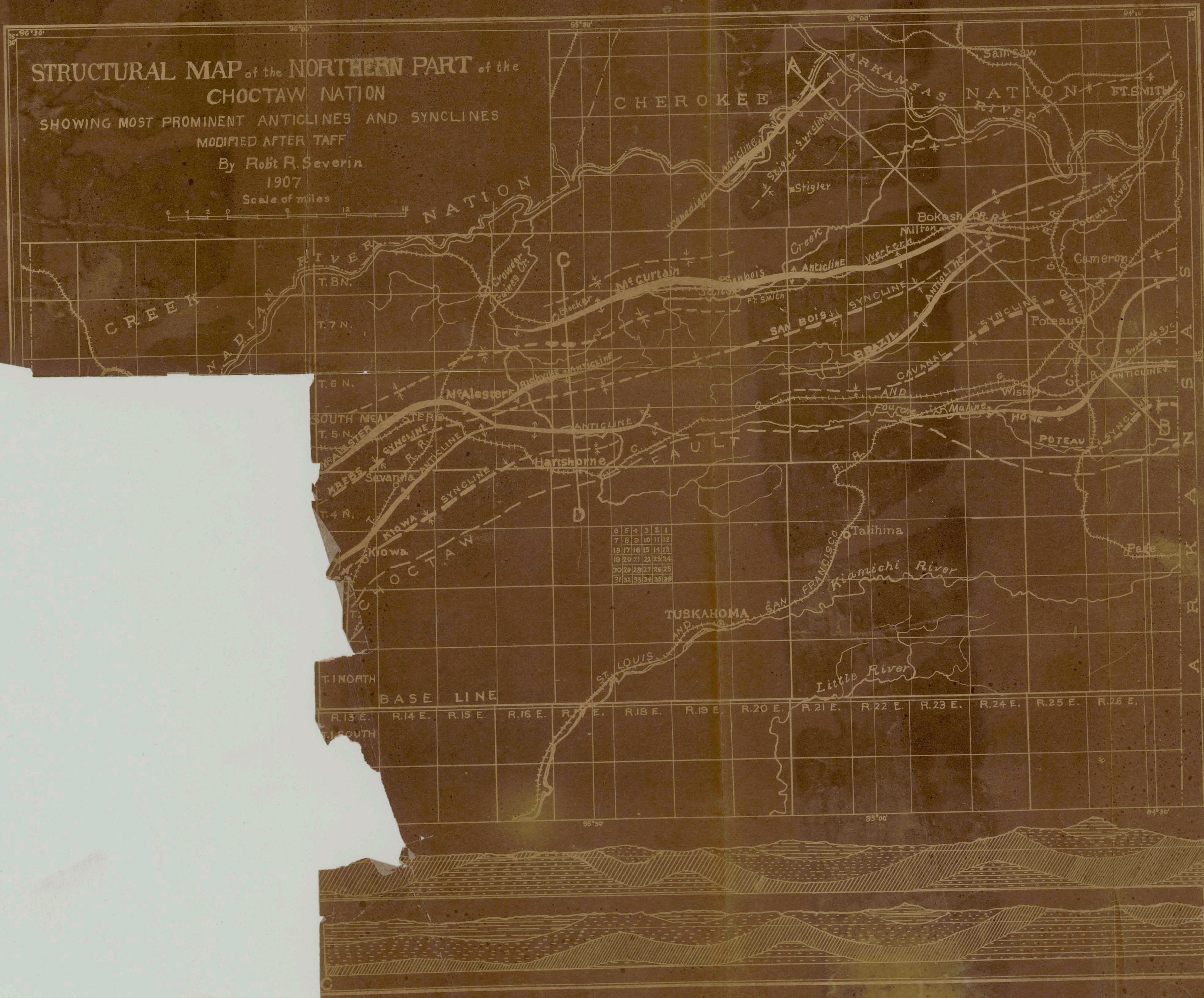
This fold extends from about the point where the M K & T Ry crosses the Fourche Creek east along the creek to the eastern side of Tp 5 N, R 25 E, then northeast branching in Tp 6 N, R 26 E, one branch extending northeast and the other east.

Canadian Anticline.

This fold extends from Tp 8 N, R 18 E in a northeast direction along the South

Canadian River as far as the Arkansas, north of which stream it probably runs out into one of the faults which are common in the region north of the Arkansas River.

It will be understood that only the approximate location of these anticlines has been described for in most cases their full extent has not yet been worked out definitely. Nevertheless, if the anticlinal theory holds true for this region as it does for the northern part of the State, these folds should all eventually become productive oil and gas fields. The character of the rocks in which thsese folds are located is the same as of those farther north where great quantities of oil and gas have been produced, hence there is no geological reason for doubting that the region of the Choctaw anticlines should not also be productive. Indeed, it is not too much to say that in the light of our present knowledge not one third of the productive oil and gas regions of Oklahoma have yet been prospected. From present indications it would seem probable that the most prolific fields in the State lie south of the Canadian River.


STRUCTURAL MAP of the NORTHERN PART of the CHOCTAW NATION
SHOWING MOST PROMINENT ANTICLINES AND SYNCLINES
MODIFIED AFTER TAFF
By Rob't R. Severin
1907
Scale of miles
CHEROKEE NATION
ARKANSAS RIVER
FT. SMITH
Sallisaw
Stigler
Stigler Syncline
Canadian Anticline
Bokoshe
Milton
Cameron
Poteau River
Poteau
CANADIAN RIVER
NATION
CREEK
T. 8 N.
T. 7 N.
T. 6 N.
T. 5 N.
T. 4 N.
T. 1 NORTH
T. 1 SOUTH
Crowder
McCurtain
Sanbois
Sans Bois Creek
Anticline
Ft. Smith
SAN BOIS SYNCLINE
BRAZIL ANTICLINE
CAVANAL AND POTEAU SYNCLINE
Wister
HOWE
POTEAU
ANTICLINES
McAlester
Richville Anticline
SOUTH McALESTER
McALESTER SYNCLINE
KREBS
Savanna
ANTICLINE
KIOWA SYNCLINE
Hartshorne
Kiowa
CHOCTAW FAULT
Fourche Maline
Talihina
Kiamichi River
Page
TUSKAHOMA
ST. LOUIS AND SAN FRANCISCO
Little River
BASE LINE
R. 13 E.
R. 14 E.
R. 15 E.
R. 16 E.
R. 18 E.
R. 19 E.
R. 20 E.
R. 21 E.
R. 22 E.
R. 23 E.
R. 24 E.
R. 25 E.
R. 26 E.
ARKANSAS
95°30'
95°00'
A
B
C
D