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BULLETIN NO. 19.

PETROLEUM AND NATURAL GAS IN OKLAHOMA.

PART I.

GENERAL INFORMATION CONCERNING OIL AND GAS.

GEOLOGY OF OKLAHOMA.

BY

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PETROLEUM AND NATURAL GAS IN OKLAHOMA.

PART I.

GENERAL INFORMATION CONCERNING OIL AND GAS.

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PETROLEUM AND NATURAL GAS IN OKLAHOMA.

INTRODUCTION.

This report on petroleum and natural gas in Oklahoma is published in two parts. Part I, deals with the general phases of the oil and gas industry, and a discussion of the geology of the State. Part II, gives a detailed discussion of the oil and gas fields of the state by counties, and includes the result of recent investigation in the field, covering untested and undeveloped parts of the State.

By this plan of issuing the report in two parts, a saving in printing is gained. Many requests come in for general information concerning the oil and gas business, or in regard to the geology of some part of the State. These wants can be supplied by Part I, without sending out a full report on the subject of oil and gas. On the other hand, requests for detailed information covering various fields may be supplied by Part II. Libraries and individuals on the exchange list are furnished with both parts of the report.

It is the purpose of this report to give to the public as much general information as possible concerning the oil and gas industry in Oklahoma. All publications of similar nature prepared by the Oklahoma Geological Survey have been completely exhausted. The demand for oil and gas publications is great. At present about 2,500 names are on file awaiting the mailing out of such information as can be offered concerning these fuel materials.

During the past three years several new fields have bee discovered and extensions to old pools developed. The New kirk, Bixby, Cushing, and Healdton fields are those of most im portance brought in since the beginning of 1912. Oklahom stands second among the oil states in production, and first i the value of production for the past three years. In 1912 th production amounted to 51,427,071 barrels, valued at $34, 672,604; 1913, 58,203,740 barrels, valued at $55,018,541 For 1914 the total production was approximately 102,800,00 barrels.

The production for the first six months of 1915 has bee estimated at 57,500,000 barrels. From all indications it a pears that the total production for the year will equal, if n exceed, that for 1914.

The price of oil began to decline in the early part of 191 and continued through 1915, until August, when the first i crease was noted. Since then the price has been advanci steadily up until the date of publication of this report.

ACKNOWLEDGMENTS.

The material contained in this report is in part the result of recent investigations in the field by the writers, and the assistants of the Geological Survey under their direction, and in part prepared from the compilation of unpublished data already in possession of the Survey, and from the former publications of the department. During the season of 1914 W. A. Buttram and Dean M. Stacy were in the oil and gas fields of the State securing general information concerning all phases of the oil and gas industry. The general information given in this report is based largely upon the data secured by these men.

George H. Myers and Fritz Aurin, field and office assistants, rendered valuable aid in gathering data, compiling tables, and correcting manuscript.

L. C. Snider, assistant director, gave many valuable suggestions pertaining to geologic conditions in the State, and offered helpful criticisms during the preparation of this report.

Five brief reports, the results of cooperative work between the United States Geological Survey and the Oklahoma Geological Survey, are included in this report. Early in 1914 arrangements were made in regard to the cooperative work, whereby the State might secure in time for this publication, such information as was available through cooperative work in advance of the complete publications which are to be published by the Federal Survey. The following are the reports submitted:

The Lawton Oil and Gas Field, by Carroll H. Wegemann and Ralph W. Howell; The Loco Gas Field, by Carroll H. Wegemann; The Duncan Gas Field, by Carroll H. Wegemann; A Structural Reconnaissance in the Vicinity of Beggs, by A. E. Fath, assisted by Wilson B. Emery; Faulted Structure in the Vicinity of the Recent Oil and Gas Development near Paden, by A. E. Fath, assisted by K. C. Heald.

These reports are published in Part II, under the various counties with which they deal, proper credit being given to the author of each paper.

PUBLICATIONS.

The purpose of the Survey is to give to the people of the State at the earliest date possible the results of field investigations, but the full printed report must often necessarily appear several months after completion of the field work. It is the present policy to issue press bulletins concerning investigations made in advance of the completed publication.

These press bulletins are printed by a number of the principal newspapers of the State, and additional copies are mailed out over the State from the Survey office.

As soon as a piece of field work has been undertaken, requests begin coming in for the maps and publication concerning the area. The interest of the people in securing information is evidenced by such requests, but, on the other hand, it must be understood that the field work represents only one part of the task. The preparation of the report and maps often requires more time than the field work. The geologist in the field is often asked for information which he cannot give until the office work has been completed. The study and compilation of the data collected often change the first notions which may be obtained in the field. Mechanical or chemical analyses are often necessary to determine certain questions. Every effort must be made by the men in the field to secure original information, but field opinions are unreliable until there has been opportunity for comparison and correlations with the subject matter already available.

In the preparation of any report concerning a mineral industry, and especially of one relating to the general phase of the oil and gas business, it is impossible to adequately discuss all the various phases which are of interest. To some persons who have a considerable knowledge of the business such a publication would necessarily seem elementary.

Work has been in progress for more than a year toward the preparation of a rather complete publication on petroleum and natural gas in Oklahoma. This bulletin when ready for the press will total approximately 500 pages of printed matter, etchings, and half tones. It is the plan to give consideration to the oil industry from the beginning of work in the Mid-Continent field down to the present time. Oil fields are being studied and a discussion of each will be given, including past and present development and possibilities of future development. New areas are being studied in detail and encouraging discoveries are being made. This new work is being done in some parts of the State by the independent work of the State Survey, and in other parts by cooperation between the United States Geological Survey and the State Survey. Arrangements have been made in regard to the cooperative work, whereby the State may secure in time for this publication such information as is available through cooperative work in advance of the complete publication which will be published by the Federal Survey. Other independent work of the United States Geological Survey will also be available so that results may be published by the State. A large amount of most valuable information reaches the offices of the Survey through the oil companies and their geologists. In some areas there are geologic conditions which cause considerable differences of opinion, and these varied opinions which are offered are the best means of checking the facts of doubtful conditions. Several thousand logs of wells are on file, and much tabulated material concerning initial production, rate of decline, and life of fields, has been collected.

The following publications concerning oil and gas have been published by the Geological Survey during the past two years:

Bulletin No. 16, The Ponca City Oil and Gas Field; Bulletin No. 17, Geology of East-Central Oklahoma; Bulletin No. 18, The Cushing Oil and Gas Field.

The report on the Ponca City oil and gas field was issued in December, 1912. The field work was begun in the vicinity of the Ponca City oil wells. The structure was worked out by alidade elevations and an anticline was found to extend to the northeast for a distance of 12 miles to the Arkansas River. The highest part of the structure is to the north. Shortly after the publication of the report work began in the locality east of Newkirk, and several producing wells have been drilled. Between this and the Ponca City area, where the anticline is not so well developed, some drilling has been done, but no large production of oil has been found. Some gas has been encountered.

Bulletin No. 17, while dealing principally with the geology of east-central Oklahoma, was written with special reference to the occurrence of petroleum and natural gas in that part of the State. The field work was done during the field season of 1913. L. C. Snider, assistant director of the Survey, was in charge of a party of four who carried on the field work for the report. The work consisted almost entirely in the determination of the structure, special attention being paid to the location of the anticlines. In the greater part of the area the folds are sharp and the dips sufficiently steep to be read with an ordinary clinometer. In the northwest part of the area it was necessary to do some areal mapping, and to take some aneroid readings to determine the structure. All of the structural lines worked were of sufficient prominence that no alidade work was carried on. In general, the outcrops are sufficiently numerous to permit the axes of the folds to be located with a considerable degree of accuracy, but in some cases the distance between observed outcrops of opposite dips were found to be considerable, and

the location of the axis could only be approximated. Little attention was given to the stratigraphy, except in the vicinity where the dips were too small to make clinometer readings sufficiently accurate to determine the dip and structure. A large part of the geology had been previously worked out in considerable detail in this region, both by the United States Geological Survey and the Oklahoma Geological Survey.

Bulletin No. 18 deals with the geology, structure, development, and production in the immediate Cushing field and adjacent territory. The field work for the report was done during the summer of 1913 Frank Buttram, field assistant of the Survey, was in charge of a party of three to work out in detail the entire region embodied in this report. In beginning the field work it was found that there was no base map of the area available, except the ordinary county map. It was necessary to use this for the plotting of all data obtained. All the information gained concerning the surface geology and structure was placed on this map. In order to determine the structure, a line of levels was run to the field with a spirit level from the government bench mark located at the southwest corner of sec. 3, T. 17 N., R. 6 E. This primary level line was carried to different parts of the field, and temporary bench marks were established. From these established bench marks secondary spirit level lines were run to all the wells in the field, which at that time approximated 700. The elevation and location of each well were determined and plotted. Later the log of each well was obtained. Most of these logs give the depths of the producing sands, the amount of initial production, the lease name or number, the owner of the well, and some other special information. The principal geological formations were indicated upon the map, and the elevation of a large number of points on the several outcrops determined. The Pawhuska limestone, being easily recognized, was selected as the key rock, as the outcrop appeared over a large part of the field. The elevations determined were calculated in terms of this limestone, and the structural contours drawn upon it. After the field work had been completed a map was prepared for publication showing the contour lines as obtained from the upper Pawhuska limestone. The principal axes of the anticlines and synclines, and the location of wells were also shown upon the map. This map was published several months in advance of the complete publication. A few weeks after the map appeared it was found necessary to still further delay the printing of the full report, and a lengthy press notice was then published in the leading papers of the State, and several thousand copies printed for special use of the Geological Survey. This press bulletin stated the nature of the work which had been done, and gave the location and extent of the structural features which had been worked out by the men in the field. Through the distribution of this map and press notice much interest was taken in certain extensions and in drilling to deeper sands as indicated. It is readily shown that the advance publications have given considerable influence to the activity in the Cushing field.

ORIGIN AND ACCUMULATON OF OIL AND GAS

THEORIES OF ORIGIN.

GENERAL STATEMENT.

As the investigation resultant from the wonderful devel-
opment and economic importance of the petroleum and natu-
ral gas progresses, new data are being added which will
sooner or later determine as far as is possible the nature and
method of origin of these hydrocarbons. Although it is im-
possible in a brief work of this kind to give all of the theories
extant, it is considered important to give a summary of those
most widely accepted.

Humboldt, in 1804, held that oil was distilled by volcanic
action from the rocks at great depth. In 1834, Reichenbach
declared that the action of heat upon the turpentine of pine
trees produced oil. About the year 1886, Berthelot advanced
a theory of origin based upon chemical reaction.

Theories then have taken two distinct angles. One group
of men, composed chiefly of chemists, hold to what is known
as the inorganic theory. Geologists and those familiar with
field conditions hold that organisms are the source of petrol-
eum and natural gas.

INORGANIC THEORIES.

A general statement of the fundamental tenets of the inor-
ganic theory is divided into two parts. The first advance of
a real theory was made by Berthelot, who, working from the
assumptions of Daubree that the interior of the earth con-
tains free alkali metals, determined that these, with earthy
carbonates at high temperatures, form Acetylides, which,
in turn, being acted upon by water-vapor, yield hydrocarbons,
closely resembling petroleum. Moissan, with the electric fur-
nace, proved beyond a reasonable doubt that hydrocarbons
resembling petroleum and natural gas can be produced by
the reaction of water on the carbides of both metals and alka-
lies. The best known of the chemical theorists are Berthelot,
Mendeljieff, Moissan, and Sokoloff, a Russian geologist. The
first three named writers contend that oil and gas are formed

deep within the earth. The most accurate methods of esti-
mating the weight of the earth prove that the specific gravity
at the center is more than 4 times as great as that at the sur-
face. As a natural inference, it follows that the heavier met-
als must be more abundant there. These facts, with the added
inference given by the Laplacian hypothesis, have led to the
formation of the chemical theories.

Sokoloff, in 1890, argued that all hydrocarbons are cosmic.
In other words, that as the earth was being formed, they were
inclosed in the original magma or molten mass, and have since
been transferred to the outer crust. Coste, while advancing
the volcanic theory, gives expression to the same general idea.
He assumes that all natural gas and petroleum, not including
marsh gas, are formed by entrapping emanations from a deep-
seated molten mass. This magma, with its inherent gases,
continually exerts enormous pressure on the overlying strata.
To these included gases, he attributes the power to work their
way upward with a force sufficiently strong to dome up large
areas. They are also mentioned as the cause of volcanic dis-
turbances.

The arguments for the inorganic theory may be summa-
rized briefly as follows:

1. Rocks of practically all geologic ages contain oil.

2. Organic life is often wanting or insignificant in petro-
liferous horizons.

3. All efforts to produce oil like in all ways unto natural
petroleum by artificial distillation have failed.

4. The hydrocarbons have been formed in and near igne-
ous rocks in some cases.

Objections advanced by those who hold to the organic
theory seem to answer all of the above tenets and to prove
beyond any doubt that oil and gas are not formed along the
lines advanced by the emanation or any similar hypothesis.
They may be summarized as follows:

1. It has been determined that practically every one of
the world's great oil fields are not located near regions of vol-
canic disturbance. Some of the Mexican fields might be cited
as being the exception. The world's greatest fields are far
removed from the seat of greatest disturbance. The opposite
would be expected if the inorganic theory be accepted.

2. Few if any of the old volcanic pipes or crates are re-
positories of hydrocarbons, except in very small quantities.

3. The fumes from volcanoes in nearly every case show
no signs of the presence of hydrocarbons.

4. The decadent stages of volcanic regions are not marked by the formation of oil and gas as would be expected.

5. The occurrence of water at great depth will be the rare exception, rather than the common phenomenon that would be necessary in the formation of most of the great petroleum bodies.

6. Limestones, which, according to the inorganic theory, should be partly or wholly changed to gypsum, are rarely gypsiferous.

7. The occurrence of hydrocarbons in eruptive rocks, on account of the small amount and scarcity, is of scientific importance only.

8. If chemical reactions are truly the mode of formation for oil and gas, it would be natural to expect to find them in larger quantities in rocks of Archean age. From two points in South America comes the report that small deposits have been found in rocks of this age. It seems likely that even if this is true that the deposit may not be primary.

9. If petroleum came from below, then every stratum that offers porous space should receive some deposit. Such is found not to be true.

10. The total absence of carbonic oxide in the gases accompanying petroleum speaks decidedly against the inorganic origin and high initial temperatures.

11. High temperatures which would result from the influx of fresh oil from great depths are not known.

12. Oil fields would never deplete, because of the supply being renewed from beneath.

13. Some of the greatest faults in either Europe or America are destitute of hydrocarbon deposits. In fact, the occurrence of petroliferous deposits along faults, big or little, is the exception. In the Carpathians it is recognized that even though the oil may occur along fissures, the major faults where the largest deposits would be expected, are dry. The chief production is an unfaulted area. In the Appalachians the oil and gas do not occur where the disturbance was greatest, nor is there evidence that petroleum was formerly present but has escaped into the air.

ORGANIC THEORIES.

GENERAL STATEMENT.

As was said, the inorganic theory has been met by so many objections that practically all of the fundamental tenets have been disproved. The organic theory postulates that oil and gas are a result of the distillation of organic matter imbedded

in or near the present bearing horizons. This theory, then, does not have to account for transmission through thousands of feet of sediments. Although men of science are almost unanimous upon the origin being organic, they fail to agree as to kind of organism,—whether plants or animals play the most important part. Cause for dissention has arisen over the transformation of organic tissues to oil. One school declares that the oil is indigenous, that is, now entombed where the primary decomposition took place. The other group of theorists believe that the hydrocarbons, oil and gas, have been distilled off from the organic matter, and that, after distillation, hydrostatic pressure forced it into overlying porous strata. These two schools are not sufficiently separated, since those holding to the former view are not absolute in their ideas, to be worthy of further discussion. It is thought advisable, however, to give a brief summary of development of the two views first mentioned, that petroleum and natural gas are a result of the decomposition of either animal or vegetable matter.

VEGETABLE ORIGIN.

Those who hold to plant origin agree that petroleum may be derived from marine plants, bog plants, and land plants. These include the coal-forming vegetation of both past and present. The idea of L. Lesquerewx, that the Pennsylvania oils had been formed from marine algae, found a wide acceptance and application. Practically all of the earlier theories hold to a unit origin, that is, that one kind of plant was the true source.

Orton believed that the oil, occurring in shale and sandstone, was from vegetable organisms, and that in limestone, from animal remains. Peckham suggested that when oil contained paraffin it is of vegetable origin.

Recent investigation by Craig* of the Trinidad deposits has added much valuable data to the vegetable-origin theory. The following quotation from his work gives a fair idea as to his reasoning for the vegetable origin of oil:

> It is only from fatty parts of animal organisms that the petroleum could be formed, so it is only a portion, and often a very small portion of the soft parts that can be utilized. The elimination of nitrogenous compounds, and at the same time the preservation of the fats must be presupposed, and such an assumption may be said to beg the whole question. The theory is that the animal matter decomposes in such a manner that, before it is entombed, practically all nitrogenous matter has been removed (since only the merest traces of nitrogen compounds have ever

*Craig, E. H. Cunningham, Oil Finding, p. 9.

been found in natural petroleum), and the preservation action of salt water has even been adduced to make such a retarded decomposition appear less improbable. But can we find any evidence of such a selective decomposition in nature? Are fats preserved, even in sea water, while flesh is decomposed and dissipated as gases? Let any one who has studied the formation or guano, or who has been unfortunate enough to have the processes in the decomposition of a dead whale forced upon his senses, answer.

Another difficulty which the animal-origin theorists have to encounter is the disposal of the phosphorous contents of the animal matter. This, of course, on the decomposition of the animal organisms, naturally takes the form of phosphates. Now, of all salts formed in nature, the phosphates, whether of iron or calcium, or double and compound phosphates, are among the most difficult to dissolve and remove in solution. Hence, phosphatic beds or lines of phosphatic nodules may be abundant. The phosphates, indeed, remain chiefly as, or in, the hard parts of the organisms when the softer parts have been decomposed or absorbed into the economy of other living organisms. The proportion of derived phosphates to animal fats is very high in nearly all marine and fresh-water organisms. If, then, we are to contend that the petroleum of our great oil fields is derived from animal matter, vast stores of phosphate must be present somewhere in the vicinity of the place where the oil has been formed. But we know of no great phosphatic deposits associated with oil-rocks or within the confines of oil fields.

ANIMAL ORIGIN.

Redwood* gives the following summary of Hoefer's ideas on animal origin:

1. Oil is formed in strata containing animal, but little or no plant remains. This is the case in the Carpathians and in the limestone examined in Canada and the United States by Sterry Hurst.

2. The shales from which oil and paraffin were obtained in the Liassic oil shales of Swabia and of Steierdorf in the Banat, contain animal, but no vegetable remains. Other shales, as, for instance, the copper shales of Mansfield, where the bitumen amounts to 22 per cent, are rich in animal remains, and practically free from vegetable remains.

3. Rocks which are rich in vegetable remains are generally not bituminous.

4. Substances resembling petroleum are produced by the decomposition of animal remains.

5. Praas observed exudations of petroleum from a coral reef on the shores of the Red Sea, where it could only be of animal origin.

Hoefer concludes that oil and gas are not only of animal origin, but that they have been formed in all rocks containing animal remains, without the presence of excessive heat. He

*Redwood, Sir Boverton, A. Treatise on Petroleum, Vol. I, 1913, p. 279.

considers oil a primary and gas a secondary product. Orton expresses a little different opinion when he concludes that the oil and gas which are of both animal and vegetable origin are no longer being formed within the rock.

Kraemer and Boeltcher have added much valuable data to Peckham's view that oils with asphaltic base are of animal origin, while those with paraffin base are derived from vegetables. These views, under the present status of knowledge, should be given full consideration.

A survey of Oklahoma's fields seems to point to the fact that both animal and vegetable matter have played parts in the formation of our petroleum and natural gas. It seems evident, however, that the larger part of these hydrocarbons must have been derived from the carbonaceous shales, and so is of plant origin. This dual theory, first advocated by Engler-Hoefer, probably has the largest following of any theory so far advanced. Future investigation will undoubtedly show the relative merits of animal and vegetable matter in the origin of both oil and gas. It seems probable that bacterial action, slow distillation at low temperatures, hydrostatic pressure, and gravitation have all combined to bring about the transformation of organic matter to oil and gas, and their transportation into pools of commercial value.

MODE OF ACCUMULATION.

GENERAL STATEMENT.

A careful study of the various productive fields has led to a fuller understanding of the occurrence of oil and gas. Whereas, it was first thought (when the anticlinal theory was first promulgated) that all oil and gas lay in pools along the crests of anticlines, it is now known that at least seven different modes of occurrence have been definitely identified. These are varieties of structure. F. G. Clapp* has proposed the following classification of oil and gas structure. It is considered advisable here to enumerate the fields mentioned under each separate head.

I. Where anticlinal and synclinal structure exists.
- (a) Strong anticlines standing alone.
  Ureka-Volcano Burning Springs anticline of West Virginia; Baku, Russia.
- (b) Well-defined anticlines and synclines alternating.
  Appalachian field of Pennsylvania; West Virginia; eastern Kentucky; southern Ohio and Indiana; Oklahoma; Caddo,

*Economic Geology, Vol. V, No. 6, September, 1910, pp. 503-521.

Louisiana; north Texas; Colorado; Wyoming; and Montana.
(c) Monoclinal slopes, with change in dip.
Most of the pools of southeastern Ohio; part of the Florence, Colorado, field.
(d) Terrace structure.
Macksburg field of southern Ohio—common in this general region.
(e) Broad geanticlinal folds.
Cincinnati anticline.
(f) Overturned folds.
A few in California.

II. Domes or quaquaversal structures.
Fields of Louisiana and Texas.

III. Sealed faults.
Some in Los Angeles field; some in the Lompoe, California, field; and some in British Columbia, and at Gaspi, Quebec.

IV. Oil and gas sealed in by asphaltic deposits.
Pitch lake of Trinidad.

V.. Contact of sedimentary and crystalline rocks.
Chiefly in Quebec and northern Ontario; possibly northern New York.

VI. Joint cracks.
Occurs some in Florence field of Colorado.

VII. Surrounding volcanic vents (or igneous intrusion).
Certain fields in Mexico.

The above classification does not attempt to separate oil and gas structure and includes only a small number of fields. Other subdivisions may be necessary to cover new occurrences of oil or gas.

In addition to the seven kinds of structure already mentioned, the idea that petroleum and natural gas may occur in the upper part of lenses, that is, in porous beds which thin in all directions from a certain point, has been advanced. A great many geologists consider that a part of the "spottedness" of the Okmulgee-Glenn Pool region may be accounted for in this way.

ANTICLINAL THEORY.

Soon after oil became a factor in the commercial world, scientists noticed that oil and gas often held the same relative position with respect to structure. In 1859, T. Sterry Hunt published this opinion in the Canadian Naturalist. In 1861, E. S. Andrews of Marietta, Ohio, working independently, arrived at the same conclusion. About the same time, Hans Hoefer of Austria published the same idea in his Petroleum Industry of North America.

The anticlinal theory, briefly stated, is that oil and gas

were originally widely disseminated throughout the formations in which they now occur, or in nearby formations, and that they have collected at structural dips because of the difference in specific gravity between oil and gas and water. In other words, if these hydrocarbons are in a porous medium when it is tilted because of earth stresses, they will arrange themselves with the gas on top and the water at the bottom, because oil floats on water and gas is lighter than either water or oil. Following this generalization a step farther, and assuming the presence of oil, we find several prerequisites for the fomation of economic quantities of petroleum and natural gas. They are:

1. Water in the formation.
2. A porous rock, usually sandstone or limestone, for a reservoir.
3. An impervious cap rock, usually a fine shale, embricating sandstone, or closely knit limestone.
4. An anticlinal or up fold.

The anticlinal theory has been found to be fairly successful in a large number of fields. It has shown defects through its inability to explain certain details which are thought to be more or less essential. Suggestions and modifications to obviate these defects have taken two trends: (1) Those that hold that the difference in gravity of oil, gas, and salt water cause accumulation. (2) And those that contend that other factors have played an important part in accumulation.

Griswold* has given a good summary of the earlier views and also an admirable statement of the difference-in-gravity theory. He says:

> Whether the petroleum comes from within or below the shales, it must pass through them, and to do this it must pass through the very small pores existing in those relatively impervious beds. The nature and cause of this movement are not understood. Capillary action and great rock pressure may be suggested as causes which aid in forcing the petroleum out of the shales, but there are not sufficient data on this subject to justify any scientific explanation. It matters little what is the ultimate source of the oil; the important facts are its occurrence now in the porous sandstones, its circulation through the rocks, and the conditions leading to its accumulation in commercial deposits.
>
> *Movements in Porous Rocks.*—The porous rocks into which the oil and gas enter may be dry, or they may be completely saturated with water. In most cases it is probable that a combination of these two conditions exists—that the porous rocks are completely saturated with water up to a certain level, but above that point they are dry. The movement of the

*Griswold, W. T., Bull. U. S. Geol. Survey, No. 318, p. 13.

hydrocarbons through the rocks will not be the same in the two cases, and therefore each condition must be considered separately.

If small quantities of oil and gas enter a dry, porous rock at different points, the oil will flow down as long as gravity is sufficient to overcome the friction and the capillary attraction. The gas will diffuse with the air or water vapor contained in the pores of the rock.

Oil and gas entering a porous rock that is completely saturated with water will be forced up to the top of the porous stratum by the difference in the specific gravity of the hydrocarbons and the water. Here the oil and gas will remain if the porous stratum be perfectly level, but if it has a dip sufficient to overcome the friction, the particles of oil and gas will gradually move up this slope, the gas with its lower specific gravity occupying the higher places.

In case the porous rocks are partly saturated, a combination of these two actions will take place. The oil entering above the line of complete saturation will flow down to that line and the oil entering below will be forced up the top of the completely saturated portion.

Objections to this view are too numerous to be recited here.

M. J. Munn* advances a somewhat different idea, under the second head. The fundamental principle of the hydraulic theory is that moving water, caused either by hydraulic or capillary pressure, has been the direct agent whereby oil and gas have been collected into pools. As a corollary, it may be added that these pools are held intact by water under hydraulic and capillary pressure. Without going into detail, the following reasons may be given why the hydraulic theory is superior to the difference-in-gravity idea. In the first place, it provides for the transference of the oil into the pay streak or porous medium; in the second place, it provides means preventing diffusion by sealing up the pore space by water under either hydraulic or capillary pressure; in the third place, the soucre of pressure is ascribed to the expansive force of gas which was either collected with the oil or subsequent to its formation in pools, and, in part, to capillary and hydraulic pressure; and last, it provides a more adequate explanation of the structural position of pools of petroleum and natural gas. It seems probably that investigation along the lines here laid down, may ultimately lead to a better knowledge of conditions of accumulation, as they exist in nature.

The writer is of the opinion that hydraulic or "rock pressure," as it is commonly called, is the prime factor in forcing oil out at the surface. It is possible, however, that the continued flow is due in part to the expansive force of volatilizing hydrocarbons under releasing pressure. How great a part

*Economic Geology, Vol. IV, No. 6, September, 1909, pp. 518-529.

the latter plays will depend upon the character of the oil, hydrostatic pressure, and possibly upon the location of the well with respect to the main body of oil. Every pool will undoubtedly show a different relationship between the factors which cause this pressure.

George F. Becker, writing in Bulletin No. 401 of the Unted States Geological Survey, advances the idea that oil fields may be located by the use of the compass, since the needle is often more disturbed in oil fields than elsewhere. He believes that petroleum and natural gas are formed from carbides, and are due to magnetic metals near the oil pools. Following the line of experimentation laid down, many are attempting to use the compass for mapping oil fields.

OIL AND GAS INDUSTRY.

HISTORY OF DEVELOPMENT.

MID-CONTINENT FIELD.

The Mid-Continent oil and gas field is composed of the petroleum producing regions of Kansas, Oklahoma, and northern Texas.

Prospecting for oil and gas began near Panola, Kans., as early as 1860, and by 1873 considerable gas had been found near Iola, and Panola was heated and lighted by natural gas in 1882. Real development began in 1890 and production has gradually increased until the Mid-Continent field ranks first among the producing regions of the United States, the total amounting to practically one-fourth of the total production of the country. In 1912 the production of the field amounted to 65,400,000 barrels, and in 1913 to over 66,500,000 barrels. The total production for 1914 was almost 103,000,000 barrels.

Petroleum was first discovered in Texas about 1860, near Nacogdoches, at a depth of 100 feet. The Sour Lake find was made in 1893. Many of the first wells had a depth of about 280 feet. The Corsicana field was developed in 1894, and 546,000 barrels of oil were produced in 1898, but the real importance of Texas in oil production did not begin until 1901, with the bringing in of the Lucas well at Beaumont (Spindletop). The production placed Texas second in rank in 1905, but decline soon followed, until the opening of the Electra, Petrolia (Henrietta), and Burkburnett fields. Other small fields recently opened are those of Iowa Park, Powell, and the fields of Marion County. The Electra field was opened in 1899, when showings of oil were found at depths of 200 and 500 feet. Six years later a well drilled 1850 feet gave only showings of oil. In the spring of 1910 the Producers Oil Company drilled six other wells within a radius of one-half mile of the initial well and little is known of these undertakings except that enough oil was found to pay for pumping. By September, 1911, there were 18 producing wells. Drilling was begun on the well in the Burkburnett region about the first of 1912, and completed the first of July. It gave an estimated production of 100 to 200 barrels. The well was owned by the Corsicana Petroleum Company, and the leases on the land ranged from $5 to $50 per acre, with some valuations as high as $10,000 for 80 acres. The Iowa Park field was opened in 1913. The first well came in as a producer of about 30 barrels at a depth of 475 feet. In a short time the production was down to 5 barrels and the well was drilled deeper.

The Saratoga pool was opened in 1901 with small production, but in 1903 produced 150,000 barrels. The Matagorda field has been principally developed since 1903. The Batson Prairie pool was opened in 1904, and in one year produced 10,000,000 barrels. The fields of Humble and Dayton and some other small fields were opened between the years 1903 and 1905.

Recently several new fields have been opened up in Texas. The most important ones are the Strawn and Thrall fields. The former, located in Palo Pinto County, was opened up in January, 1915, when a well drilled to a sand at a depth of 840 feet produced about 40 barrels daily. The Thrall field, located in Williamson County, was opened up in February, 1915, and later 15 wells, having a total daily production of 6,000 barrels and ranging from 200 to 2,000 barrels on intial flow, were completed. The oil of the Thrall field, as found at present at a depth of about 820 feet, appears to be associated with marl and clay in the Taylor formation of Upper Cretaceous age.

The Texas fields, the production of which is included in the Mid-Continent field, comprises those in northern Texas, Corsicana, Henrietta, Powell, Electra, South Bosque, those in Marion County, and a few minor pools. The present production of the states in the Mid-Continent field shows for northern Texas 5,275,524 barrels in 1912, the total production for the State being 11,735,057 barrels. The first reported production from the field was 1400 barrels in 1896. Kansas produced 500 barrels in 1889, and reached its maximum production in 1905-1906, when over 6,000,000 barrels were produced. Oklahoma is credited with 30 barrels of oil in 1891 and did not reach the 1000 barrel mark until about 1900. In 1904 the production passed the 1,000,000 barrel mark, while for 1912

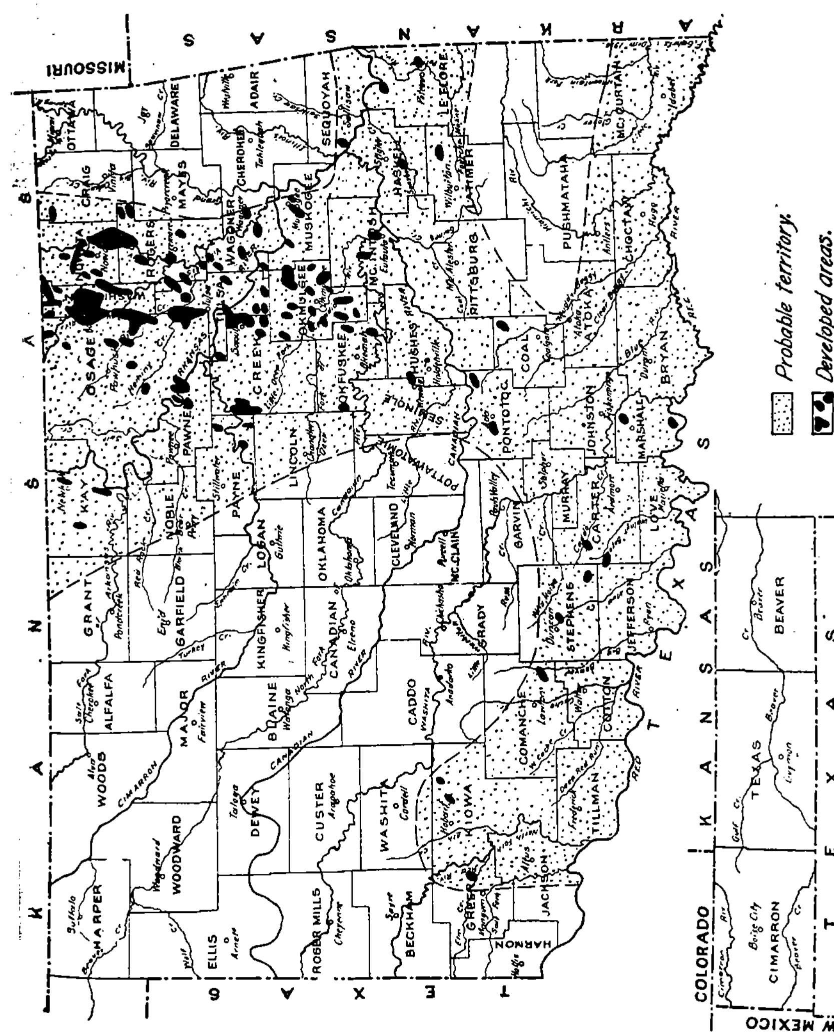


Figure 1.—Map of Oklahoma showing probable oil and gas territory and developed areas

the production was 51,427,071 barrels, and in 1913, 55,018,541 barrels. The total production for 1914 exceeded 100,000,000 barrels. These high productions placed Oklahoma second in rank in production and first in value of oil.

DEVELOPMENT IN OKLAHOMA.

The discovery of oil in Kansas created excitement on the Indian Territory side, and in 1884 the Choctaw Oil and Refining Company was formed. One well was begun about 20 miles north of Tahlequah and another on Clear Boggy Creek, about 14 miles west of Atoka. Neither produced more than showings of either oil or gas. There was no further activity until 1894, when the Cudahy Oil Company drilled two wells at Muskogee, each of which showed good prospects, but no active development took place in this field until 1904, when it became possible to secure proper titles to land and to have allottees' leases approved by the Department of the Interior.

The Red Fork-Tulsa district was opened by the drilling of a producing well in 1901. Practically all the activity in the early part of 1904 was confined to the Osage Nation. The Cleveland field was opened in September, 1904, and some development occurred in the vicinity of Muskogee, Chelsea, Red Fork, Bartlesville, Alluwe, Lenapah, and Dewey. In 1904 there was considerable active development and extension of known fields.

The Wheeler field, northwest of Ardmore, was discovered in 1905. In 1906, in addition to active development, the famous Glenn pool was opened. This pool reached its maximum production in October, 1907, when 2,441,662 barrels were produced. The field about Dewey was opened in 1906, as was also the Morris pool. By the close of the year the production for the State was about 7,000,000 barrels. In 1908 a new pool of excellent high-grade oil was found at Muskogee. The principal features of this year were high production wells and the finding of deeper sands in producing fields.

The production and activity of 1910 considerably surpassed that of 1909. The chief centers of new activity were Henrietta and Osage. Gas was discovered at Poteau. In 1911 further development was shown in the fields and a special increase in the Hogshooter region.

Early in 1912 the price of oil advanced from 50 cents to 83 cents per barrel. Drilling was greatly stimulated, and as a result old fields were extended and much "wildcatting" was done, which, in some cases, proved successful. The most striking feature of the new development was the discovery of the Cushing field. Other important developments were the dis-

covery of deeper sands in the Cleveland field; the eastward extension of the Glenn pool; the opening of the Adair pool, west of Nowata; renewed activities in the Ponca City field; and in Okmulgee County. A good gas well was brought in near Duncan, and some development was made at Loco.

In 1913 the price of oil advanced to $1.05 per barrel, with a premium of 20 to 50 cents per barrel additional for certain light grade oils. During this year the principal new development was the opening of the Healdton field. The first well was drilled in August, and by the close of the first year more than 300 wells had been drilled, with 270 of these as producers. Several shallow wells were drilled in the vicinity of Lawton and numerous "wildcatting" adventures were made throughout central and southwestern Oklahoma. Activity was renewed in the Madill region. Several new fields were added to the list early in the year by the bringing in of good producers in localities outside of the proved fields. The conditions of the oil market have prevented further drilling in these localities. During 1913 and the early part of 1914 drilling operations reached the highest point of activity. When the drop in the price came in the early part of 1914 the State was producing over 250,000 barrels of oil daily. The first half of the year showed a total production of 45,600,650 barrels. In the latter half of the year development was as much curtailed as possible, but even then the production exceeded that of the first six months of the year.

During 1915 the principal features of development were extensions to the Cushing and Healdton fields, and drilling of many "wild cat" wells. In the Cushing field the drilling campaign which began in the early part of 1914, continued, and as a result a prolific production was obtained in the Bartlesville sand. In the Healdton field there has been renewed activity the daily production increasing to almost 90,000 barrels (Jan 1, 1915). Some of the most important "wild cat" tests drilled were those in the vicinity of Holdenville and Graham.

LIST OF OIL AND GAS FIELDS IN OKLAHOMA.

Ada
Adair
Allen
Amabel
Atoka
Avant
Back Creek
Bald Hill
Bartlett
Beggs S.
Beggs W.
Beland
Bigheart
Bird Creek
Bixby
Blackwell
Booch Sand Area
Boston
Boynton
Broken Arrow
Bristow
California Creek
Canary
Caney
Catoosa
Checotah
Chelsea
Chicken Farm
Claremore
Claremore E.
Cleveland
Coal County
Coody's Bluff-
Alluwe
Copan
Collinsville
Coweta
Cruce
Cushing
Dawson
Delaware-Childers
Delaware-
Extension
Depew
Dewey-
Bartlesville
Duncan
Eufaula
Eram
Flat Rock
Francis
Fox
French Pool
Graham
Granite City
Glenoak
Gotebo
Hamilton Switch
Hanna
Harry
Haskell
Healdton
Hichita
Hickory Creek
Hobart
Hoffman
Hogshooter
Holdenville
Honey
Homer
Hominy
Inola
Kellyville
Kiefer
Lark
Lauderdale
(Ranch Creek)
Lawton
Lenepah
Leonard
Lightning Creek
Loco
Lost City
Madill
Mannford
Meramec
Mansville
Morris N.
Morris S.
Mounds
Morse
Muskogee
McAlester
Natura
Nelagony
Neodesha
Newkirk
Nowata-Claggett
Ochelata-Ramona
Oil City
(Wheeler)
Okmulgee S.
Okmulgee NW.
Oolagah
Owasso
Paden
Pawhuska
Pine
Ponca City
Porter
Poteau
Preston
Prue
Ralston
Ramona
Ranch Creek
Red Oak
Ringling
Salt Creek
Schulter-
Henryetta
Spiro
Stidham
Stigler
Taneha-Jenks-
Red Fork-Glenn
Pool
Tiger Flats
Turley
Vera
Vian
Wagoner
Wainwright
Wann
Weimer
Weleetka
Wewoka
Wicey
Woodville
Wynona
Yale
Yarhola

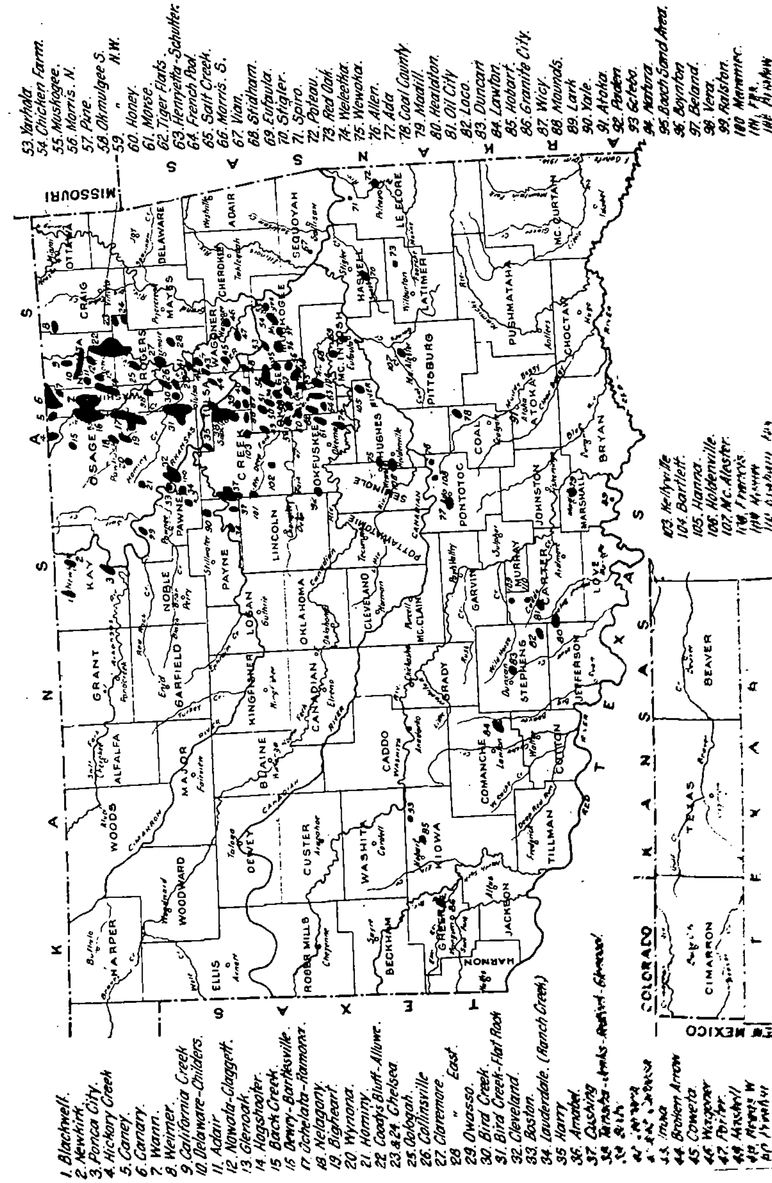


Figure 2. Map of Oklahoma showing location and names of oil and gas areas.

The list of oil and gas fields given in the table (p. 30) may not be complete in detail. Some of the names are combinations of several fields, while others may include one or more small pools. Some of the latest additions to the list are new localities where not more than one or two wells have been drilled, but conditions indicate that they may be classed among the productive areas.

LEASING OIL AND GAS LANDS.

There are many forms of leases in common use, covering the leasing of oil and gas lands in Oklahoma. Only a short discussion of the general type will be considered in this report. The usual form of oil and gas leases grants the lessee an irrevocable and exclusive right to seek for oil and gas, and for this right it is the common practice for the lessee to pay the lessor the sum of $1.00 to make the lease legally binding. However, in some cases other considerations are given.

An important consideration in the leasing of oil and gas lands is the bonus, or money paid in addition to a stated compensation. The amount of bonus varies greatly, depending upon the probability of the lease being productive and the amount of royalty to be paid. In purely "wildcat" regions a bonus is seldom considered, but in a district which is located near good production, or from other physical conditions is likely to be productive, a bonus may be given. The amount varies in each case as the parties concerned agree upon. Usually, when the customary royalty of one-eighth or one-sixth is given on relatively good leases, the bonus is large. For instance, some of the leases made under the regulations of July 3, 1912, in Osage County, where the royalty was fixed at one-sixth, were made with a bonus of as high as $150 per acre. On the other hand, there are instances reported in the Cushing field where a royalty of 50 per cent was given without any bonus in the consideration.

Another thing considered in oil and gas leases under certain conditions is the rental. Whenever the lessee reserves the

right to drill or not to drill on a lease, he may arrange to pay so much rent per year for the lease, and thereby hold it till it expires. This is not a very popular form of leasing and is now less practiced than in former years, as the owner of the land does not wish to bind himself to a rental lease, especially when there is a chance to lease his land to a company that will drill immediately. The common rental for commercial leases is $1.00 per acre per year. In some cases the leases have been so drawn that by the payment of 25 cents per acre annually after the expiration of the first period of time the lessee may continue the lease for 5 or 10 years, or indefinitely.

The most important feature in oil and gas leases is the royalty, which varies from one-sixteenth to one-half, the customary amount being one-eighth for oil and $100 to $150 per year for each gas well. In purely "wildcat" territory a maximum of one-fouth is sometimes paid. Sometimes in consigning a lease to another company an additional royalty is given to the holding company. A good example of this practice may be cited in the "blanket lease" in Osage County. Here one-eighth royalty is paid to the Indians. But in sub-letting a part of this area was let for one-sixth, thereby giving the original lessee one-twenty-fourth royalty. In some other cases the compensation for the middle man is limited to a specific sum to be taken from the oil and gas produced. The royalty on gas wells is so variable that there seems to be no customary amount. Often an amount agreed upon is paid yearly for every gas well used. This system of royalty payment is not so satisfactory as an actual percentage royalty based on some method of gauging the amount of natural gas used or sold. Under the "blanket lease" in Osage County the company paid $100 for each gas well that was used, but under the regulations of July 3, 1912, they are required to give an actual one-sixth royalty of the natural gas.

The customary length of an oil and gas lease ranges from 1 to 5 years and "as long thereafter as oil and gas is produced in commercial quantities." This statement is sometimes conditioned by the clause that such a time shall not exceed 25 years.

In many leases a time is set for the beginning and completion of drilling a well, a clause being inserted to the effect that drilling shall be begun within 90 days and completed to a specified depth, provided that oil or gas is not found in paying quantities above this depth, within a year from the date of lease. It is not uncommon for a clause to be inserted in the lease requiring some sort of systematic continuation of drilling after the first well has been drilled. Reasonable damages on crops incurred by the lessee are usually paid to the lessor.

In some leases a bond is required of the lessee as a guarantee to the lessor for fulfilling the terms of the lease in payment of royalties, rentals, and damages.

It is advisable for the lessor to have a clause inserted in the lease to the effect that said lease shall be put in escrow till oil or gas be discovered. The advantage of this is that it saves the trouble and expense of having the lease cancelled should the lessee fail to develop the property, and the lessor need not fear to lease his land to another company at a later date.

Sometimes leases are drawn so that the lessor is misled by the wording and consequently signs a contract which he would not otherwise have signed. For instance, one case is reported where a lease was made for the rental of 25 cents per acre for the first year and 25 cents a year thereafter. The lessor believed that he would receive 25 cents per acre yearly. The lessor should know a good contract and should also know enough about leasing so that he may have inserted in the lease just exactly what he wants and yet be fair to the lessee.

OIL AND GAS SANDS.

One of the necessary conditions for the occurrence of oil or gas in a locality is the presence of a stratum of porous rock which forms a reservoir for the material.

In order to properly retain the accumulated petroleum or natural gas, the porous rock must be entirely covered with an impervious stratum, one through which neither oil nor its volatile gases will pass even under the enormous pressure to which it is subjected. Such impervious cover usually consists of a fine-grained shale. It often happens that a considerable part of the shale may show the presence of oil, and by distillation processes oil may be obtained.

An "oil sand" may be defined as a porous rock which contains oil. The same sand in all places does not contain oil and is therefore not an oil sand. It is often stated in reporting the progress of "wild cat" wells that great thicknesses of oil sands were encountered but were "dry." Such cannot be considered oil sands. All that the statement means is, that a formation was encountered as consisted of the proper sized grains and a sufficient amount of pore space for the rock to serve the purpose of an oil reservoir had the oil been present.

It often happens that one well will prove a "gusher" while another nearby, at the same depth and in the same sand, comes in dry. This may be attributed to several causes, the

chief of which is that the drill has pierced a close-grained or non-porous part of the reservoir rock.

The geology which is of particular interest to the practical oil man is the extent of the formations which are, or may be productive of oil and gas. The one series of rocks in Oklahoma of special importance from this standpoint are the Pennsylvanian rocks. However, in some areas the lower members of the Permian have proved productive, as in the Wheeler, Healdton, and other pools of the southwestern part of the State. The lower part of the Trinity sand, the basal member of the Cretaceous series, has proved productive at a few localities, the chief location being that of the Madill pool. Sufficient correlations have not been made in northeastern Oklahoma to determine whether any of the wells of good production are in, or below the Mississippian rocks. However, the logs of some of the wells in the vicinity of Muskogee and Wagoner seem to indicate that some of the production occurs below the top of the Mississippian rocks.

The "Mississippi lime" of the drillers may be either the Pitkin limestone, limestone in the Fayetteville shales, the Mayes limestone, or the Boone chert. Drilling is usually discontinued when the driller is satisfied that these horizons have been reached. As before stated, oil and gas are not definitely known to occur in, or below these horizons, and in nearly every case where they have been penetrated strong flows of salt water have been encountered. It is probably true that drilling is often discontinued when some of the limestones in the Lower Pennsylvanian are encountered and mistaken for the Mississippi lime. It is thought by some that oil and gas production might be found in some of the sands of the older systems lower than the Mississippian, and the Bergen sandstone has been suggested as a probable source of oil and gas. However, investigations that have been made show that this sandstone is barren of organic matter and is not likely to be productive.

The horizontal extent of the various productive sands is not known. Even within the drilled areas it is difficult to correlate the sands because of inaccurate records. Even the top of the Mississippian is not positively recognized in drilling records, and the top of the Pitkin, or even higher limestones, are often mistaken for the "main Mississippi lime."

The Bartlesville sand is the most widely known oil sand in the State, and more oil has been produced from this sand than from any other horizon in Oklahoma. This sand occurs near the base of the Cherokee formation. The heavy sandstone outcropping east of Welch, at Blue Jacket, and northwest of Vinita, is probably the Bartlesville. It has been recognized to the westward through Osage County and as far as the drilled areas in Kay County, and to the southwest in the Cushing field, where it has proved the sand of big production. In the latter field it occurs at depths from 2,400 to 2,800 feet. This formation is not an oil sand in all of its areal extent, although the term is very properly applied to the strata occurring at this horizon. The sands found in the wells drilled at Paden and Holdenville have been termed the Bartlesville sand. However, no definite correlation has been made to show the southwestern extension. The base of the Cherokee formation also includes the Bixler (Squirrel), Markham, Barnett, and other productive sands which lie above the Bartlesville.

The Wheeler "sand" of the Cushing field is a good example of formations other than true sands forming oil reservoirs. This sand, which changes in character from an impure limestone to a sandy lime, is probably the equivalent of the Fort Smith or Oswego lime, which is one of the most constant formations underlying practically the entire oil and gas area of northeastern Oklahoma.

The correlation table included in this report gives the names of the known producing sands, the depth, thickness, and importance in the various fields.

INITIAL PRODUCTION AND DECLINE OF OIL WELLS.

Considerable information has been collected by the Geological Survey in regard to the initial production and the rate of decline in oil wells. However, the data are not in shape to use for this publication. It is impossible to determine with any degree of accuracy the life of any well. Some wells which were among the first drilled in Oklahoma, although never large producers, are still considered paying, while others which came in as gushers at a much later date have dwindled to very low production, or have been abandoned altogether. What is to be considered a paying well depends on price, accessibility, and character of the oil.

Some figures relating to the production and decline of wells in the Cushing field during 1913 and 1914, will give some idea as to the changes taking place. In February, 1913, 161 wells in the Layton and Wheeler sands gave an average daily production of 23,079 barrels. Notwithstanding the fact that new wells were being completed daily, the production gradually declined. At the close of May, 1913, 301 wells were giving an average daily production of 18,574 barrels. These

figures show that during this period 140 main wells with an average initial production of about 97 barrels were completed and still the daily production declined 4,505 barrels which shows that the original 161 wells had decreased approximately one-half in 3 months.

The discovery of the Bartlesville sand in the latter part of 1913 caused a very great increase in production for the field, but the higher sands were scarcely considered from that date until the present time. It is also shown by the investigation of initial productions that as a rule the Layton wells had a larger initial production than the Wheeler wells, but on the other hand, the Layton wells declined much more rapidly than the latter.

The behavior of 5 wells in the Bartlesville sand shows the general condition of decline.

No. 1, initial production 2,200 barrels, completed May 12, 1914.
No. 2, initial production 1,104 barrels, completed June 26, 1914.
No. 3, initial production 2,640 barrels, completed July 18, 1914.
No. 4, initial production 432 barrels, completed Sept. 15. 1914.
No. 5, initial production 1,100 barrels, completed Sept. 28, 1914.

The total initial production of these 5 Bartlesville wells was 7,476 barrels. On October 1, 1914, 3 days after the last well was drilled in with an initial production of 1,100 barrels, the 5 wells were making a total production of only 2,000 barrels per day.

Many wells have come in with an initial production of from 1,000 to 5,000 barrels, and a few have been reported to have an initial flow of 10,000 to 12,000 barrels per day. The daily average for the Cushing field has been estimated at about 140,000 barrels for 1914 and 1915, or a monthly production of from 2,500,000 to 5,000,000 barrels. The maximum daily production for the field was 285,000 barrels in the early part of June, 1913. The rate of decline in the gushers is very marked and in order to keep up the average, it is necessary for the Cushing field to bring in thousands of barrels every day to keep up the average. The average daily decline at the present time is about 9,000 barrels per week. However, during the week ending December 2nd, there was an increase of about 1,000 barrels daily.

LOSSES OF OIL AND GAS BY FIRE.

The causes of fires in oil fields may be classified under two divisions: First, accidents which could have been prevented if proper care had been taken; second, fires caused by lightning. Most oil and gas well fires belong in the first class, and most oil tank fires belong in the second class.

In this report only two phases of the subject will be discussed; namely, methods used to lessen the chance of fires caused by lightning, and some of the common ways of extinguishing oil field fires.

There is a general belief among oil men that certain localities are more subject to the effect of lightning than others. However, there has never been enough data collected to prove this. In fact, what data there are seem to disprove it. It has been suggested that tanks or oil wells located on a hill are more likely to be struck by lightning than those located in a valley, and the fact that an electrically charged body tends to discharge at points more readily than at any other place is offered as an explanation. Considering the hills as points on the earth's surface it seems reasonable that the discharge between a cloud and the earth would tend to take place on a hill. It is also claimed that tanks located on the prairie away from the oil fields is the best location. Actual observation tends to prove this, but just why this is so is hard to explain from what is known of lightning at present. Since the majority of lightning fires are caused by the gases being ignited which hover around oil fields, the fact that tanks are located on the prairie where little gas can hover around the tanks might explain in part the reason why lightning does not light oil tanks here.

It has become the common practice in some places to build the oil tank so that an electric spark will not ignite the oil or so that the fire can be extinguished after it has started. For instance, around refineries tanks that contain oil that are easily lighted are often built with an air-tight steel roof with a trap door which immediately falls, thus closing in a great quantity of carbon dioxide which extinguishes the fire. This is a relatively safe way to put out the fire, and the only objection to it is that the air-tight steel roof for the standard 55,000 barrel tank is about $2,500 more expensive than the standard wooden roof. But when one considers the actual amount of waste of a tank with a wooden roof as compared with that of an air-tight steel roof it is economical from this standpoint alone. A 55,000 barrel wooden roof tank of standard construction during six months of the warm season in Texas loses about five barrels a day by evaporation, while the same size steel roof tank loses only about one-half as much. The loss is the best part of the crude gasoline which may be computed at 10 cents per gallon, so it is evident that the steel

roof will soon pay for itself by preventing so much evaporation, besides being good insurance against fires. Recently it has been considered advisable to build tank roofs entirely of steel as it is believed that the danger from lightning would be much less by the elimination of all wood. Better insurance rates can be obtained on all steel tanks. The fire guards built around the tanks should be high enough that the enclosure would hold as much oil as the tank and thus prevent the spread of fires from overflow.

Some small tanks, usually not more than 50 feet in diameter, are constructed so as to permit a small reservoir of water to be stored on top of the tank. These are called "water top" tanks and so far as is known have never been struck by lightning. This is probably due to the fact that these tanks are always well grounded both by the water pipes which supply the water for the reservoir and by the base of the tanks being moist from the overflowing water which runs down the sides of the tank.

Observation and statistics show that buildings, bridges, and ships of all steel construction, or nearly so, are seldom ever damaged by lightning. This is explained in the fact that such constructions being well grounded act as good conductors of lightning. These observations have led to the grounding of steel tanks; those being well grounded are not so likely to be struck by lightning. A good method used to ground a tank is to have one or more of the pipe lines which are connected to it buried about three feet in the ground. A well grounded tank works on the same principle as a lightning rod.

Another safeguard against lightning fires which is practiced in Oklahoma is turning steam into the tank when the thunder-storm is seen to approach. Should the tank be struck the gas is well saturated with steam and is not combustible. This method under the ordinary conditions of a thunder-storm will prevent the tank of oil from being ignited and has the advantage of not being so expensive as some of the above methods.

A combination of several of the above devices for the prevention of oil tanks being ignited by lightning is often used in building permanent storage tanks. First of all the tank is constructed of all steel, the roof being air-tight and the tank being well grounded. It is also connected with steam pipes so that steam may be used in case a storm is seen to approach. Ventilators are also connected to the air-tight roof provided with wire gauze which works on the same principle as the "Davy Lamp" is preventing any fire from reaching the contents of the tank in case any gas is ignited near. This type of construction is practically safe from the effect of lightning.

Recently several attempts have been made to extinguish oil tank fires with certain chemicals and reports sent out say they are successful. For instance, The Erwin Company of Milwaukee, Wisconsin, manufacturers of an automatic chemical extinguisher, made three important tests for the purpose of demonstrating the efficiency of the Erwin extinguisher in connection with oil tank fires. First 60 gallons of gasoline were ignited and the blaze was extinguished in 12 seconds after the chemical was applied. Second, a mixture of 3000 gallons of Mexican crude, some naphtha, and water in a wooden tank with a wooden roof were ignited and 9 seconds after the chemical had been applied the fire was extinguished. In the third test the same amount of crude was used as in the second, but the roof had been removed. The fire was allowed to burn five minutes before the chemical was applied, 30 seconds after this time the fire had been extinguished.

It is now believed that in the majority of the cases lightning does not strike the tank directly but ignites the gas above it which back-fires into the tank. Safety devices to prevent this gas fire from entering the tanks have been made and are successful.

After a tank is on fire the crude will become so heated that it boils over. The length of time after the fire has started till it boils over depends upon the character of the crude. Fresh crude will boil over more quickly than a well settled crude. A low grade crude will boil over more quickly than a high gravity crude. A high gravity crude, for example that of the Cushing field, will throw out 3000 or 4000 barrels of oil in the shape of burning foam upon boiling over, which may be carried as far as 600 feet from the tank. One of the chief factors which causes oil tanks to boil over is the moisture combined with the minute particles of bottom settlings, which are held in suspension in the oil. When the fire has burned a sufficient length of time for the heat to be conducted below the surface by radiation and convection the small globules of water are heated till they reach the critical temperature, whereupon they are suddenly converted into steam with an expansion of 1200 times and a partial explosion.

After a tank has been ignited one of two methods may be used to prevent it from boiling over. The oil may be drained out by shooting holes in the tank with a cannon or the tank may be provided with a large pipe connection near its base, which, in the advent of a fire, is used for drawing off as much

crude as possible, thus saving part of the crude and also preventing the tank from boiling over.

When an oil well is on fire there are various methods of extinguishing it. The method used depends mostly upon the size of the well and its rock-pressure. Steam is generally used. Sometimes mud is pumped into the fire and is effective. Recently a big levee was built around a burning oil well and filled with water, thus drowning it out.

Like oil well fires, burning gas wells can often be extinguished by pumping steam into the flame. But when this fails, two very effective methods, the "Cap" and "Hood" are used. The "Cap" method is very simple—a heavy iron weight in the form of a cap is placed over the well, which closes it in and extinguishes the flames. The "Hood" method, however, is much more complicated and is better adapted for larger gas fires. This method consists in placing a funnel-shaped hood which tapers from about 3.5 feet at the base to 1 foot at the top, where arrangements for carrying off the flow are made with "T" connections. The "Hood" also contains openings in the side for carrying off the surplus gas. This hood is made of five-sixteenth inch steel. It is placed over the burning gas well and cemented at the base so that the gas cannot escape here. Then the top gate is shut quickly, forcing the gas out through the connections in the top and sides of the hood. The chief difficulty of this method is putting the hood over the flames, which is done by using a derrick made of pipe with a crane fastened to it.

The largest oil field fire that ever occurred in Oklahoma started August 27th, 1914, and lasted 6 days. During this period thirteen 55,000 barrel tanks and sixteen smaller tanks, ranging from 250 to 1600 barrels, were burned. It is estimated that the total amount of damages by these fires amounted to $900,000. The fires occurred both in the Cushing field and in the Healdton field. The loss was divided about equally between the two fields, being about $500,000 in Cushing and $400,000 in Healdton.

The losses in the Cushing field were as follows: The Gypsy Oil Co., five 55,000 barrel tanks, all full; six 1600 barrel tanks; one 800 barrel tank; one 500 barrel tank; one 250 barrel tank; five derricks, and several lease houses. The Prairie Oil and Gas Co., two 55,000 barrel tanks, a gas well, and some lease equipment. Cushing Gasoline Co., a ground reservoir containing 10,000 barrels of oil and two 1600 barrel tanks; White and Sinclair, six 1600 barrel tanks and a damaged pipe line.

The losses in the Healdton field were as follows: The Magnolia Pipe Line Co., three 55,000 barrel tanks, two full and one half full; The Corsicana Petroleum Co., one 55,000 barrel tank; full; The Corsicana Petroleum Co., one 55,000 barrel tank; The Twin State Oil Co., one 55,000 barrel tank; The Rex Oil Co., three earthen reservoirs containing 45,000 barrels of oil, four 1600 barrel tanks, and three 2500 barrel tanks; Hernstadt, two earthen reservoirs containing 10,000 barrels of oil, five 1600 barrel tanks, and his entire lease equipment; The Dundee Petroleum Co., an earthen reservoir containing 25,000 barrels of oil, and two 1600 barrel tanks; Crosbie and Davis, two 1600 barrel tanks and one derrick; Gunsberg and Forman, one 1600 barrel tank; The Mutual Benefit Oil Co., two 1600 barrel tanks; Bayou-1911 Oil Co., four 250 barrel tanks; The Crystal Oil Co., one rig and a big "gasser."

During the spring and early summer of 1915 electrical and rain storms were of frequent occurrence. Enormous losses were caused in the oil fields of the State from lightning, and hundreds of thousands of barrels of oil which had been stored in earthen tanks were lost by the breaking of the banks during the heavy rains. The total losses were far greater than recorded for any equal period of time.

A new schedule of insurance rates is being considered by the State Insurance Board. At present 4 per cent straight is being charged on tank storage, but a higher rate will be demanded in heavy gas districts. The usual amount of insurance on a 55,000 barrel tank is about $31,000 and at 4 per cent the premiums charged would be $1,200. In case of loss, the insurance is paid on the basis of the market price of oil at noon on the day before the fire.

TRANSPORTATION OF OIL.

PIPE LINES.

In this publication it is impossible to give much detailed information concerning the transportation of petroleum through the pipe lines of the State. Besides the four or five big pipe line systems, there are over 35 local companies operating lines in the State. Some are operated by producers, and others by individuals or corporations.

Pipe lines, like refineries, are continually increasing their capacity to keep up with the increase in production. Consequently no report on either capacity or extent of lines can be considered accurate for any length of time.

The first pipe lines constructed in Oklahoma were built by the Prairie Oil and Gas Company as extensions of their lines

TANK FIRES CAUSED BY LIGHTNING IN CUSHING FIELD.

in Kansas. From a line connecting wells at Thayer, Kans., with a small refinery at Neodesha, Kans., in 1893, the company's system of lines has grown until it is now the largest in the Mid-Continent field, and one of the largest in the world. All the crude transported through the pipe lines of this company is used by the Standard ex-subsidiaries; principally by the Standard plants at Whiting, Ind., Wood River, Ill., Sugar Creek, Mo., and Neodesha, Kansas. In December, 1913, the total runs to the Atlantic Coast by way of Whiting, Ind., amounted to about 60,000 barrels daily.

When this company began the building of its lines from Thayer, extensions were made to Peru, Sedan, Coffeyville, and other places in Kansas, and then into the Osage Nation in the Indian Territory. When production became too large for the refineries a line was built, in 1907, from southern Kansas to Whiting, Ind., a distance of 600 miles. The Prairie Oil and Gas Company now has 4 main lines from the Mid-Continent field to Whiting. Also in 1907, 240 miles of 8-inch pipe line were laid between Humboldt, Kans., and Griffith, Indiana. As production increased and it became necessary to put thousands of barrels a day in storage, a line was built to Alton, Ill., and about 20,000 barrels a day were sent to the plant at that place. This line was built in the summer and autumn of 1913. The Prairie Oil and Gas Company now has lines to all the principal fields in northern Oklahoma. In the Cushing field this company has two 6-inch lines and an 8-inch line, which run to the North Indian pump station, and 400 miles of 8-inch and 12-inch pipe line is now being constructed from Cushing, Okla., to Alton, Ill. It is estimated that this addition will increase the pipe line facilities of the company at least 10,000 barrels daily. The total daily capacity of the Prairie Oil and Gas Company's pipe lines is estimated at 70,000 barrels. In the year 1907 these lines handled about 30,000,000 barrels of crude oil, or about 75 per cent of the total Mid-Continent production. In 1913 the total runs amounted to 38,720,262 barrels, an average of 106,082 barrels a day. In 1914 the total runs amounted to 40,201,527 barrels, an average of 110,141 barrels a day.

Until 1907 the Prairie Oil and Gas Company was the only large organization of its kind in the Mid-Continent field. In that year the Gulf Pipe Line Company and Texas Pipe Line Company built lines into Oklahoma for the purpose of securing crude for the refineries in Texas. The Gulf Pipe Line Company, the producing end of which is the Gypsy Oil Company, came to Oklahoma in 1907, after the decline in the Texas production, and the increase in the Oklahoma output.

In that year an 8-inch pipe line was built from Glenn pool to Sour Lake, Texas. In 1913 this line was extended by a loop from Oklahoma to Port Arthur, Texas, which, together with the increased efficiency of the Fort Worth, Texas, and Shreveport, La., branches enables the company to run approximately 30,000 barrels daily. In 1913 a 6-inch line of 11,000 barrels daily capacity was laid from Perryman, Texas, to the Cushing and Cleveland fields. In addition to the pipe line facilities, this company has steel storage capacity for about 6,000,000 barrels of oil in Oklahoma. It transfers its crude to the plants of the Gulf Refining Company at Fort Worth and Port Arthur.

The Texas Pipe Line Company (Producers' Oil Company) was organized in 1902. An 8-inch pipe line was built from Glenn pool to Dallas, Texas, and later extendeed to Corsicana and Humble, Texas. Pumping stations are located at the following places in Oklahoma: Keifer, Henryetta, Stuart, Coalgate and Armstrong. The crude is transferred to the refineries of the Texas company at Dallas, Port Arthur, and Port Neches, Texas. This company has a 6-inch line of about 15,000 daily capacity from the Cushing field to the main trunk line.

The Magnolia Pipe Line Company is the latest large pipe line company to enter the State. In the early part of 1914 an 8-inch line from Alvord, Texas, was built to the Healdton field, and it has been stated that the intention of the company is to build the line through to the Cushing field with branches to the Glenn Pool and Okmulgee fields. The Magnolia Refining Company, of Texas, with which the Magnolia Pipe Line Company is associated, has a line from Electra, Texas, to Beaumont, Texas. The Oklahoma crude handled by this pipe line company is transported to the refining company's plants at Fort Worth, Corsicana, and Beaumont, Texas.

The Oklahoma Pipe Line Company has an 8-inch pipe line from Jenks, Okla., to Baton Rouge, Louisiana. This line was laid in 1910. In 1915 an 8-inch line was constructed from the Cushing field to connect with the northern terminus at Jenks, a distance of 40 miles. This will give the company an outlet for the Cushing oil to their refinery at Baton Rouge, Louisiana. The capacity of this line is given as 20,000 barrels daily. A large pumping station has been constructed at Pemeta, in the Cushing field.

From January, 1914, to January, 1915, has been a period of great development for pipe lines. The chief center of this activity was in the Cushing field, where there are at least twenty-eight conections with tank farms, loading racks, and larger lines. A summary of the pipe line facilities in this field, not including those previously mentioned, is as follows:

The Cosden Company is operating a 6-inch line from this field, and also a 6-inch line from Bixby to the Cosden refinery in West Tulsa. The capacity of the line is estimated to be 10,000 barrels daily.

The Chanute Refining Company has a 4-inch line of 7,000 barrels daily capacity from the field to its refinery at Cushing, and to a loading rack at the same point for the shipment of petroleum to their refinery at Chanute, Kansas.

The Hill Oil and Gas Company has a 6-inch line from the field to their tank farm at Depew, where the company also has a loading rack.

The Indiahoma Refining Company has a 3-inch line of 4,000 barels daily capacity from the field to its refinery at Okmulgee, and a loading rack at Bristow.

The Jane Oil Company has a 4-inch line from the field to Cushing; also a 1¼-inch line from its gasoline plant in the field to Cushing.

John H. Markham, Jr., has a 4-inch line from his property in the field to storage tanks and racks at Yale.

The McMann Oil Company has constructed an 8-inch line from the field to Red River, south of Addington, Okla., a distance of 155 miles, connecting its two 4-inch lines in the field with the Magnolia's 8-inch line which in turn has connections with the lines leading to the Magnolia refineries at Ft. Worth, Beaumont and Corsicana, Texas. The daily capacity of the McMann lines is estimated to be 23,000 barrels.

B. B. Jones has a 4-inch line to his tank farm and rack at Norfolk, and a line to Bristow.

The Pierce Oil Corporation has a 6-inch line of 10,000 barrel daily capacity to its refinery at Sand Springs, near Tulsa.

White and Sinclair have a 4-inch line and a 6⅝-inch line from the field to their tank farm south of Cushing.

T. B. Slick has a 4-inch line to his tank farm at Bristow.

C. B. Shaffer has two 4-inch lines to his refinery and tank farm at Cushing.

The Silurian Oil Company has two 4-inch lines to its tank farm.

The Southern Pipe Line Company has a 4-inch line to its storage tanks and loading racks at Yale.

The Twin States Oil Company has a 4-inch line to its refinery and loading racks at Yale.

The Yarhola Pipe Line Company has two 4-inch lines from the field to the tank farm south of Cushing.

The Milliken Refining Company has a 6-inch line of about 12,500 barrels capacity from the field to the company's refinery at Vinita, a distance of 80 miles.

The National and Cudahy Refining Companies are going to build an 8-inch pipe line from the field to Coffeyvile, Kansas.

The present daily pipe line capacity of all lines when in operation in the Cushing field has been estimated to be about 243,000 barrels.

Several of the new and smaller fields over the State which have been developed during the past years have been seriously handicapped by the lack of pipe line facilities. Prior to January 20, 1914, there were no pipe line connections with the Newkirk, Inola, or Healdton fields. Two small companies were formed to lay lines into the Inola field and a little later the Magnolia Company built its line into the Healdton field. One of the companies in Inola field is known as the Inola Pipe Line Company, and a 4-inch line has been laid from the field to the Missouri Pacific Railroad, a distance of 8 miles. The company has one pumping station and a 12-car loading rack. The other line is known as the Protection Line, and is a combination 3 and 4-inch line from the field to West Tulsa, a distance of 23 miles. It has one pumping station.

Several other companies have contemplated building lines into Oklahoma fields, but the present decline in the oil business has stopped such projects, for the present at least. Independent producers have under consideration various schemes for the building of pipe lines and the installation of refining plants to take care of their production.

The Atchison, Topeka & Santa Fe Railway, which owns the greater part of the production in the Wheeler oil field, has a pipe line from that field to the railroad at Ardmore. Recently the line from Wheeler was connected with the Healdton field, and the line now conveys the oil which is used by the Ardmore refinery. A small line from the wells in the region of Madill extends to the St. Louis & San Francisco Railroad east of Madill, where a small loading station has been constructed.

The Muskogee Refining Company contemplates building a pipe line from its plant at Muskogee to Okmulgee County. The refinery at Gainesville, Texas, is building a pipe line from their plant to the Healdton field.

Pipe line runs in Kansas and Oklahoma, 1914.

Month.	Prairie Oil and Gas Co.	Gulf Pipe Line Co.	Texas Co.	Magnolia Pipe Line Co.	Other Lines.	Total.
January	3,710,894	622,000	496,000		1,250,000	6,078,894
February	3,288,029	523,600	560,000	106,400	1,306,000	5,784,029
March	4,090,608	525,000	560,000	124,000	1,315,000	6,618,608
April	3,738,909	825,500	802,500	147,000	1,386,000	6,900,509
May	4,209,858	883,500	837,000	251,100	1,488,000	7,669,458
June	3,865,620	862,500	816,000	252,000	1,455,000	7,251,120
July	3,585,106	868,000	830,000	372,000	1,860,000	7,515,906
August	2,529,281	558,000	550,000	363,215	1,820,576	5,820,576
September	1,789,008	555,000	348,691	280,840	2,570,000	5,543,539
October	2,993,649	578,305	501,525	360,015	2,640,000	7,073,494
November	3,158,650	630,000	620,997	180,000	2,720,000	7,319,647
December	3,407,245	666,500	664,080	232,500	3,050,000	8,020,325
Total	40,266,877	8,097,905	7,586,793	2,669,150	22,870,576	81,596,115

Pipe line runs in Kansas and Oklahoma, 1915.

Month.	Prairie Oil and Gas Co.	Gulf Pipe Line Co.	Texas Co.	Magnolia Pipe Line Co.	Other Lines.	Total.
January	2,855,566	684,325	681,844	330,000	3,131,000	7,682,735
February	2,576,000	622,150	412,812	27,000	2,520,000	6,157,962
March	2,790,000	625,270	802,067	31,000	2,790,000	7,038,337
April	2,250,000	750,000	762,336	125,000	2,400,000	6,287,336
May	2,790,000	837,000	932,710	170,500	2,480,000	7,210,210
June	2,100,000	820,000	769,667	213,000	2,250,000	6,152,667
July	2,790,000	950,000	882,307	300,000	2,170,000	7,092,307
August	2,945,000	980,000	780,161	248,000	2,170,000	7,123,161
September	2,700,000	850,000	691,783	350,000	2,100,000	6,691,783
October	2,225,000	756,000	702,324	401,460	2,077,000	6,161,784

REFINING OF PETROLEUM.

HISTORY AND METHODS.

The history of refining of petroleum dates back to the 18th century, and perhaps earlier. In 1823 a refinery was erected at Masdok, Russia, in the Caspian district. The apparatus consisted of an iron still set in brick work, and a copper worm

condenser in a barrel of water. The refining of petroleum in the United States dates from the year 1855.

Crude petroleum is a complex substance containing the whole range of paraffin hydrocarbons, from liquid to solid, olefins, various basic bodies, and in some cases sulphur compounds. The process of refining aims at the elimination of the oxygen, basic, and sulphur compounds and obtaining the paraffin and olefin hydrocarbons in the finished products. The process is essentially one of distillation, accompanied by treatment with certain chemicals to rid the desirable products of impurities. The products obtained by refining methods consist of the following:

1. Light liquids and naphthas.
2. Kerosene and burning oils.
3. Lubricating oils.
4. Paraffin wax.
5. Residuum.

The methods of refining are guided to some extent by the quality of the crude petroleum. There are several methods employed in the United States. The writers do not intend to give a detailed description of each method, but to give in brief a few of the essential features of such a process*. Some refineries are equipped with apparatus for the production of naphtha, illuminating oils and residuum or fuel oil; in others the operations are confined to the destillation of the residuum for the production of lubricating oils, paraffin, etc., while in a few, both sets of products are manufactured.

In a refinery of the first type the apparatus usually consists of a battery of stills comprising three of the cheese-box type* anl six plain cylinder stills*, 30 feet long by 12 feet 6 inches high, all having sheet-iron jackets, a condenser of the parallel-tube type, and vapor pipes.

A simple and general process for obtaining the various products is the following: The crude oil as received at the refinery by tank cars or pipe lines is run into storage tanks where it is kept warm by means of steam pipes. The oil is then run into the still and distilled by fire heat or by a combination of fire heat and superheated steam. The vapor passes from the still into a condensing arrangement, around which cold water is allowed to flow. The liquid product is then run into underground tanks. The first distillate to come over is

*In Sir Boverton's "Treatise on Petroleum," vol. 2, will be found a detailed description concerning the refining of petroleum.

*Redwood, Sir Boverton, A Treatise on Petroleum, vol. 2, p. 3.

the naptha or benzine. When the specific gravity has reached 0.760 to 0.780 the current of the distillate is changed. The last product is classed as kerosene or burning oil. The residual oil is often subjected to a process known as "cracking." It consists in distilling oils at a temperature higher than the normal boiling points of the residual constituents intermediate between kerosene and the lubricating oils and are converted into hydro-carbons of lower density and boiling point, suitable for illuminating purposes. This process is usually accomplished by distillation under pressure, or by allowing the distillate to fall into the highly heated residue in the still.

The distillates are purified by treatment with chemicals and divided into smaller fractions of different gravity by re-distillation. The final refined products usually obtained are given in the following table:

Name.		Density Baume.	Specific gravity.	Use.
Petroleum ether	Rhigolene or cymogene	90°	0.636	For surgical purposes as an anesthetic
	Gasoline	88° to 86°	0.642 to 0.648	For air-gas machines
Petroleum spirit	C. Naphtha	76° to 70°	0.679 to 0.700	Illum't'g purposes
	B. Naphtha	66° to 65°	0.714 to 0.718	Illum't'g purposes
	A. Naphtha	59° to 58°	0.741 to 0.745	Illum't'g purposes and varnish making
Residuum	--------------	-----------	------------------	Fuel oil

By present refining processes about 240 products are manufactured from crude oil. These include benzine, gasoline, naptha, kerosene, fuel oils, lubricating oils, illuminating oils, and paraffin, which is used for many purposes, including the manufacture of chewing gum, asphalt products, axle grease, coal tar, and washing, scouring, and shaving soaps.

The approximate proportion of the different products obtainable from crude oil is given in another part of this report on refineries.

The general method of treating the residium is as follows: It is first removed to a large tank and warmed by means of steam, so as to make it fluid, then run into a still in which it is heated by fire heat alone, superheated steam, or both. The products obtained are a light distillate containing solid paraffin, solid residue of cake remaining in the still. The distillate is treated with sulphuric acid and caustic soda, then

transferred to a still and re-distilled. The products obtained usually consist of three portions:

1. Heavy burning oils.
2. Light lubricating oil and paraffin.
3. Heavy lubricating oil and paraffin.

These products are again further treated, separated, and refined into various grades.

In recent years new and improved methods of refining have been introduced. Dr. Walter F. Rittman has discovered a process whereby a petroleum of low gravity may be made to produce a greater per cent of light grade oils than by the present methods of refining. Briefly stated, the process consists in subjecting the oil in the form of vapor to a pressure from 90 to 500 pounds to the square inch and to a temperature of about 450° C. In a chemical way the kerosene molecules are transformed into gasoline molecules. It is claimed that this process doubles the amount of gasoline obtained from crude oil. The same process is used to obtain toluol and benzol. Independent refiners have produced 12,000,000 barrels of gasoline a year, and with the new process they can produce 36,000,000 barrels from the same quantity of crude oil.

REFINERIES.

GENERAL STATEMENT

Any information which may be prepared for publication concerning oil refineries is soon out of date, for the reason that new refineries are constantly being constructed and old plants rebuilt or enlarged. That 8 modern refineries were built in Oklahoma in 1913, and enough improvements made in the old plants to make the total daily capacity of all plants in the State 20,000 barrels greater than that of the previous year serves as a proof of this fact.

Large amounts of Oklahoma crude are carried to refineries in Kansas, Indiana, and other states by the pipe lines of the Prairie Oil and Gas Company, and to the refineries in Texas and Louisiana by those of the Texas Company, Gulf Pipe Line Company, and Oklahoma Pipe Line Company. The Cudahy and National refineries at Coffeyville, Kansas, are also large users of crude from Oklahoma. About 30 per cent of the State's production is refined in the State. In discussing the history of refining of Oklahoma oils it is necessary to give the development of that industry in Oklahoma, Kansas, Illinois, Missouri, Indiana, north Texas, and Louisiana, because most of the refineries in these states have been using Oklahoma crude almost since production began. Many refineries outside the State have been built exclusively for the use of Oklahoma crude.

The location of refineries is determined: By facilities for securing the crude product from the field, either by pipe lines or railroad transportation; by conditions suitable for distribution of refined products; and a suitable water supply. If the transportation facilities be favorable a plant may be located some distance from the field. Many of the plants outside of Oklahoma were built to use crude from the immediate vicinity but the failure of the near-by fields led to the use of Oklahoma oil.

Prior to 1905 there were only 2 refineries in the Mid-Continent field—the Standard Oil Company's plant at Neodesha, Kans., constructed in 1897 with only 2 stills, and the plant of the Webster Refining Company at Humboldt, Kans., with a capacity of 350 barrels. At the beginning of 1907 there were 13 refineries in operation and 5 under process of construction, with a total capacity of about 16,700 barrels. In July, 1913, there were 40 plants in the field with a daily capacity of 150,000 barels. Besides the crude used by the local refineries, 60,000 barrels were sent daily to eastern refineries.

The period from January, 1914, to July, 1915, has been one of marked activity in the refining industry. Plants have been built in localities where none existed before. Additional refineries have been located in the proved fields, especially in the Cushing field, where the production justified such enterprises.

Other features of the development of the industry are the increase in capacity of the older plants by the installation of additional stills and pipe line facilities; the improvement in the methods of refining; and the installation of modern apparatus for the extraction of more by-products. The Western Refiners Association has made arrangements to erect a plant at the Phoenix Refinery at Sand Springs to test the Rittman process for extracting a larger percentage of gasoline from crude and fuel oils. This process is the most modern improvement to be added to the refining of oil, and if successful it will probably be installed in the leading plants throughout the State.

From the data compiled for 1914 and part of 1915, the estimated requirement of Oklahoma petroleum for the different refineries is given in the following table:

	Amounts daily in barrels.
Refineries in Kansas	14,956
Refineries in Oklahoma	52,211
Refineries in Texas	55,000
Refinery at Baton Rouge, La.	20,000
Eastern Refineries	65,000
Total	207,167

PROFITS IN REFINING.

The difference between the price paid for crude oil and the price secured for refined products allows a good dividend to be paid on money invested in the refining industry. The highest price paid for Oklahoma oil has been $1.05 per barrel, with 20 to 50 cents premium for certain light oils. From a barrel of crude oil about 6 gallons of gasoline, 11 gallons of kerosene, and many of the other by-products can be manufactured. The usual price of gasoline and kerosene is from 8 to 10 cents per gallon, thus giving a value of $1.35 to $1.70 for these two products derived from a barrel of oil, in addition to the value of the other products.

With oil selling at $1.00 to $1.30 per barrel, the profit is large. One refinery is said to have paid 2 to 3 per cent profit a month during 1913, while another cleared $100,000 on the investment for the year. One of the new refineries in the State paid 70 per cent dividends for the first six months of 1913.

The building of refineries immediately follows the development of new fields. The Cushing field opened about 2 years ago, and now it has 9 refineries. The cost of building and equiping a refinery in the State ranges from $25,000 to $2,000,000, acording to capacity and nature of equipment. Refineries using Oklahoma crude November 1, 1915, are given in the following table:

Refineries using Oklahoma Crude.

Name.	Location.	Year Built.	Capacity barrels.	Total Investm't	Tank Cars. No.	Tank Cars. Cost (est.)	Distributing Stations.	Miles of Pipe Lines.
Alluwe Ref. Company	Coffeyville, Kans.	----	1,250	---------	---	------	--------	-------
*American Ref. Company	Okmulgee, Okla.	1906	1,500	$ 500,000	---	------	--------	-------
Ardmore Ref. Co.	Ardmore, Okla.	1914	1,500	50,000	310	341,000	--------	-------
Bartlesville Ref. Co.	Bartlesville, Okla.	----	1,000	---------	---	------	--------	-------
Continental Ref. Co.	Bristow, Okla.	1914	200	20,000	---	------	1	-------
Chanute Ref. Co.	Chanute, Kans.	1906	1,750	450,000	290	290,000	33	60
Chanute Ref. Co.	Cushing, Okla.	1914	2,750	300,000	---	------	--------	-------
Brown's Ref. Co.	Cushing, Okla.	----	500	---------	---	------	--------	-------
Chelsea Ref. Co.	Cushing, Okla.	1914	2,000	100,000	67	60,000	--------	30
Cleveland Pet. & Ref. Co.	Cleveland, Okla.	1913	1,000	100,000	100	125,000	--------	-------
Cleveland Pet. & Ref. Co.	East St. Louis, Mo.	1909	500	50,000	---	------	--------	-------
Constantine Ref. Co.	Tulsa, Okla.	1911	3,000	70,000	59	62,000	--------	21
*Consumers Ref. Co.	Cushing, Okla.	----	4,500	464,791	239	239,000	--------	118
Cosden Ref. Co.	Cushing, Okla.	1914	1,000	---------	568	550,000	--------	-------
Cosden Ref. Co.	Tulsa, Okla.	1913	20,000	3,000,000	---	------	1	114
Cosden Ref. Co.	Bigheart, Okla.	1914	800	---------	---	------	--------	-------
Colonial Ref. Co.	Cushing, Okla.	----	1,500	---------	---	------	--------	-------
Cudahy Ref. Co.	Coffeyville, Kans.	1908	6,000	1,000,000	335	300,000	610	-------
*Cudahy Ref. Co.	Muskogee, Okla.	1905	1,000	95,000	---	------	--------	128
Cushing Ref. Co.	Cushing, Okla.	1914	934	90,000	100	100,000	--------	-------
Eastern Kansas Ref.	Moran, Kans.	1905	400	300,000	29	26,000	--------	10
Gulf Refining Co.	Fort Worth, Texas	----	----	---------	---	------	--------	-------
Gulf Refining Co.	Port Arthur, Texas	----	----	---------	---	------	--------	-------
*Great Western Ref. Co.	Erie, Kans.	1905	2,000	754,000	40	50,000	1	24
Hillman Ref. Co.	Cushing, Okla.	----	600	---------	---	------	--------	-------

Refineries using Oklahoma Crude.—(Continued).

Name.	Location.	Year Built.	Capacity Barrels.	Total Investm't.	Tank Cars. No.	Tank Cars. Cost (est.)	Distributing Stations.	Miles of Pipe Lines.
Indiahoma Ref. Co.	Okmulgee, Okla.	1910	1,200	335,000	83	99,600	3	43
Indiahoma Ref. Co.	East St. Louis, Mo.	1907	700	100,000	---	------	--------	-------
Jane Oil Refining Co.	Cushing, Okla.	1914	2,000	150,000	39	39,000	--------	-------
*Kansas City Ref. Co.	Kansas City, Kans.	1906	1,000	250,000	42	42,000	--------	-------
*Kansas Co-op. Ref. Co.	Chanute, Kans.	1906	500	200,000	30	32,148	20	6
Kansas Oil Ref. Co.	Coffeyville, Kans.	1906	1,800	250,000	52	50,100	--------	60
Kanotex Ref. Co.	Caney, Kans.	1907	1,000	250,000	41	41,000	31	33
Kansas Crude Oil Co.	Chanute, Kans.	1909	----	12,000	---	------	--------	-------
Fort Smith Ref. Co.	Fort Smith, Ark.	1911	150	15,000	---	------	--------	-------
Lesh Oil Co.	Arkansas City, Kans.	1914	500	25,000	10	10,000	--------	-------
Miller Ref. Co.	Humboldt, Kans.	1906	350	30,000	25	27,125	6	7
*Milliken Ref. Co.	Vnita, Okla.	1910	4,000	999,800	370	409,495	--------	65
*Muskogee Ref. Co.	Muskogee, Okla.	1905	750	300,000	49	45,000	--------	18
Magnolia Ref. Co.	Fort Worth, Texas	1914	10,000	1,000,000	343	345,000	--------	-------
Magnolia Ref. Co.	Corsicana, Texas	----	5,000	---------	---	------	--------	-------
Magnolia Ref. Co.	Beaumont, Texas	----	----	---------	---	------	--------	-------
*National Ref. Co.	Coffeyville, Kans.	1907	3,000	500,000	315	315,000	50	110
New State Ref. Co.	Cushing, Okla.	1914	1,000	51,000	35	36,750	--------	-------
Okla. Ref. Co.	Oklahoma City, Okla.	1906	600	100,000	40	40,000	50	-------
*Petroleum Prod. Co.	Independence, Kans.	1910	3,500	2,500,000	182	212,000	--------	170
Phoenix Refining Co.	Sand Springs, Okla.	1913	3,000	300,000	60	60,000	--------	24
Pierce Oil Corp.	Sand Springs, Okla.	1913	10,000	600,000	400	400,000	400	35
*Ponca Ref. Co.	Ponca City, Okla.	1912	1,000	225,000	120	120,000	--------	30
Paoli Ref. Co.	Paoli, Kans.	----	150	---------	---	------	--------	-------
Producers Ref. Co.	Gainesville, Texas	1915	7,500	---------	---	------	--------	-------

Refineries using Oklahoma Crude.—(Continued).

Name	Location	Year Built.	Capacity Barrels.	Total Investm't	Tank Cars. No.	Tank Cars. Cost (est.)	Distributing Stations.	Miles of Pipe Lines.
Rollins Ref. Co.	Rollins, Kans.	1908	40	15,000	----	----	----	----
Riverside Western Oil Co.	Tulsa, Okla.	1913	----	300,000	20	19,700	----	----
Sapulpa Ref. Co.	Sapulpa, Okla.	1908	3,000	337,000	69	79,360	----	35
Shock Ref. Co.	Niotaze, Kans.	1905	500	275,000	15	18,000	----	----
Standard Oil Co.	Neodesha, Kans.	1897	8,000	----	----	----	----	----
Standard Oil Co.	Sugar Creek, Mo.			----	----	----	----	----
Standard Oil Co.	Whiting, Ind.	----	65,000	----	----	----	----	----
Standard Oil Co.	Alton, Ill			----	----	----	----	----
Standard Oil Co.	Baton Rouge, La.	----	----	----	----	----	----	----
Standard Oil Co.	Staten Island, N. J.	----	----	----	----	----	----	----
Texas Company	Tulsa, Okla.	1906	5,000	50,000	378	378,000	----	----
Texas Company	Fort Worth, Texas	----	----	----	----	----	----	----
Texas Company	Port Arthur, Texas	----	----	----	----	----	----	----
Texas Company	Dallas, Texas	----	----	----	----	----	----	----
Twin State Ref. Co.	Yale, Okla.	1914	2,000	200,000	----	----	----	----
Uncle Sam Oil Co.	Tulsa, Okla.	1906	1,000	50,000	32	32,000	----	----
Uncle Sam Oil Co.	Cherryvale, Kans.	1906	400	125,000	56	56,000	----	----
Webster Ref. Co.	Coalton, Okla.	1911	350	15,000	----	----	----	1
Wichita Ref. Co.	Wichita, Kans.	1914	100	3,000	----	----	----	----
Webster Ref. Co.	Humboldt, Kans.	----	350	----	----	----	----	----
Wilhait Ref. Co.	Joplin, Mo.	1913	500	90,000	27	27,000	----	----

Refineries having lubricating plants.

NOTE: The distributing stations are given only for the independent refineries.

The following refineries in Oklahoma are being built, or are contemplated:

Name.	Location.	Capacity Barrels.
Ames Refinery	Drumright	1,000
Bristow Oil and Refining Co.	Bristow	----
Capital Refining Co.	Oklahoma City	300
Carter Oil Co. Refinery	Cushing	15,000
Coalton Refining Co.	Coalton	250
Healdton Refining Co.	Healdton	----
Ponca City Refining Co.	Ardmore	----
Portland Refining Co.	Okmulgee	1,000
C. D. Webster Refining Co.	Yale	250

PRICES OF CRUDE OIL.

Statistics concerning the prices of petroleum in Oklahoma from the beginning of production to the present are incomplete. Prior to 1896 the production was very small, the average price being about 50 cents a barrel. During 1897 there was a gradual decline, the average price for the year being 40 cents a barrel. At the end of the next three years the average price had advanced to 90 cents a barrel, but this was followed by a decline to 86 cents in 1901. In 1902 the price advanced only a few cents, but in 1903 there was a marked advance, the average price being $1.05, and the maximum $1.16 a barrel. The next four years was a period of gradual decline, after which the market remained stable for almost two years, until in the latter part of 1909 the price had dropped to 35 cents a barrel, the lowest mark in the history of the oil industry in Oklahoma. From 1910, however, there was a gradual increase to $1.05 in February, 1914. This was followed by a decline, perhaps the most marked and best remembered of any previous one. The cause of such a change, according to the opinion of prominent oil men, was due to an over production in the Cushing field.

The minimum price was reached in March, 1915, when oil was selling at 40 cents a barrel in the northeastern fields, and 30 cents a barrel in the Healdton field. In contrast to this condition, the price began to increase rapidly from August, 1915, with the exception of the Healdton production, in which the advance began one month later. The present price, December, 1915, is $1.20 per barrel for Kansas and Oklahoma crude, and 60 cents per barrel for Healdton.

From all indications it appears that the price has not reached a maximum, but will attain a price much higher than hitherto known in the market quotations of Oklahoma petroleum. See table concerning prices of oil, page 77.

NATURAL GAS IN OKLAHOMA.

GENERAL STATEMENT.

The natural gas industry showed much improvement during the year 1914 and the first half of 1915. The output has been gradually increasing and new fields of importance have been developed. Cushing is the largest and most important of the new gas fields. Many gas wells are reported here with large volumes and high rock pressure. The chief gas sands are the Layton, Jones, Wheeler, and Bartlesville, with some 6 other sands reported as containing gas in commercial quantities.

During 1913 about the only demand put on this vast amount of gas was the field operations, the refineries, two casing-head gasoline plants, and the towns of Cushing, Drumright, and Dropright. But during the year 1914, the Creek County Gas Company, besides supplying Cushing, Sapulpa and Okmulgee was also selling considerable gas to the Wichita and Quapaw companies, which furnish Wichita, Kans., and Joplin, Missouri. The Oklahoma Natural Gas Company has also completed a line to Cushing and is supplying Oklahoma City with gas from this field.

Another field that has produced a large amount of natural gas, only a small amount of which has been utilized, is Healdton. Someone has estimated that enough gas has been wasted in this field to supply Oklahoma with heat for two years. In Muskogee, Wagoner, and McIntosh counties much gas has been discovered over wide territory; for instance, in McIntosh County some 240 square miles of territory has been tested and found to have some gas scattered all through it. Several big gas wells have been closed in this district awaiting better market conditions.

The older gas fields, such as Glenn Pool and Hogshooter have practically been exhausted as far as piping the gas out is concerned, but the casing-head gas gasoline industry has been established profitably here and in other older oil fields. At one time the great Hogshooter field was actually piping out 200,000,000 cubic feet per day, while in the fall of 1914 it was piping out practically nothing.

In Tulsa and Osage counties much new gas has been discovered, especially in the Bird Creek area. During the latter part of 1913 a new gas field was opened up in Osage County,

5 or 6 miles west of Hominy. This gas has been piped to Hominy for city use.

Gas from Kay County wells was piped to Ponca City, Tonkawa, Newkirk, Uncas, Blackwell, Braman, and Kildare. In Okfuskee County a small quantity of gas was furnished to Okemah. In Stevens County a new gas field was discovered and some 10 wells with 250-330 pounds pressure were brought in and the gas piped to Duncan, Marlo, and Lawton. These wells ranged from 702 to 907 feet in depth and showed no evidence of being exhausted at the close of 1914. Comanche County produced some gas, most of which was piped to Lawton and consumed there.

In Pontotoc County, the new Ada gas field is coming into prominence. Skelly and Sanky who are operating in this field have a production of about 25,000,000 cubic feet and have recently been granted a franchise to supply gas to the city of Ada. The total production of the field is estimated at 75,000,-^00 cubic feet.

Estimates of the quantity of natural gas that will be consumed daily in the larger cities and manufacturing centers in Oklahoma for the winter of 1915-1916 are as follows: Oklahoma City 20,000,000 cubic feet; Tulsa 12,000,000 cubic feet; Muskogee 12,000,000 cubic feet; Shawnee 8,000,000 cubic feet; Guthrie 8,000,000 cubic feet; Ardmore 6,000,000 cubic feet; Bartlesville, with the zinc smelter, 18,000,000 cubic feet; the two zinc smelters at Collinsville 11,000,000 cubic feet; Okmulgee, with the glass factories and refineries, 18,000,000 cubic feet; Cushing, with the refineries, and Sapulpa, with a glass factory and refinery, 25,000,000 cubic feet.

There are something like 100 other smaller towns using gas for domestic and industrial purposes, the aggregate amount of which will be large. Also it is estimated that something like a total of 100,000,000 cubic feet will be piped daily to Wichita, Kans., and Kansas City and Joplin, Missouri. Added to this is the amount that will be used in field operations, and also the amount used for the casing-head gas gasoline plants. From these figures it is evident that the outlook for the natural gas industry is better for Oklahoma than for any year previous.

The number of productive gas wells at the close of 1913 was 1,052, as compared with 936 at the close of 1912. During the year 721 wells were drilled for gas, 423 of which were productive and 289 dry. In all, there were 307 wells abandoned during the year 1913. The number of productive gas wells drilled in 1914 amounted to 539.

In comparing the production of natural gas by states in 1914, Oklahoma ranks third, being surpassed by Pennsylvania and West Virginia. However, in ranking the states according to the value received from the natural gas, Oklahoma ranks fourth, being excelled by Pennsylvania, West Virginia and Ohio.

The gas developed on initial flow in Oklahoma in 1914 amounted to 2,985,228,000 cubic feet. The month of February was the most active, there being 432,600,000 cubic feet uncovered. The Creek area, which includes the long strip of territory from Tulsa south to McIntosh County, was the leading gas-producing area, being credited with 1,085,310,000 cubic feet.

The following table will give the gauge of gas developed in 1914 on initial flow by months in Oklahoma:

Month	Cubic feet.
January	214,400,000
February	432,600,000
March	375,500,000
April	311,000,000
May	351,650,000
June	299,860,000
July	192,250,000
August	203,968,000
September	143,000,000
October	162,000,000
November	169,000,000
December	130,000,000
Total	2,985,228,000

The following table gives the gas developed in 1914, giving the initial flow in Oklahoma by districts:

District	Cubic feet.
Cherokee d. s.	775,006,000
Cherokee s. s.	14,500,000
Osage	292,150,000
Cleveland	25,000,000
Cushing	608,000,000
Creek	1,085,310,000
Kay	18,000,000
Southwest Oklahoma	226,200,000
Miscellaneous	3,000,000

Table showing the production of natural gas in Oklahoma in 1914.

Condition of Gas.	Quantity. (M cu. ft.)	Cents per. (M. cu. ft.)	Value.
Produced	78,167,414	10.30	$8,050,039
Consumed	55,544,105	7.61	4,226,318

PRICES OF NATURAL GAS.

On the whole, the year of 1913 was a prosperous year for the natural gas industry in Oklahoma. The total production was 75,017,668,000 cubic feet, valued at $7,436,319, or 9.91 cents per 1000 cubic ft., as compared with 73,799,319,000 cubic feet, valued at $7,406,528, or 10.04 cents per 1000 cubic feet in 1912. It will be noted that there was a decrease in the average price of natural gas per 1000 cubic feet from 10.04 cents in 1912 to 9.91 cents in 1913. This was probably due to the fact that there was a large increase in the amount of natural gas used for manufacturing and industrial purposes within the State. In 1913, the amount of natural gas consumed for industrial purposes in Oklahoma was 44,098,000 cubic feet, valued at $2,484,163, as compared with 35,049,341,000 cubic feet, valued at $1,860,482 in 1912. The various industries that consumed large quantities of natural gas in this State were zinc smelters, cement plants, glass factories, brick plants, a carbon-black plant, gas engines, and steam engines operating in oil fields and elsewhere.

Another interesting phase of the development of the Oklahoma natural gas industry in 1913 which has a bearing on the price also, was the fact that more natural gas was consumed in Oklahoma and less was piped out of the State as compared with 1912. In 1913, 48,553,886 cubic feet of natural gas were consumed within the State, while in 1912 only 41,549,403,000 cubic feet were used. The amount of natural gas produced within the State and consumed outside in 1913 was 27,463,782,000 cubic feet, as compared with 32,249,916,000 cubic feet in 1912. The consumption of natural gas for domestic purposes showed an increase in the amount and a slight decrease in price. In 1913, the amount used for domestic purposes was 7,039,196,000 cubic feet, valued at $1,256,818, as compared with 6,500,062,000 cubic feet, valued at $1,288,894 in 1912.

In comparing the actual fuel value of the amount of heat energy produced by natural gas with coal, one can easily see the advantage that gas has over coal. In the first place, natural gas is more convenient in handling. In the second place, with the present rate of natural gas in Oklahoma, it furnishes more heat-energy for the same cost. Few actual analyses and heat value tests of Oklahoma natural gas have been made. The university Geological Survey of Kansas has made some such tests of the gas from fields in southeastern Kansas and their figures show that the amount of heat was about 930 B. t. u., per 1000 cubic feet. Assuming this to be about the average efficiency of Oklahoma natural gas and figuring the fuel value of Oklahoma coal at 12,000 B. t. u. per pound, and also taking into consideration the fact that in using coal there is always more or less waste due to incomplete combustion, it is calculated that about 20,000 cubic feet of natural gas equals one ton of coal in fuel value. From this it is evident that when gas can be bought for 9.91 cents per 1000 cubic feet it can compete with coal at $2.00 per ton. Many factories and plants are taking advantage of this cheap, efficient fuel that is offered in natural gas in Oklahoma. The supply is good for many years yet, and it is hoped that various other industries will come into the State because of this cheap fuel-energy. The list of cities and towns furnished with gas, which is given in another part of this report, have in most cases a good supply of gas and can furnish it for manufacturing purposes at reasonable rates.

It is estimated that the ordinary gas light consumes two and one-half cubic feet of gas per hour and that at a 30-cent rate it would amount to 27 cents a month if allowed to burn during 12 hours of the day.

NATURAL GAS GASOLINE.

Throughout the oil and gas fields of the State there has been a tremendous waste of the gas. Various plans have been adopted to preserve this gas, but even with the most satisfactory arrangements the waste is great. Wells having a capacity of from 2,000,000 to 50,000,000 cubic feet per day have been allowed to run unchecked for days, weeks and even months. Gas torches needlessly burn the entire 24 hours. Stoves burn full blast because gas is cheap or free. In some fields there is no available market, or the wells decline so rapidly that the transportation of gas through pipe lines is not profitable. The best efforts at proper conservation have not been entirely successful.

During the past few years a process for the separation of the more volatile grades of gasoline from natural gas issuing from the wells has become a profitable industry of importance.

Natural gas may be divided into two classes, (1) a so-called "dry gas" known and used as a natural gas of commerce, and (2) a gas containing easily liquified vapors, known as "wet gas", which is also used for commercial purposes. This latter class forms the basis for the so-called "natural gasoline" industry.

The liquefaction of natural gas products is by compression. The process was recognized and put into practice about 1904 in Pennsylvania. The method of manufacture is briefly described in the following paragraphs*:

Up to the last two years the general practice in the manufacture of liquid natural gas was to make the product by compression of the gas in single-stage compressors operated at a pressure of 150 to 300 pounds per square inch. The one product thus obtained, so-called "natural gasoline," was run into a tank and "weathered". The weathering consisted in allowing the lighter portions to volatilize spontaneously and escape into the open air until such time as the boiling away of the liquid had practically ceased. Thus the process involved a loss of 25 to 50 per cent, or even more. This loss was an absolute waste, not only of power and of cost of operating the engines and compressors, but of the product itself.

The next step in the industry was to pass the waste gases (of which only the small quantity used for power had been utilized) from the single stage compressor through a higher stage compressor, thereby getting a second and more volatile product—a "wilder" liquid—which was run back into the first tank and mixed with the first or heavier condensate. The mixture was then again weathered to a safe degree, whereby it lost the greater part of the more volatile product that had been condensed in the second stage.

Recently the process has been improved another step, in that first-stage compressor product is run into one tank and handled as ordinary gasoline; the second-stage compressor product is run into a second tank and handled as a lighter gasoline, with which the heavy refinery napthas can be enriched or enlivened.

The last-mentioned method of using the second-stage compressor product should receive wide recognition, and a market for the product should develop that would be no mean factor in the industry. Blending in the proportions of, say, 1 part of the product to 4 or 5 parts of the refinery naphthas makes these heavy napthas more volatile and of greater value as fuel for automobiles; it also greatly increases their general usefulness. The proportions to be used in blending, however, must be determined more definitely by test.

The natural gas of this country frequently contains light products that do not condense in the second-stage compressor, and for which it is practicable and necessary to install three, four, and even higher stage compressors. These light products—true gases at ordinary temperatures and pressures—

*Allen and Burrell, Liquified products from natural gas: Technical Paper No. 10, Bur. Mines, 1912.

can be compressed and liquefied, but the liquid gases so obtained must be handled as gases and not as oils. The mistake heretofore made in the "natural gas gasoline" industry, as some have recognized, has been the attempt to handle the light gaseous products as oils and not as gases. Until the manufacturers of this lightest third or fourth-stage compressor product recognize its gaseous nature, the absolute necessity for insuring the safety of the public involves certain restrictions in its transportation, and not until the realization that this extremely volatile liquid should be handled only in strong steel containers capable of withstanding high pressures will it be transported with safety.

The natural gas from some regions will yield no gasoline, while that from other localities produces as much as 8 to 10 gallons per thousand cubic feet, the average being about 3 gallons per thousand cubic feet. The gasoline thus manufactured is very different from that which is the product of the refineries. Some of the dry gases will produce gasoline under high pressure, and some of the wet gases will produce gasoline simply by cooling without compression.

Reports from producers of gasoline from natural gas indicate that approximately 400,000 gallons of gasoline were produced in 1911, not less than 144,629,000 cubic feet of gas being used and the average yield per thousand cubic feet was 2.68 gallons, the production varying from one-fourth gallon to 4 gallons. The gravity varied from 67° to 86° Baume. The average price was 5.4 cents per gallon. Eight plants were in operation.

In 1912 there was a remarkable increase in the production of natural gas gasoline. The total number of plants increased to 12 and the amount produced to 1,575,644 gallons, valued at $99,626.00. The average price increased to 6.3 cents. The advance in the price of gasoline for this year was less in Oklahoma than in any other state. The average yield was 2.25 gallons per 1,000 cubic feet.

At the close of 1913 the number of plants in the State had increased to 49 under the management of at least 20 different companies. The amount produced was 6,462,968 gallons, with a value of $577,944.00. The amount of gas used was 2,152,503,000 cubic feet, and the value of the gas used $82,742.00. The highest yield was 7½ gallons; the next, 5 gallons; and the lowest, one-half gallon to 1,000 cubic feet of gas used. The gravity ranged from 70° to 96° Baume.

During 1914 several additional plants were put in operation and some of the old plants doubled their capacity. The "casing-head" gas produced from the Glenn Pool district proved to be very rich in gasoline, and the district leads in the

number of plants. At the close of 1914, there were over 60 plants in the State, and the production for that year amounted to more than 10,000,000 gallons.

The following list gives the number and location of the plants in operation during 1914:

Alluwe	3	Mounds	1
Bartlesville	2	Morris	1
Childers	1	Muskogee	7
Delaware	2	Okmulgee	2
Dewey	2	Cleveland	1
Drumright	5	Sapulpa (Taneha)	2
Glenn Pool and Kiefer	30	Tulsa	5
Hamilton Switch	1	Watowa	2
Lenapah	1		

After the gasoline has been extracted the residue, or "exhaust" gas, is utilized in various ways. In some cases it is run through the pipe lines to gas consumers for domestic and industrial purposes. In others it is used to drive gas engines or to run the gasoline plant, or in some cases returned to the original producer for field purposes, or allowed to waste.

Some of the natural gas gasoline is sold as crude gasoline, or ordinary gasoline, but all the high gravity products are blended with various percentages of heavy naptha, thus reducing the gravity to any degree desired. For example, an 87° Baume is mixed with 50 per cent naptha and the product sold for 9 to 10 cents per gallon. A 94° Baume is blended with heavy naptha so that the gravity is reduced to 69°.

The rapid growth of the industry in Oklahoma has placed the State first in the production of natural gas gasoline. In 1913 the production increased to 4 times that in 1912, advancing the State from fourth to second rank in the United States, while the production of 1914 almost doubled that of the previous years. One plant located near the town of Delaware, in Nowata County, and two or three of those in the Glenn Pool region, are said to be the largest plants of their kind in the world. The daily capacity of each is 2,500,000 cubic feet or more, or 10,000 gallons of gasoline. Practically all the plants constructed in the State have a larger capacity than the plants of other states. At the close of 1913 the 49 plants had a capacity nearly twice as large as the 115 plants in West Virginia. The greatest activity at present in the building of plants is in the Cushing field.

Details of production of natural gas in some of the Oklahoma plants in 1913.

Location of plant.	Quantity of gas used.	Number of wells connected to plant.	Number of compression units comprising plant.	Reduced pressure to which gas is subjected.	Compression to which gas is subjected.	Gravity of gasoline in accumulator.	Purpose for which gasoline is used.	Value of plant equipment.	Quantity of gasoline sold per month.
	Cubic ft per 24 hours.			Inches of mercury.	Pounds per square inch.	Baume:.			Gal.
Cushing, Okla.	250,000	5	1	--------	40 to 300	86	Gasoline gas.	------	-----
Alluwe, Okla.	375,000	260	2	--------	up to 300		Blending.	$30,000	33,000
Coalton, Okla.	125,000	38	1	0 to 20	up to 350	-------	"	------	8,000
Kiefer, Okla., Glennpool	300,000	-------	1	0 to 20	up to 300	-------	"	17,000	-----
Kiefer, Okla., Glennpool	800,000	-------	4	0 to 15	25 to 50 and 275 to 350	76 to 98	"	24,000	50,000
Delaware, Okla.	250,000	-------	1	--------	50 to 250	100	"	40,000	45,000
Kiefer, Okla.	40,000	10	-------	--------	30 to 40	80	"	6,000	4,000
Near Muskogee, Okla.	40,000	5	1	16	50 to 55 and 250 to 300	100	"	11,000	3,000
Near Muskogee, Okla.	70,000	-------	1	25	40 and 250	88	"	5,500	4,500
Near Kiefer, Okla., Glennpool, No. 1 plant	250,000	36	1	0 to 20	30 to 40 and 175 to 300	98	"	11,000	3,700
Near Muskogee, Okla., Glenpool	200,000	11	1	0 to 20	30 to 40 and 175 to 300	94	"	10,000	19,000
Near Kiefer, Okla., Glennpool	150,000	9	1	--------	30 and 250	87	"	12,000	18,000
Near Kiefer, Okla.	170,000	-------	1	--------	30 and 300	78	"	10,000	10,000

*Analysis of natural gas at Plant 4, Kiefer, Okla. (Glenn Pool).**

Condition of Gas.	Calculated gross heating value per cubic foot at 0° C and 706 mm. B. t.u.	Spacific gravity at 0° C. and 760 mm. (air-1)	Proportion absorbed by 35 C. C. of oil.	Composition								
				Air.	CH_4	C_2H_6	C_3H_8	C_4H_{10}	N_2	CO_2	Total.
Natural gas as drawn from well.	1,344	.83			49.1	44.1			.7	6.1	100
Residual gas after removal of 250 lbs. of compression product	1,313	.76	22.4		60.7	35.8			.6	2.9	100

Remarks.

The output of gasoline was 1 1-2 gallons of "wild" gasoline per 1,000 cubic feet of gas. The gas was drawn from the wells under a reduced pressure of 20 inches of mercury. The gasoline was blended with refinery naptha and then marketed.

*Burrell, Seibert, and Oberfeel, Gasoline from natural gas: Bull. 52, Bureau of Mines, 1915, p. 62.

Statistical data concerning natural gas gasoline, 1913 and 1914, by counties.

Location of plants, by counties.	No. of operators 1913-1914		No. of plants in operation		Yield of gasoline per thousand cubic feet. (gallons)		Average gravity gravity of gasoline as produced and before blending.	
	1913	1914	1913	1914	1913	1914	1913	1914
Creek	12	16	27	32	2.5-5.5	2.5-6.0	86°-94°	80°-90°
Muskogee	4	7	4	7	2.5-3.0	2.5-3.5	86°-90°	80°-90°
Nowata	3	8	3	8	3.0-7.5	3.5-8.0	80°-92°	80°-94°
Okmulgee	3	3	5	5	2.0-3.0	2.0-3.0	82°	82°-86°
Pawnee	1	1	1	1	0.5-	0.5-	70°-76°	68°-76°
Tulsa	3	4	7	8	2.0-3.0	2.0-3.0	82°-90°	80°-90°
Washington	1	2	1	3	2.5-	2.5-3.5	84°	84°-86°
Total	27	41	48	64	-----	-----	------	------

The list of operators as given in the county totals shows some duplication since the same operators have plants in more than one county. For 1913 the total number of operators is about 20 and for 1914 approximately 30.

WASTE OF NATURAL GAS.

Gas men say that our present methods of drilling alone waste 10 times as much gas as is ever usefully consumed. During 1913 the Government sent two experts from the Bureau of Mines to Oklahoma to show the drillers how to prevent a large part of this waste. They started their experiments in the Cushing field and in most cases received the hearty cooperation of the drillers in making their tests. Their first attempts were remarkably successful, as they succeeded in drilling two wells through the gas stratum with practically no loss of gas, which would have had a combined waste of more than 20,000,000 cubic feet daily under the old method of drilling. They also directed the drilling of other wells through the gas horizon without waste of gas. Briefly, the system consists in pumping a mud-laden fluid into the porous space, thus sealing up the stratum so that the gas cannot penetrate the well. It is not denied that this system will prevent the waste of gas, but it is claimed by some that it is too expensive. Actual tests, however, go to prove that this is not the case and some of the prominent oil companies have witnessed to this fact. The system has other merits besides the preservation of the natural gas. It furnishes a method whereby a gas stratum with an enormous rock pressure can be penetrated without loss of time. Under the old method of drilling, such a well would either be allowed to exhaust itself or never be drilled deeper. Also it

is claimed that in some cases under the new method water is prevented from coming in and drowning out the oil sand.

In the June, 1915, issue of the Natural Gas Journal, Alfred J. Diescher, a prominent oil and gas man of Bartlesville, has an interesting article on the waste of natural gas in the Mid-Continent field. The article as quoted in full is as follows:

In the Western States, especially Oklahoma and Kansas, the past few years have seen probably the greatest waste of natural gas throughout the history of the industry in those states. In the past year a great deal of attention has been centered on this subject and generally public interest awakened to the importance of taking measures to prevent the continuance thereof and the ultimate control of these valuable resources so as to bring about a greater benefit and a more permanent use from natural gas to the people of those states. Not only is the waste of gas enormous through the blowing of wells open to the atmosphere, to exhaust the supply of gas in order to facilitate oil production, but there is another waste taking place on a large scale, which is designated by the United States Bureau of Mines as underground waste, which is the dissipation of the gas in the reservoirs through escape to other previous strata due to improper packing or no packing at all in the wells. Such waste is probably as much larger than the loss of gas blown into the atmosphere in many of the fields, as the gas escaping to these other sands or strata, dissipates so low in pressure that it is impossible to gather it for commercial use.

There is a second loss through this migration to other sands which—while it alone would not affect the quantity of gas lost, yet entails a great economic loss due to the cost of gathering and artificially recompressing such expanded gas which might be recovered back to the high pressures necessary to transport it to market. Any loss of pressure in a gas reservoir represents a great financial loss, when one considers the great expense of installing and operating compressor stations to restore the pressure originally in the gas as produced by nature.

Aside from the waste by the blowing of the gas to the atmosphere, or by the escape of it beyond recovery by dissemination through other strata, the loss of gas along the transporting and distributing lines is a most important factor in the natural gas industry. Then, too, when we consider the great inefficiency or application of gas after it reaches the market and in bringing it to useful domestic or industrial purposes, one cannot help but feel shocked at the large percentage of gas which ultimately serves no useful purpose whatsoever. By this I mean that the efficiency of combustion, whether used in a house stove or whether used in a boiler, or in a gas engine, is very, very low and it may be said that as between the gas taken or escaping from the original reservoirs, on the one hand, and the amount which in the final service represents actual useful work, that it cannot represent over one or two per cent of the original reservoir, if that much. I mention this simply to call attention to the fact that the real conservation of our gas reservoirs is not fulfilled when there is no further blowing of gas from the wells, and when the wells are properly sealed to confine the gas without loss in the reservoir where it was originally found, but that it involves also the solution of the problem of eliminating loss in the transportation and distribution, and also losses in the application of the gas by consumers. The subject is a very broad one, and no doubt offers a field for great improvement.

In the Mid-Continent field—especially Oklahoma—conservation laws have been passed by the State of Oklahoma, and regulations are being promulgated by the Department of Interior as regards gas production on Indian lands, which if properly enforced will be one of the greatest steps in advance through legislation in properly protecting this great public resource.

The greatest loss of gas in the Mid-Continent field is no doubt in Oklahoma, Kansas having long ago learned that the supply was exhaustable and requiing conservation if its citizens were to enjoy the use of gas for any extended period of time. The great loss, however, is in Oklahoma, where at this time I have no doubt there is fully five hundred million feet being lost daily in all of the fields of the State, and that at times during the past year, there were daily losses in excess of one billion feet, and that during the year 1914, a safe estimate would place the losses for the State far in excess of one hundred billion cubic feet.

Other oil and gas men, who have studied this question from a practical standpoint, have come to the same conclusion, and have suggested several methods for minimizing natural gas waste. Some of the methods suggested are the application of a packer on the casing at the top of the gas-bearing sand, and the use of separators at the mouth of wells to prevent the gas from escaping behind the casing and dissipating. The first method would throw all the gas from the sand into the casing with the oil and would cut the gas loss or waste at least 50 per cent. The second method separates the oil and gas so that both can be utilized.

As stated in Mr. Diescher's article, the rapid exhaustion of the gas in the Oklahoma fields makes it necessary that some method be applied in every instance where gas is encountered in large quantities. The extent to which the conservation methods will be carried out depends to a great extent upon the rigid enforcement of State laws dealing with such matters.

LIST OF CITIES AND TOWNS IN OKLAHOMA SUPPLIED WITH NATURAL GAS.

Ada
Afton
Alluwe
Arcadia
Ardmore
Atoka
Avant
Barnesdale
Bartlesville
Beggs
Bigheart
Bixby
Blackwell
Bluejacket
Bowden
Boynton
Braman
Bristow
Broken Arrow
Cameron
Catale
Catoosa
Chandler
Chelsea
Childers
Choteau
Claremore
Cleveland
Coalton
Collinsville
Copan
Coweta
Cross
Crekola
Cushing
Davenport
Dawson
Delaware
Depew
Dewar
Dewey
Dropright
Drumright
Duncan
Dustin
Edmond
Eram
Eufaula
Ft. Gibson
Glenpool
Gotebo
Guthrie
Hallett
Haskell
Hatonville
Healdton
Henryetta
Heyburn
Hominy
Hoffman
Inola
Jenks
Jennings
Kelleyville
Kiefer
Kildare
Kusa
Lawton
Lefeber
Lenapah
Luther
Madill
Marlow
Meeker
Miami
Midlothian
Mohawk
Morris
Mounds
Muskogee
McAlester
Natura
Nelagony
Newkirk
Neodesha
Nowata
Ochelata
Oglesby
Oilton
Okemah
Oklahoma
Okmulgee
Oologah
Osage
Owasso
Pawhuska
Pemeta
Ponca
Porter
Poteau
Preston
Prue
Pryor Creek
Ramona
Red Fork
Ringling
Ripley
Sand Springs
Sapulpa
Schulter
Shawnee
Skiatook
Sperry
South Coffeyville
Stone Bluff
Stroud
Tahlequah
Terlton
Tonkawa
Tulsa
Turley
Vera
Vian
Vinita
Wagoner
Wainwright
Wann
Welch
Wellston
Wheeler
White City (Ragtown)
Wilson
Wirt
Yale

ANALYSES OF OIL.

The importance of chemical analyses of petroleum cannot be over-emphasized. The presence of sulphur and other detrimental substances must be known before the oils can be properly used for refining and distillation purposes. At the present time the amount of gasoline that can be obtained from the crude is the important point to be considered. In selecting petroleum for refining purposes, the naphtha, benzine, kerosene, and other light products are also of chief importance. The residuum is now manufactured into numerous articles, so that no part of the crude is wasted. It is very essential to know the percentages of each product which may be obtained from the various grades of crude. The following tables are given to indicate in a general way the comparative value of the oils of some of the Oklahoma fields.

The specific gravity of Oklahoma oils varies from 22° to 48° Baume. The heavier oils are found in the southwestern producing areas of the State.

The following specific gravities in Baume degrees are given for comparison:

Wheeler	22° to 28°
Gotebo	28° to 33°
Madill	35°
Healdton	28° to 32°
Healdton (average of 20 samples)	31.57°
Muskogee	35° to 45°
Glenn Pool	32° to 36°
Cushing	35° to 41°
Cushing (Bartlesville sand, 6 samples)	46.94°
Average of 139 samples from various pools in Oklahoma	33.96°

The following tests made of Cushing crude oil by the Cosden Refining Company, Tulsa, shows the character of the Cushing oil and will give a general idea of the materials determined by oil analyses.

Result of a test run on 30,000 gallons of 40.9° Baume Cushing crude, from Bartlesville, Wheeler, and Layton sands.

Crude benzine	36
80 per cent of this, if re-run, would be finished 60 per cent gasoline.	
Kerosene	10
Gas oil	10
Wax distillate	21
Residuum	9

Layton crude with 43.5° Baume.

Gasoline 60° to 61° gravity	50
Water white 40° to 41° gravity	12.5
Residuum or road base	33.5
Loss	4

Test of 580 bbls. Cushing crude 40° Baume from Bartlesville Wheeler and Layton sands.

207.54 bbls. crude benzine, or 35.78 per cent.
96.66 bbls. water white distillate, or 16.67 per cent.
177.68 bbls. wax distillate, or 30.64 per cent.
70.37 bbls. residuum, or 13.51 per cent.
19.7 bbls. loss, or 3.4 per cent.

Wheeler crude 41.2° Baume.

Gasoline 60° to 61° gravity	37.5
Water white 40° to 41° gravity	21.0
Wax distillate	26.0
Tar, or heavy residuum	12.0
Loss	5.5

Records obtained from the Superintendent of the Cosden Refining Company, Tulsa, Oklahoma.

J. E. Ellis, Superintendent of the Cushing Refining Company at Cushing, in discussing the crude oils of the Cushing field says that the average specific gravity of the Layton, Bartlesville, and Wheeler crudes received at his refinery is about 41°, 40.5°, and 38° to 39° Baume, respectively. The tests at his plant also show that the Layton crude is slightly better than Bartlesville crude inasmuch as it yields about 5 per cent more benzine, but since this is really the only difference, they have practically the same value. In general, the Wheeler crude proves to be of a slightly lower grade of oil than the Layton and Bartlesville crudes. Again, the Layton and the Bartlesville oils are usually of a light green color, while the Wheeler usually has a darker shade of green than that of the other two oils.

In the consideration of the character and value of oils the matter of color should be given careful attention.

The value of oils are often based upon the paraffin and asphalt content. In Oklahoma, as a rule, the oils found in the southwestern part of the State have a heavier asphaltic base than those in northeastern Oklahoma. The Muskogee oils especially, have a high paraffin base. On the other hand, many of the oils in the Oklahoma fields have both paraffin and asphaltic bases.

Average analyses showing commercial values of Oklahoma oils.

Location.	Specific gravity. (at 15°C.)	Degrees Baumé. (60°F.)	Calories per gram.	B. t. u. per pound.	Viscosity at 20° (Engler scale.)	Water. (per cent.)	Sulphur. (per cent.)
Avant	0.8617	32.49	10,828	19,490	2.3	trace	0.17
Bald Hill	.8465	35.40	10,905	19,629	2.3	0.1	.17
Bartlesville	8.604	32.71	10,883	19,585	2.3	trace	.14
Big Heart	.8547	35.58	10,904	19,589	2.3	0.0	.16
Checotah	8.610	32.60	10,910	19,638	3.5	trace	.11
Cleveland	.8388	36.94	10,921	19,658	1.7	0.0	.21
Collinsville-Claremore	.8585	33.10	10,846	19,524	2.6	.0	.20
Cushing	.8389	37.00	10,911	19,639	2.0	.0	.27
Flat Rock	.8635	32.14	10,804	19,488	3.0	.0	.26
Glenn Pool	.8445	35.83	10.879	19,582	1.8	.2	.28
Gotebo	.8595	32.89	10,925	19,665	2.9	trace	.25
Hamilton Switch	.8439	35.92	10,907	19,633	2.0	0.0	.18
Henryetta	.8720	30.55	10,761	19,370	3.3	trace	.35
Hominy Creek	.8585	33.09	10,838	19,508	2.7	0.1	.20
Madill	.8504	34.64	10,893	19,608	3.7	.0	.16
Mounds	.8635	32.14	10,826	19,488	3.5	.0	.22
Muskogee	.8304	38.60	11,009	19,817	1.5	.0	.10
Nelagony	.8615	32.51	10,827	19,489	2.4	trace	.19
Nowata	.8525	34.22	10,920	19,656	1.8	trace	.14
Okmulgee	.8530	34.13	10,850	19,531	2.6	0.1	.20
Oresa	.8665	31.58	10,836	19,506	3.0	.3	.18
Osage City	.8472	35.30	10,879	19.506	2.0	.0	.24
Pawhuska	.8710	30.73	10,807	19,453	6.6	.1	.23
Ponca City	.8144	41.91	10,998	19,797	1.2	.0	.10
Red Fork	.8457	35.57	10,928	19,670	1.9	.0	.24
Salt Creek	.8511	34.52	10,881	19,585	2.6	.0	.17
Sapulpa	.8635	32.14	10,826	19,486	2.7	.0	.25
Schulter	.8600	32.84	10,840	19,513	2.8	.0	.23
Turley	.8772	29.67	10,790	19,422	7.2	.0	.23
Wheeler	.9166	22.76	10,554	18,998	40.2	.6	1.20
Grand average	0.8544	33.96	10,870	19,567	3.9	0.0	0.23

Comparative analysis of Oklahoma oils.

		(1) Oklahoma pools. Average of 139, excluding (2), (3), and (4).	(2) Cushing pool. (Bartlesville sand only). Composite of 6 samples.	(3) Boston Pool. Composite of 5 samples.	(4) Healdton pool. Average of 20 samples.
Specific gravity at 15° C.		0.8544	0.8190	0.8330	0.8666
Corresponding gravity, Baumé		33.96	46.94	38.07	31.57
Calories per gram		10,870	10,975	10,927	10.785
B. t. u. per pound		19,567	19,755	19,661	19.414
Viscosity at 20° C. (Engler)		3.9	1.3	1.5	3.0
Water, per cent.		0.0	trace	0.1	trace
Sulphur, per cent.		0.23	0.22	0.15	0.70
Gasoline, per cent.	By weight	8.1 (59.6°B.)	*25.8 (58.5°B.)	*18.7 (58.6°B.)	6.0 (57.7°B.)
	By volume	9.4			7.0
Or	By weight	13.8 (56.3°B.)	*32.9 (55.4°B.)	*26.5 (55.4°B.)	11.2 (54.4°B.)
	By volume				
Kerosene, per cent.	By weight	38.5 (42.2°B.)	*32.0 (42.2°B.)	*32.8 (42.2°B.)	28.8 (42.2°B.)
	By volume	40.5			30.7
Or	By weight	24.2 (42.1°B.)	*20.4 (41.7°B.)	*22.1 (41.7°B.)	20.2 (41.3°B.)
	By volume				
Lubricants, per cent.	By weight	26.1 (29.1°B.)	*23.2 (29.5°B.)	*29.5 (29.5°B.)	29.7 (29.9°B.)
	By volume	25.3			29.4
Or	By weight	34.7 (30.0°B.)	*27.7 (31.7°B.)	*32.4 (31.7°B.)	33.1 (33.4°B.)
	By volume				
Residue, per cent.	By weight	25.6	17.5	16.8	34.4
Loss.	By weight	0.8	1.5	2.2	1.1
Total		100.0	100.0	100.0	100.0

*Estimated.

Average analyses of Oklahoma oils by fractional distillation.

Samples.		Naptha.						Lamp oils.					
	Pressure of mercury.	Water.	Up to 150°C.	Unrefined.	150°-175°C.	175°-200°C.	200°-225°C.	225°-250°C.	250°-275°C.	275°-300°C.	Unrefined.	300°-325°C.
	mm.	(per cent)										
Composite of 6 samples from Cushing field. Taken by O. U. Bradley, May 28, 1914......	744	trace	3.4	3.4	7.9	7.5	7.0	7.1	7.0	5.2	41.8	5.1
Composite of 5 samples from Boston pool. Taken by O. U. Bradley, May 30, 1914......	744	2.1	1.4	1.4	4.6	6.3	6.4	7.8	7.0	6.6	38.7	8.5

Average analyses of Oklahoma oils by fractional distillation.

Samples.		Lubricants.								
	Pressure of mercury.	175°-200°C.	200°-225°C.	225°-250°C.	250°-275°C.	275°-300°C.	300°-325°C.	Unrefined.	Residue.	Distilling loss.
	mm.	(per cent)								
Composite of 6 samples from Cushing field. Taken by O. U. Bradley, May 28, 1914.	13	4.5	4.5	4.5	4.5	4.2	5.5	35.8	17.1	1.6
Composite of 5 samples from Boston pool. Taken by O. U. Bradley, May 30, 1914................	8	2.9	5.0	6.0	3.8	5.7	7.0	40.9	16.8	2.1

Average analyses of Oklahoma oils, by fractional distillation.

Location.	Specific gravity. (at 15°C.)	Degrees Baumé. (60°F.)	Calories per gram.	B. t. u. per pound.	Viscosity at 20°C. (Engler scale)	Water. (per cent)	Sulphur. (per cent)
Composite of 6 samples from Cushing field. Taken by O. U. Bradley, May 28, 1914	.8190	40.94	10,975	19,755	1.3	trace	0.22
Composite of 5 samples from Boston pool. Taken by O. U. Bradley, May 30, 1914..	.8330	38.07	10,924	19,661	1.5	0.1	0.15

Table showing average monthly price per barrel of Oklahoma petroleum, January, 1906-*November,* 1915.

MONTH.	YEAR.											
	*1906	*1907	*1908	*1909	*1910	1911	1912	1913	1914 Kans.-Okla.	1914 Healdton.	1915 Kans. Okla.	1915 Heald ton.
January	$.52	$.39	$.41	$.41	$.35	$.44	$.54	$.83	$1.03*	$1.03*	$.55	$.50
Feb.	.52	.396	.41	.41	.35	.44	.60	.88	1.05	1.03*	.47	.30
March	.52	.407	.41	.41	.364	.44	.60	.88	1.05	.98*	.40	.30
April	.52	.41	.41	.41	.38	.44	.62	.88	.90	.61	.40	.30
May	.52	.41	.41	.41	.38	.46	.67	.88	.75	.50	.40	.30
June	.52	.41	.41	.41	.38	.48	.68	.88	.75	.50	.40	.30
July	.517	.41	.41	.37	.38	.48	.69	.92	.75	.50	.40	.30
August	.437	.41	.41	.35	.38	.48	.70	1.00	.75	.50	.62	.30
Sept.	.39	.41	.41	.35	.40	.50	.70	1.03	.65	.50	.76	.31
Oct.	.39	.41	.41	.35	.40	.50	.70	1.03	.55	.50	.80	.395
Nov.	.39	.41	.41	.35	.41	.50	.73	1.03	.55	.50	.91	.50
Dec.	.39	.41	.41	.35	.42	.50	.79	1.03	.55	.50	----	----
Average	.47	.407	.41	.381	.382	.471	.668	.939	.777	.637		

* Price paid for petroleum over 32 degrees Baume.

NOTE. Except where indicated, the price is that paid for all grades of petroleum.

Table showing wells completed in Oklahoma during the year 1914.

Month.	Completed.	Oil.	Gas.	Dry.
January	876	689	38	149
February	849	656	58	135
March	929	733	47	149
April	976	725	60	191
May	1,043	705	70	178
June	829	661	53	115
July	668	531	36	101
August	588	484	25	79
September	527	427	30	70
October	372	282	46	44
November	282	215	30	37
December	358	253	36	69
Total	8,297	6,451	529	1,317

Table showing wells completed in Oklahoma, January to December, 1915.

Month	Completed.	Oil.	Gas.	Dry.
January	292	213	24	55
February	293	223	20	50
March	929	733	47	149
April	976	725	60	191
May	275	215	22	38
June	276	219	18	39
July	263	206	13	44
August	285	216	14	55
September	292	180	36	76
October	485	365	40	80
November	708	498	51	159

Table showing number of wells completed in Oklahoma, 1904-1914.

Year	Completed.	Oil.	Gas.	Dry.
1904	361	243	21	97
1905	2,510	2,059	98	353
1906	2,779	2,268	163	348
1907	3,956	3,490	148	318
1908	2,844	2,458	102	284
1909	3,279	2,742	157	380
1910	3,777	3,188	181	408
1911	4,084	3,294	489	304
1912	5,993	4,712	438	843
1913	8,851	6,965	578	1,308
1914	8,297	6,451	529	1,317
Total	46,731	37,870	2,904	5,960

In the following table is given a record of the natural-gas industry in Oklahoma from 1906 to 1913, inclusive:

Record of natural gas industry in Oklahoma, 1906-1913.

Year.	Gas Produced.		Gas Consumed.			Wells.		
	Number of producers.	Value.	Number of consumers.		Value.	Drilled.		Productive Dec. 31.
			Domestic.	Industrial.		Gas.	Dry.	
1906	50	$259,862	8,391	202	$ 247,282	81	33	239
1907	107	417,221	11,038	277	406,942	99	41	344
1908	115	860,159	17,567	356	860,159	73	40	374
1909	131	1,806,193	32,907	1,527	1,743,963	97	35	454
1910	168	3,490,704	38,617	1,557	1,911,044	93	58	509
1911	204	6,731,770	44,854	1,507	2,092,603	303	143	732
1912	242	7,406,528	47,017	1,651	3,149,376	329	197	936
1913	347	7,436,389	49,308	1,793	3,740,981	423	298	1,052

In the following table are given the depth and pressure of gas wells in Oklahoma from 1909 to 1913, inclusive, by counties:

Depth and gas pressure of wells in Oklahoma, 1909-1913, *by counties.*

County.	Depth in feet.	Pressure, in pounds.				
		1909.	1910.	1911.	1912.	1913.
Hughes	1,000-2,000	--------	--------	--------	200	10-350
Carter	590-1,840					
Cherokee	600- 650	50-350	60-100	48-150	--------	--------
Comanche	380- 400					
Craig	500					
Latimer	1,575	--------	--------	40-470	--------	--------
Sequoyah	1,200					
Creek	400-2,500	50-900	40-450	20-700	40-850	20-900
Kay	436-1,600	60-385	60-375	40-390	165-365	40-650
Kiowa	350- 825	--------	35	10- 50	--------	--------
Le Flore	1,300-2,200	--------	350	300-355	350-355	300-375
McIntosh	962-2,700					
Marshall	480- 525	--------	--------	--------	150-600	150-400
Muskogee	800-1,910	130-160	50-500	18-225	15-350	10-350
Nowata	450-1,700	120-500	70-100	60-450	25-150	25-300
Okfuskee	1,450	--------	--------	--------	--------	--------
Okmulgee	760-2,600	150-700	150-800	100-700	300	80-800
Osage	900-2,200	300-850	200-650	150-650	200-780	100-700
Pawnee	1,200-2,560	160-260	150-200	200-450	40-800	--------
Rogers	380-1,250	50-550	125-530	90-480	40-525	25-500
Stephens	702- 907	--------	--------	--------	300-325	250-330
Tulsa	580-2,000	50-700	50-650	80-400	50-625	100-650
Wagoner	750-1,700	210-600	90-120	100-300	--------	--------
Washington	425-2,260	60-800	80-740	15-620	10-250	19-350

Table showing production, value, etc., of petroleum in Oklahoma, 1900-1914.

Year.	Production barrels.	Increase.	Percentage of increase.	Value.	Rank. Prod.	Rank. Value.
1900	6,472					
1901	10,000	3,528	54.51	$ 7,125		
1902	37,100	27,100	271.00	32,940		
1903	138,911	101,811	375.68	142,404		
1904	1,366,748	1,227,837	884.00	1,325,745		
1905 (e)	6,466,200	5,099,452	373.05	3,524,122		
1906 (e)	18,500,000	12,033,800	537.33	8,000,000	2	4
1907	44,300,149	25,800,149	135.27	17,824,342	1	2
1908	45,798,765	1,498,616	5.23	17,694,843	1	3
1909	47,859,218	2,060,453	4.50	17,428,990	2	4
1910	52,028,718	4,169,500	8.71	19,922,660	2	2
1911	56,069,677	4,040,919	7.77	26,451,767	2	2
1912	51,852,457	*4,217,180	*7.52	34,957,612	2	2
1913	63,579,384	11,726,927	23.63	59,581,948	2	1
1914	102,897,327	39,317,943	61.80	82,053,017	2	1

(e) Estimated. * Decrease.

NOTE: The production of petroleum in Oklahoma for the first 6 months of 1915, is estimated at 57,500,000 barrels.

GEOLOGY OF OKLAHOMA.

In Oklahoma there are 70,470 square miles of territory. Of this area about 70,000 square miles are covered by sedimentary rock outcrops. In the Arbuckle and Wichita mountains a number of pre-Cambrian granite cores are exposed, which aggregate 470 square miles. The Ozark, the Arbuckle, and the Wichita mountains have heavy beds of limestone. There are several beds of Cretaceous limestones in the southeastern part of the State. Aside from these regions the entire southern, central, and western portions of the State are lacking in this kind of formation. In general then, the limestone area may be said to be limited to the north and northeastern parts of the State. By far the largest part of the surface rocks are sandstones, sandy shales, or shales. Nearly all of the Pennsylvanian, Permian, and Cretaceous rocks are sands, shales, or varying combinations of the two. The great series of sandstones and shales that were laid down in the Permian period contain massive beds of gypsum. The rocks of Pennsylvanian and Mississippian age of eastern Oklahoma dip more and more gently as they pass westward under the younger Permian or Redbed series. In the middle-western Redbeds the normal dip changes to almost flat or slightly tilted toward the south and east. Over the entire State the deformation has been slight, except in the regions of the mountain uplifts.

In this paper the rocks have been subdivided into a number of geologic provinces. The order given below shows at a glance their relative importance in the oil and gas world, the most important being given first.

1. Pennsylvanian or Sandstone Hills region of east-central and north-central Oklahoma—subdivided on account of the difference in liothologic character into:
    - a. Area of Pennsylvanian rocks north of Arkansas River.
    - b. Area of Pennsylvanian rocks south of Arkansas River.
2. Pennsylvania-Cretaceous region south of the Arbuckle and Wichita mountains.
3. Cretaceous region located south and east of the Arbuckle Mountain region—between the Arbuckle and Ouachita mountains on the north and Red River on the south.
4. Permian region covering most of central and western portions of Oklahoma. This series of rocks is also subdivided as follows:
    - a. Non-red Permian, occurring chiefly in Kay County.
    - b. Red Permian, occupying all of western Oklahoma, except where overlaid by younger rocks.
5. Wichita Mountain region of central-western Oklahoma.
6. Arbuckle Mountain region in south-central Oklahoma.
7. Ozark Mountain or Mississippian region of northeastern Oklahoma.
8. Ouachita Mountain region in the southeastern corner of Oklahoma.

PENNSYLVANIAN OR SANDSTONE HILLS REGION.

GENERAL STATEMENT.

The area thus designated is composed of about 20,000 square miles of territory, bounded on the south by the Ouachita and Arbuckle mountain uplifts, on the west by the Permian Redbeds, on the northeast by the Grand and Arkansas rivers which approximately mark the western and southern boundaries of the Mississippian rocks. These rocks have an eastward extension into Arkansas, and continue northward into Kansas.

PENNSYLVANIAN AREA NORTH OF THE ARKANSAS RIVER.

GENERAL STATEMENT.

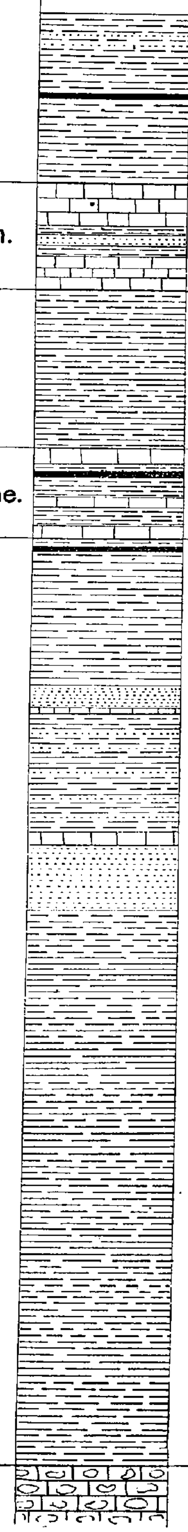
The rocks of Pennsylvanian age north of the Arkansas River are made up of shales, sandstones, and a few limestones. In a general way the shale outcrops conform to the valleys, while the sandstones and limestones cause eastward-facing scarps. The area slopes gently to the south and east, so that the escarpments actually rise one above the other, like stairsteps, in going westward. This area contains a number of important oil and gas fields, and is made up of all of Washington, Nowata, Rogers, and Wagoner counties, a large part of Tulsa, Craig, Mayes, Osage, and Kay counties, and a small portion of Ottawa County.

STRATIGRAPHY.

The following series, beginning with the youngest, is exposed in this area. The last three named formations at the top of the series have been little studied in Oklahoma. They are given here chiefly because they play a part in the oil situation of Kansas.

	Geologic section.	Feet.
17.	Undescribed series in Osage Nation	700
16.	Elgin standstone	50-140
15.	Oread limestone	0- 17
14.	Buxton formation	450-600
13.	Wilson formation (Avant limestone)	280-400
12.	Dewey limestone	23
11.	Unclassified shales and sandstones	75
10.	Hogshooter limestone	10
9.	Coffeyville formation	370
8.	Lenapah limestone	20
7.	Nowata shale	100
6.	Altamont limestone	35
5.	Bandera shales	0-120
4.	Pawnee limestone	43
3.	Labette shale	120
2.	Ft. Scott formation	38- 65
1.	Cherokee formation	450-500

Generalized Section of the Lower Pennsylvanian of North-East Oklahoma.



Formation Name	Columnar Section.	Thickness in Feet.
Nowata Shale.		50-600'
Oolagah Formation.		80-150'
Labette Shale.		30-200
Fort Scott Limestone.		50-135'
Cherokee Shales.		450-1000'
Mississippian.		

F.G.

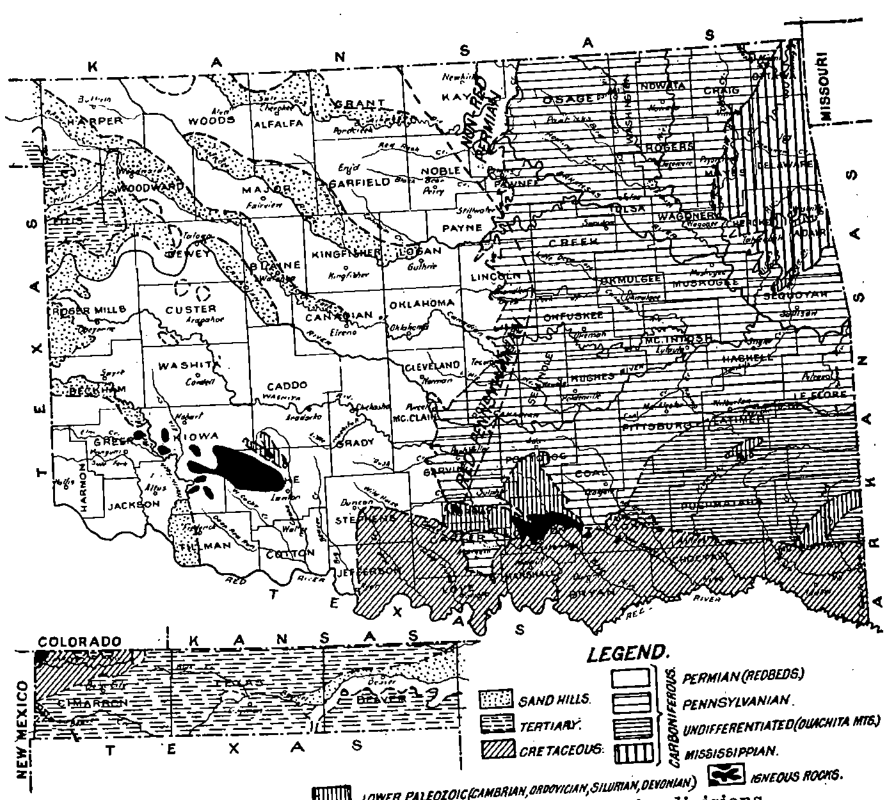


Figure 3.—Map of Oklahoma showing geologic divisions.

1. *Cherokee formation.*—The Cherokee formation consists of a series of shales, sandstones, limestones, and coal beds. In the northern part of Oklahoma the formation, which measures about 450 feet, thickens rapidly to 1,000 feet at Pryor Creek. Near Muskogee it has been correlated with the Winslow and Boggy, which aggregate 1,500 feet. Owing to the importance of this formation in a discussion of oil and gas, the following section made by Ohern and Wolf is copied verbatim: *

Section from 1 mile east of Pryor Creek to Claremore.

	Feet.
Shale, with a few interbedded sandstones	135
Massive, medium-grained sandstone	17
Shaly sandstone	3
Argillaceous, heavily-bedded, fossiliferous limestone	2½
Shaly sandstone	8
Massive medium-grained sandstone	37
Bluish shale	35
Carbonaceous shale, capped by 6 inches of ferruginous, siliceous limestone	3
Gray, fine-grained sandstone	7
Arenaceous shale	70
Alternating shales and sandstones	70
Argillaceous, fossiliferous limestone	8
Massive, medium-grained sandstone	14
Bluish shale, weathering to a light yellow, and a few interstratified sandstones	550
	960

The Cherokee formation is probably the source of most of the production from northern and northeastern Oklahoma The Bixler, Markham, Barnett, Bartlesville, and Burgess sands all lie in this series of sandstones and shales. With these are correlated the Squirrel, Glenn, Tucker, Squaw, Tanaha, and Meadows sands. Smith* would place the Dutcher and Rhodes at this horizon. Of these sands the Bartlesville is of most importance. Probable outcrops of this sand have been located east of Welch, northwest of Vinita, and at Bluejacket. From drill records it has been recognized as far westward as the Ponca City field, and southward in the fields of Pawnee, Creek, and Tulsa counties. Further investigation may prove its presence over an even larger area.

2. *Fort Scott formation.*—The Fort Scott consists of a

*Ohern, D. W., Research Bull. State Univ. Oklahoma, No. 4, 1910, pp. 12-13.
*Smith, Carl D., Bull. U. S. Geol. Survey, 541-B, plate III.

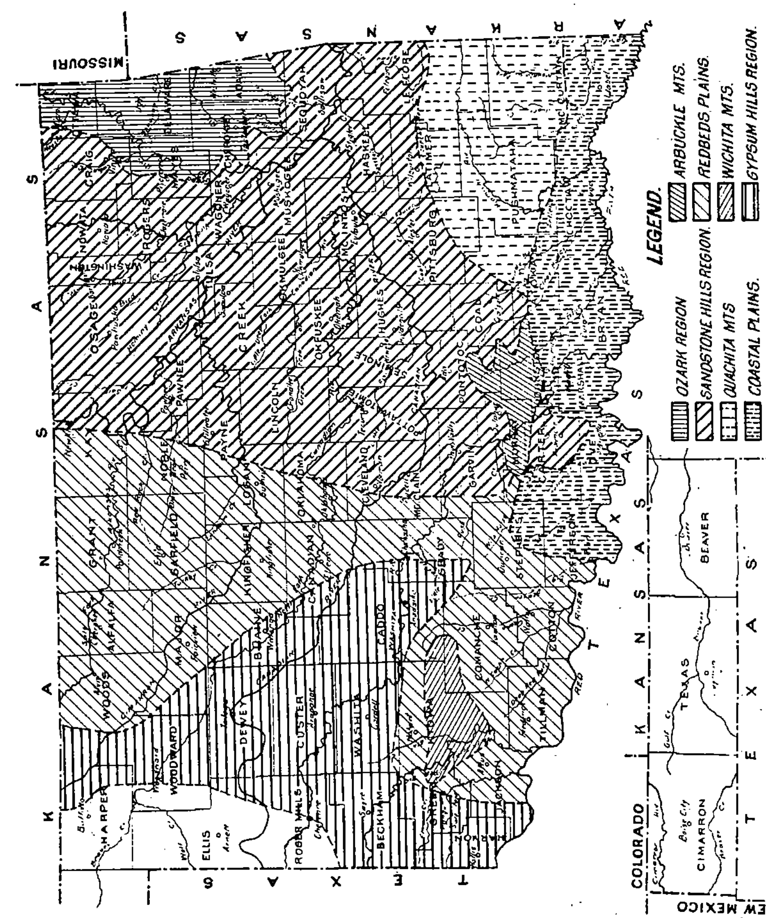


Figure 4.—Map of Oklahoma showing physiographic provinces.

lower limestone, 10 feet thick, a shale parting of 8 feet, and an upper limestone, 20 feet thick. Ohern* has discussed these beds under the title of Claremore formation. He also gives the following section of the Claremore or Fort Scott, from 3 miles west of the town of Claremore:

Section 3 miles west of Claremore.

	Ft.	In.
Massive, fossiliferous limestone, top eroded in front of schoolhouse	5	3
Carbonaceous shale, seen at cross roads	2	6
Cherty limestone, weathering to yellowish, spongy, siliceous fragments, fossils abundant	2	8
White, massive, fossiliferous sandstone	4	8
Shale	5	6
Hard sandstone	2	0
Shale	21	6
Chert, giving polygonal fracture on surface	0	4
Shale, weathering to buff	0	10
Massive, bluish, fossiliferous limestone	3	0
	48	3

Careful summing up of the data at hand shows that the Wheeler sand of Cushing and the Oswego sand of the Bartlesville pool are probably located in this formation. Carl D. Smith* has placed the 1,090 and 1,150-foot sands of Glenn pool also at this horizon.

3. *Labette shale.*—Adams of Kansas first applied the name Labette to the great mass of shales above the Fort Scott and below the Pawnee. In thickness they measure fully 120 feet. Lithologically, the formation consists of thick shales, with occasional heavy sandstones. A fine-grained, buff sandstone has been found always near the top of the formation. Northeast of Nowata is one of these heavy sandstone outcrops. It has been fairly well determined by Hutchinson, Ohern, and others, that the thickness increases from the Kansas line southward, being almost 200 feet, near Cody's Bluff.

4. *Pawnee limestone.*—The Pawnee limestone is generally massive and fine-grained. In Kansas it varies from 8 to 52 feet, while in Oklahoma the thickness is about 43 feet. At Talala the shale above the Pawnee pinches out, and the Pawnee and Altamont join to form the "Big lime." Further south this term is applied to the Oologah formation.

5. *Bandera shales.*—Immediately above the Pawnee

*Ohern, D. W., Research Bull. Univ. Oklahoma, No. 4, 1910, pp. 15-17

*Smith, Carl D., Bull. U. S. Geol. Survey, No. 541-B, 1913, plate III.

limestone is a thick, lenticular mass of bluish to black shales, which measures fully 120 feet at the Kansas line, but thins rapidly to the southward. At Nowata it has thinned to approximately 20 feet, while at Talala, 12 miles south, in northern Rogers County, it disappears entirely.

The Peru sand of the Dewey-Bartlesville field probably comes within this formation. It is rather unlikely, however, that the sands called the Peru further south are in this group of shales, since they thin out and disappear entirely. Whether the formation thins equally as fast to the west is a matter of supposition.

6. *Altamont limestone.*—The Altamont limestone which lies just above the Bandera shales is uniformly about 30 feet thick. In character it is highly siliceous, hard, massive, and bluish. It outcrops along the bank of the Verdigris River, from Nowata to Oologah. The frequent occurrence of the fossil form *Squamularia perplexa* (McChes.) is a good means of identification.

7. *Nowata shales.*—The Nowata shales occupy a greater surface exposure than most Pennsylvanian formations. The outcrop increases in width from a narrow band at the Kansas line to 2 miles at Nowata, 8 miles at Tulsa, and 10 miles or more at Arkansas River. These shales increase in thickness from 50 feet at the State line to 130 feet at Nowata, and possibly 600 or more feet at Tulsa, and to the southward even greater. These thicknesses have been determined by the drill. In lithologic character the formation is essentially clay, but arenaceous layers are not infrequent. In color they vary from bluish to greenish or even buff, depending on the amount of oxidation. A persistent horizon throughout the extent of these shales is a seam of coal 20 to 30 inches thick, near the middle of the formation. This coal, according to Taff,* extends far south of the Arkansas River.

It is more than probable that the Wayside sand of the Bartlesville region is an arenaceous member of these shales.

8. *Lenapah limestone.*—The Lenapah limestone lying between the Nowata shales and the Coffeyville formation is named from the town of Lenapah in Nowata County. Here the bed of limestone is typically and extensively exposed. The Lenapah over a large part of the Nowata quadrangle forms the cap rock on the hills. Over the northern area of outcrop it extends over a large surface, because it occupies a dip slope. South of Nowata the outcrop is narrow, but continues on as far south as Buck Creek.

*Taff, Joseph A. Bull. U. S. Geol. Survey, No. 260, 1905, pp. 396-397.

In general, the formation may be said to consist of a single, dense, blue semi-crystalline limestone with fossils. On weathering, it gives no chert. The thickness varies from 8 feet in southern Kansas to fully 20 feet in northern Oklahoma, and finally to 3 feet or less in the region south of Nowata.

9. *Coffeyville formation.*—The Coffeyville formation of the Kansas geologists lies between the Lenapah and Hogshooter limestones. Following the general rule, it thickens from the Kansas line southward, the average thickness being 370 feet. The formation generally consists of shale, but near the top sandstones are prominent. Ohern* has suggested the name Curl formation for the above series.

Two sands, the 225-foot and 400-foot, of the Bartlesville, Dewey, Copan region are apparently in this formation. The former is in the upper part, while the latter seems to come near the middle. The oil of the Cleveland sand apparently comes from a member near the base. It seems probable that these are three separate horizons in the same formation.

10. *Hogshooter limestone.*—East of Bartlesville in Hogshooter Creek is a 10-foot limestone bearing the same name. The Hogshooter limestone enters Oklahoma 2 miles west of Coffeyville and continues southward to a point near Delaware. In character it is usually a single bed, massive in the north, but more or less thin-bedded to the southward.

Careful work has correlated the Hogshooter with the Lower Drum of Kansas. Fossils are abundant.

11. *Unnamed.*— Above the Hogshooter limestone and below the Dewey limestone is a thick series of shales, with heavily bedded sandstone members and a few limestone lentils. Ohern mentions this series under the name "Copan Member."

Some regard these as the equivalent of the middle part of the Drum limestone which splits just west of Coffeyville, Kansas. It seems likely, however, that the two references are not the same in scope.

An examination of well records and a correlation of formations places the Layton sand of the Cushing field at this horizon. The data at hand show this to be the only oil sand of note at this point in the geologic section.

12. *Dewey limestone.*—The Dewey limestone extends from north of Wann south to beyond the limits of the Nowata quadrangle. The lens varies from 3 feet in its northern extension to a maximum of 25 feet near Dewey. In character it is a bluish, semi-crystalline limestone, often massive. A

*Ohern, D. W., Research Bull. State Univ. Oklahoma, No. 4, 1910, pp. 26,28.

means of recognizing it is by the abundance of fossils—especially *Campophyllum torquium.* Good exposures are to be found in Bartlesville, near Dewey, and on the bluffs west of Ochelata and Ramona.

13. *Wilson formation.*—The Wilson formation of the Independence quadrangle thickens from 280 feet to about 400 feet in the Pawhuska quadrangle. This is an approximate section from eastern Osage County: *

Section of Wilson formation in eastern Osage County.

	Feet.
Sandstone, exposed near Torpedo	30
Shale, thin sandstones, and thin limestones	240
Limestone (Avant)	0- 35
Shale, thin sandstone, and limestone	45- 90
Average total	355

The chief sandstone lens, about 30 feet thick, lies nearly 100 feet below the top of the formation. The chief limestone, typically exposed near Avant, is known as the Avant limestone member.

The 1,060-foot sand of Cleveland is probably in this formation, or its equivalent.

14. *Buxton formation.*—The Buxton formation, following the general rule, thickens as it passes southward into Osage County, where it measures fully 550 feet. The following is a generalized section given by Ohern in Bulletin No. 16 of the Oklahoma Geological Survey:

Section of Buxton formation in Osage County.

	Feet
Shale, sandy shale, and sandstone	140-155
Sandstone, exposed near Nelagony	50
Limestone, lentil	20
Shale, sandy shale, and thin sandstone	100
Sandstone, exposed near Bigheart	140
Shale and sandstone	180

The series has been traced southwest to the border of Osage County, and is believed to extend into Creek County.

The 50-foot sandstone shown in the above section is prominent near Nelagony. The limestone, though having a maximum thickness of 20 feet, plays out rapidly in all directions.

After a careful examination it is believed that several oil and gas sands are in this formation. It seems probable

*Ohern, D. W., The Ponca City oil and gas field, Bull. Okla. Geol. Survey, No. 16, 1912, p. 14.

that the 900-foot stray-sand above the Layton in the Cushing field, the 500-foot sand of the Cleveland field, the 1,375 and the 1,550-foot Ponca sands, and probably some in the Newkirk field are all in this formation. The question of correlation which follows naturally will be discussed under separate heading. The effort here is to locate these sands in the geologic column.

15. *Oread limestone.*—Lying immediately above the Buxton formation is the Oread limestone which caps Mt. Oread upon which Kansas State University stands. Throughout central Kansas the formation is said to be 40 to 60 feet in thickness. At the State line it is 17 feet. In the next 11 or 12 miles south it pinches out entirely. In southern Kansas and northern Oklahoma it forms characteristic dome-like hills with small irregularities. The stone breaks into large slabs.

16. *Elgin sandstone.*—Just above the Oread limestone of Kansas is a massive sandstone named the Elgin. It extends from Kansas southward through the Pawhuska quadrangle, across the Arkansas River to near Cleveland. Here it caps the hills. A few miles north of the Osage-Kansas line at Elgin this formation, which is made up of two sandstone members separated by a sandy shale, is about 140 feet thick. By following the sandstone southward it is found to become thinner, with little or no shale parting. In southern Osage County it is usually a single massive sandstone 50 to 75 feet in thickness.

It seems, from a careful study of logs, dips, and formations, that the 1,000-foot sand of the Ponca City field and the 970-foot sand of the Newkirk pool are both in the Elgin sandstone, or its equivalent.

17. *Undescribed series.*—Of formations outcropping in western Osage County little is known, except that they are composed of rapidly alternating shales, sandstones, and thin-bedded limestones. This series of sediments makes up a section about 700 feet in thickness. These unnamed formations have for their equivalent the following series in Kansas and represent the interval between the Elgin sandstone and Wreford limestone.

Kansas section representing the interval between the Elgin sandstone and Wreford limestone.

		Feet
18.	Garrison formation	140-160
17.	Cottonwood limestone	6
16.	Eskridge shales	30- 40
15.	Neva limestone	10.
14.	Elmdale formation	130
13.	Americus limestone	8
12.	Admire formation	50
11.	Emporia lime	30
10.	Willard shales	80
9.	Burlingame limestone	29
8.	Howard limestone	2- 7
7.	Severy shales	40- 60
6.	Topeka limestone	20- 25
5.	Calhoun shales	50
4.	Deer Creek limestone	20
3.	Tecumseh shales	40- 70
2.	Lecompton limestone	15- 30
1.	Kanwaka shales	50-100

Not all of the above section is Pennsylvanian. The Permian-Pennsylvanian contact has been drawn by Beede below the Neva limestone at the Elmdale horizon. It has been estimated by Ohern* that the entire thickness between the Elgin sandstone and Wreford limestone is less than 700 feet. Some further discussion will be entered into in considering the area of non-red Permian.

STRUCTURE.

In general, the structure north of Arkansas River is a monocline, with a westward dip of approximately 30 feet per mile. The rate of dip increases to the south and can often be detected with the naked eye, or by the use of a clinometer. In some cases where the westward dip is not broken by a local east dip the strata flatten out and then dip more steeply to the west than normally. The result is practically the same, in the first case forming a small anticline, and in the latter case a small monocline, on the larger structure. In a few cases the anticlines are shortened into domes. It is possible in some of the oil fields for the oil to accumulate in sandstone lenses instead of in structural features. Detailed studies of the formations and structure are o be published by the United States Geological Survey coverng most of the region just briefly described. This informaion, however, is not yet available.

PENNSYLVANIAN AREA SOUTH OF THE ARKANSAS RIVER.

GENERAL STATEMENT.

The region of Pennsylvanian rocks south of the Arkansas River is distinctly marked off from the northern area by the absence of limestone, and the increased occurrence of sandstone and coal. These rocks contain all of the principal coal

*Ohern, D. W., Bull. Oklahoma Geol. Survey, No. 16, 1912, p. 12.

beds of this State. The abundance of resistant sandstones has caused this section to be more deserving of the name Sandstone Hills region than that farther north.

The area extends from the Ouachita Mountains and Choctaw Fault on the south to the Arkansas River on the north. It embraces all or a part of the following counties: LeFlore, Latimer, Payne, Haskell, Okmulgee, Muskogee, Pawnee, Tulsa, Creek, Lincoln, Pottawatomie, Garvin, Pontotoc, Seminole, Okfuskee, McIntosh, Coal, Pittsburg, Atoka, and Hughes.

Physiographically, the region can be said to lie within the drainage basin of the Arkansas River. The tops of the hills are broad and flat. The rivers are generally broad and sluggish. Detailed study of the region has shown that the structure and general topography are closely related. The larger hills and mountains are synclinal, while many of the smaller features are similarly related.

STRATIGRAPHY.

The rocks exposed in the southern part of this region have been carefully studied by Taff,* and a detailed discussion is given in his report. Additional work has been done by various members of the State Survey. The following section shows the formations exposed. The table from top to bottom reads from youngest to oldest.

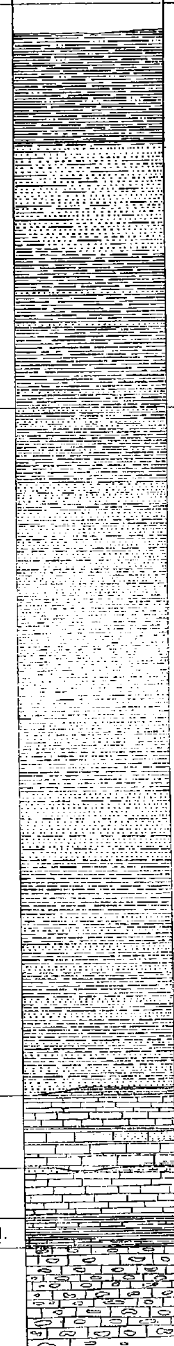
Geologic section.

		Feet.
14.	Seminole conglomerate	50
13.	Holdenville shale	260
12.	Wewoka formation	700
11.	Wetumka shale	120
10.	Calvin sandstone	200
9.	Senora formation	500
8.	Stuart shale	90- 280
7.	Thurman sandstone	80- 250
6.	Boggy shale	2,000-3,000
5.	Savanna sandstone	1,200-1,500
4.	McAlester shale	2,000-2,500
3.	Hartshorne sandstone	100- 200
2.	Atoka formation	2,000-7,000
1.	Wapanucka limestone	100
	Total (approximately)	14,900

*Taff, Joseph A., and Adams, Geo. I., Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, pp. 271-279.

GENERALIZED SECTION
FOR THE
MUSCOGEE QUADRANGLE.

System.	Period.	Formation Name	Columnar Section.	Thickness in feet.
Carboniferous	Pennsylvanian.	Boggy Formation.		500+
		Winslow Formation.		800-1000
		Unconformity.		
		Morrow Formation.		100-120
		Unconformity.		
	Mississippian.	Pitkin Limestone.		60±
		Fayetteville Formation.		20-60
		Boone Formation.		200+



After J.A.Taff.

F.G.

Above the formations given in the section and farther west is a series of unnamed shales and sandstones. Some writers consider them a part of the Permian, because of their red color. It is probable that a portion, however, will prove to be Pennsylvanian. The names used here are applicable only to the southern part of the area. A preliminary study of some of the region near the Arkansas River tends to show that some of the formations are continuous throughout the region.

1. *Wapanucka limestone.*—The oldest formation of the Pennsylvanian so far studied in Oklahoma is the Wapanucka limestone. This limestone at the top is white, massive, and sometimes oolitic. Below these constant beds a massive, white limestone occurs, whose thickness and character are variable. Still lower in the formation near its base, there is a series of calcareous and cherty sandstones. The whole formation which measures 100 feet at the eastern extremity of the outcrop, thins to 30 feet or less along the westward extension. The oolitic portions of this limestone are being used as building stone, and have proved to be very good. The largest quarry using this stone is at Bromide.

2. *Atoka formation.*—The Atoka formation, a few miles west of Heavener, measures between 6,000 and 7,000 feet in thickness. Not all is exposed. So far as could be examined, shales and sandstones constitute the whole formation. The sandstones are usually about 100 feet thick and the separating shales 1,000 to 1,200 feet thick. The shales have small sand stone beds occurring throughout them. The sandstones are generally light-colored, gray or brown, and thin-bedded. In most cases small shale partings separate the layers of sandstone. The hills and pronounced ranges are due to sandstone outcrops. The shales, where exposed, are bluish clays with ferruginous sandstone concretions. In texture the sandstones are medium to fine-grained.

The sand of the Mansfield (Ft. Smith) gas field is in the Atoka formation. Recent drilling near Atoka has revealed other pay sands in this formation at depths of 312-360 feet and 404-446 feet.

3. *Hartshorne sandstone.*—The Hartshorne sandstone is the horizon of the lowest and one of the most valuable beds of coal found in Oklahoma. It is made up of 100 to 200 feet of sandstone, shaly sandstone, shale, and coal. The gradation of the Hartshorne shales into those of the underlying Atoka makes the line of contact difficult of determination. For the most part the shales and sandstones are thin-bedded, varying from thin plates to massive strata 3 feet thick. The upper portion has

the more massive beds. The sandstones grade into the shales above and below through shaly sandstone beds. The sandstones are fine-grained, hard, and brown on the weathered surfaces.

The lower Hartshorne coal lies approximately 50 feet below the McAlester shale, just above the Hartshorne sandstone, and the upper coal bed at the base of the McAlester. The formation outcrops around the Backbone and Milton anticlines* and west of Heavener on the ridge which forms a pronounced eastward loop on the Heavener anticline.

It is especially important in this connection, because it is the horizon of the gas-producing stratum of the Poteau field.

4. *McAlester shale.*—The McAlester shale lying above the Hartshorne sandstone is composed of shale, sandstone, and clay, with a maximum thickness of 2,500 feet. Shales make up the bulk of the formation, but lenticular sandstones and at least two workable beds of coal are worthy of mention. The lenses vary from infinitely small to several miles in length, with considerable thickness. The great mass is made of laminated, blue and black clay shales. The softness of the clay shales prevents fresh exposures being of frequent occurrence. Two sandstones separated by 400 feet of shale occur near the base, and two or more thin sands are in the upper portions. Two coals occur, the one near the base and the other 650 feet below the top. This is the McAlester bed. Both coals are being mined.

The McAlester shale areas are characterized by flat prairie lands, marked by a large number of peculiar, hummocky mounds. The sandstones usually form the hills.

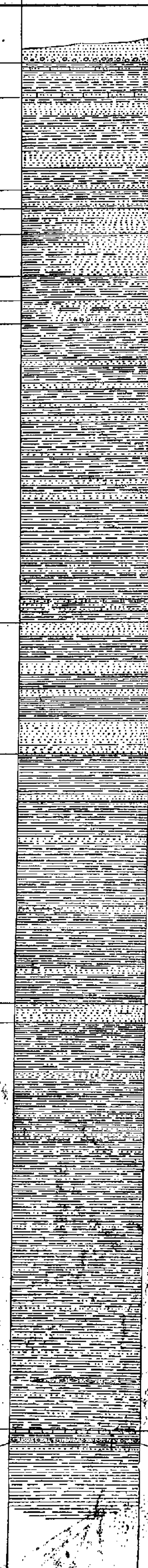
5. *Savanna sandstone.*—Three prominent sandstone members separated by shales make up the Savanna sandstone. The upper sandstone is 200 feet thick. In some places five or more sandstones are present. These, with intervening shales, make up a total thickness of 1,200 to 1,500 feet. These beds are so nearly alike in appearance that they can be distinguished only by their thickness, position, or fossil remains, which are sometimes present. Generally, they are gray or brown on weathered surfaces. In texture they are fine and compact, with occasional inclusions of chert.

The sandstones are thicker and generally harder near the eastern exposure, with the cherty conglomerate most abundant. Siliceous limestones are often associated with the uppermost Savanna in the eastern part of the Coal-

*Snider, L. C., Oklahoma Geol. Survey, Bull. No. 17, 1914, p. 8.

Generalized Section
for the
Coalgate Quadrangle.

Period	Formation Name.	Columnar Section.	Thickness in feet.
Carboniferous.	Seminole Conglomerate.		50+
	Holdenville Shale.		260
	Wewoka-Formation.		700
	Wetumka Shale.		120
	Calvin Sandstone.		145-240
	Senora Formation.		140-485
	Stuart Shale.		90-280
	Thurman Sandstone.		80-260
	Boggy Shale		2000-2600
	Savanna Sandstone		1000
	Mc Alester Shale		1800-2000
	Hartshorne Sandstone.		150
	Atoka Formation.		3100
	(Chickachoc Chert Lentil.)		(0-80)
	Wapanucka Limestone.		100
Carboniferous and probably Devonian.	Caney Shale		600+



After J.A. Taff.

F.G.

Pennsylvanian paleogeologic map of Oklahoma (exclusive of
andle) showing rocks below Pennsylvanian in subsurface (modif
Jordan, 1962). Stipple areas denote Devonian through L
rian; pattern in Wichita uplift region denotes Middle Cambr
usive and flow rocks; V-pattern represents Precambrian grani

gate quadrangle. The sandstone outcrops are marked by wooded ridges. No coal of importance has been found in this formation.

6. *Boggy shale.*—Above the Savanna sandstone is a great thickness of shale and irregularly distributed, thin-bedded sandstone, termed the Boggy shale. To the casual observer it appears to be more of a sandstone than shale, but in reality the sandstone makes up less than one-sixth of the entire thickness of from 2,000 to 3,000 feet. This is due to the fact that the sandstones weather more slowly. The result is, the steeper slopes of the mountains are covered by sandstone boulders, remnants of the sandstone ledges. Exposures of the shale are rare. The formation occurs along the slopes of Cavanal, Sugarloaf, Poteau, and Sans Bois Mountains, and also over large areas to the north.

7. *Thurman sandstone.*—The Thurman sandstone marks a change in sedimentation. Whereas the older deposits had been fine shales, they are now followed by a deposit of coarse, white chert and quartz. Fifty feet of the total 80 to 250 feet is composed of this conglomerate. The sandstones of the upper part become finer and thinner in texture to the west. They also include small shale beds and some thin, impure fossiliferous limestones. The formation throughout its area of outcrop dips 60 to 100 feet per mile. The harder members make rugged, stony, high points, usually densely wooded.

8. *Stuart shale.*—Above the Thurman sandstone are 100 to 275 feet of thin-bedded, shaly sandstone and shales interstratified, called the Stuart shale. The maximum development occurs in the northeastern portion of the Coalgate quadrangle. The Stuart shale is composed of an upper and lower shale, separated by a sandstone member which varies from 10 to 50 feet. The lower shale is usually 120 feet thick, with a local chert conglomerate lentil at the center, until near the southwest of the Coalgate quadrangle. It is composed chiefly of black and bluish shale. The upper member, 50-120 feet in thickness, is bluish in color. The upper shale outcrops along steep scarps, instead of upon level, grassed prairies, as does the lower member.

9. *Senora formation.*—The Senora formation in the northwest corner of the Coalgate quadrangle measures almost 500 feet in thickness. The thickness decreases toward the southwest. The sediments consist of sandstones and shales interstratified, with the former thickening to the northeast. The sandstones are frequently divided or completely replaced by shale members. Lithologically the shales are bluish clays and

brownish sandy shales, while the sandstones are generally fine-grained and gray or reddish brown in color.

10. *Calvin sandstone.*—The Calvin sandstone is a deposit of thin-bedded sandstones, with some shales, which measures 140 to 240 feet in thickness. The lower 140 feet is composed of massive, rather soft sandstone. The upper 60 to 100 feet takes on more of the character of the overlying formation, being a series of sandstones and shales, with the shales increasing in proportion to the nearness of the other formation. The outcrop of this sandstone is usually very rugged.

11. *Wetumka shale.* Above the Calvin sandstone is the Wetumka shale, composed almost wholly of friable, laminated clay shales. The central part of this 120-foot formation consists of thin, shaly sandstones.

An absolute line cannot be drawn between the Wetumka and Calvin sandstone, since the shaly beds of the latter grade into the succeeding shales of the former. In some places the single name Wetumka is given to the entire series here discussed under the two names.

12. *Wewoka formation.*—The Wewoka formation consists of 700 feet of massive, brown, friable sandstone, with interstratified soft, blue clays and an occasional limestone. The separate beds of sandstone are sufficiently large to be mapped, were it not for the friable nature of the beds which obscure them. Near the base is a local sandy-chert conglomerate, which is best exposed along the bluffs of Boggy Creek valley. In the Canadian valley to the eastward this phase has almost disappeared.

In the 120 feet of shale just above the sandy conglomerate are abundant fossil remains while the succeeding 110 feet of massive, friable sandstone is free from such remains. The next bed above consists of 130 feet of soft blue, fossiliferous clay shale. Here many shells are perfectly preserved. Other beds occur still higher. A 60-foot sandstone, 45-foot shale, and 100-foot sandstone, complete the section.

13. *Holdenville shale.*—Above the Wewoka formation lies the Holdenville shale. This formation consists of 260 feet of friable, blue clay, with local thin beds of shelly limestone and calcareous sandstone. The shales are rarely exposed.

14. *Seminole conglomerate.*—The Seminole conglomerate where exposed in its full thickness is about 150 feet. A small area, 50 feet thick, of the lower portion is exposed in northwestern Coalgate quadrangle. This part is composed of laminated, subangular chert, with some quartz, cemented together by a fine brown, ferruginous sand. The upper portion consists almost wholly of brown sandstones.

STRUCTURE.

The structure of this region very closely resembles that north of the Arkansas River; that is, it is a monoclinal dip to the west, interrupted occasionally by gentle folding. The crumpling or local changes of dip increase in intensity upon approaching the Ouachita Mountain uplift, resulting in crumpling, up-ending, and faulting. The region just south of the Arkansas River has not been worked out carefully, so the details of structure are not so well known as farther south, where both the Oklahoma and Federal Surveys have done considerable work. Careful discussions of the latter region are given by J. A. Taff in the Nineteenth and Twenty-first Annual Reports of the United States Geological Survey, and by L. C. Snider in Bulletin No. 17 of the Oklahoma Geological Survey. These reports contain maps and diagrams illustrating the principal structural features, so that what is said here is in a way only a brief summary of what might have been included.

THE PENNSYLVANIAN-CRETACEOUS REGION.

GENERAL STATEMENT.

Concerning the area between the Arbuckle and Wichita mountains on the north, Red River on the south, Criner Hills on the east, and the Chicago, Rock Island & Pacific Railway on the west, the information for the most part is general, and owing to differing opinions, is in a somewhat chaotic condition. Formerly the whole area was considered a part of the Redbeds. Recent investigation by members of the Survey and others has not only caused the previous assumption to be doubted, but has proved that in certain localities the evidence points overwhelmingly toward a belief in the presence of Cretaceous sediments.

The topography which slopes from the northwest to the southeast seems to be closely allied to the structure. As a result, the streams occupy the synclines, while the high points of structure and topography likewise conform. The area drains southward into Red River through Walnut Bayou and Simon and Mud creeks and their tributaries.

STRATIGRAPHY.

The rocks exposed in this region are Cretaceous and Permian in age, with a few small areas covered by Pleistocene or recent deposits.

The sub-surface formations of this region are probably Pennsylvanian. Owing to the fact that outcrops of these rocks are not recognized except in the region to the east and north, our knowledge is limited to what can be determined from a study of well records and materials from various wells. The sediments of this age are much the same in character as those in the northeastern third of the State, being composed chiefly of shales, sandy shales and sandstones, with an occasional limestone or calcareous shale or sandstone. The shales generally are blue or gray in color and friable in texture. A comparative study of the section here, revealed through well logs, and the Glenn formation which outcrops to the north and east along the foothills of the Arbuckle Mountains, shows a sufficient degree of similarity in lithologic character to warrant the idea that they are the same or that the latter formation is at least contained in the section. The dip of the rocks also points to probability of the presence of these sediments in this area.

The following logs from two of the wells drilled, the one near the southeastern and the other near the northwestern end of the field, show the character of the formations:

Baker, No. 1, sec. 19, T. 6 S., R. 4 W., Grady , Okla.

Character of rock.	Thickness.	Depth.	Character of rock.	Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Turf	5	5	Blue shale	50	600
Red clay	45	50	Sand—salt water	30	630
Blue shale	50	100	Sandy blue shale	230	860
Red rock (sandstone mostly)	200	300	Sand—salt water	28	888
			Blue shale	72	960
Blue shale	50	100	Sand, dry	7	967
Water sand, fresh	30	350	Blue shale	263	1,
Blue shale	50	500	Sand—salt water	15	1,
Red rock (probably sandy shale)	50	550	Blue shale—caves	75	1,
			Sand—salt water	15	1,

Mollie Ingram, No. 1, sec. 17, T. 4 S., R. 3 W.

Character of rock.	Thickness.	Depth.	Character of rock.	Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil	5	5	Sand and salt water	25	895
Red mud	65	70	Brown shale	105	1,000
Blue mud	20	90	Sand and salt water	30	1.030
Red mud	55	145	Blue slate	20	1,050
Sand and water (s.w.)	15	160	Brown shale	50	1,100
Red shale	10	170	Blue shale	35	1,135
Blue shale	20	190	Sand and salt water	20	1,155
Red shale	35	225	Blue shale	5	1,160
Sand and water (s.w.)	25	250	Red shale	20	1,180
Red shale	24	274	Sand and salt water	25	1,205
Sand and water (s.w.)	26	300	Pink shale	35	1,240
Red shale	15	315	Brown shale	20	1,260
Sand and salt water	45	360	Sand and salt water	12	1,272
Red shale	70	430	Pink shale	8	1,280
Sand and water (s.w.)	45	475	Blue shale	10	1,290
Red shale	81	556	Sand and salt water	10	1,300
Sand and salt water	21	557	Blue shale	22	1,322
Red shale	68	645	Sand and salt water	11	1,333
Sand and salt water	30	675	Sandy lime	8	1,341
Blue shale	20	695	Dark blue shale	12	1,353
Red shale	65	760	White shale	12	1,365
White shale	15	775	Brown shale	15	1,380
Lime shell	5	780	Sand and salt water	20	1,400
Sand and salt water	65	845	Blue shale	105	1,505
Blue shale	10	855	Sand and salt water	18	1,523
Sand and salt water	10	865	Blue shale	42	1,656
Blue shale	5	870	Sand and salt water	35	1,600

Other wells show the presence of more sandstone and limestone layers, but all show a preponderance of shale, with the color chiefly red above and blue or gray in the lower depths.

Laid down upon the older rocks were beds of Permian rocks. These throughout consist chiefly of reddish colored sandstones, shales, and combinations of the two. Since the Permian rocks are younger than the Pennsylvanian just described, it follows that they are on top, as there have been no great movements of the surface strata. A casual glance at the first 500 or 700 feet of the above well records shows that the rocks are probably Permian, since they are predominantly reddish. An examination of the formations below the 550-foot mark shows a little difference in color. In studying the outcropping formations the same means of differentiation may be used over local areas.

To the south of the Healdton oil field, nearer Red River, the Permian Redbeds material seems to pass under still younger rocks. These sediments consist chiefly of white or light-colored pack-sands and clays, with an occasional conglomeratic layer made up of quartz pebbles. These beds are supposedly Cretaceous, and probably belong to the Trinity sand horizon. Fossils are few, with the exception of silicified wood which is very abundant, but a fairly careful correlation of the formations in Oklahoma with those in north Texas, which are known to be Cretaceous, lends added strength to this contention. The occurrence of a number of remnants of this formation in the neighborhood of the oil field points to a more widespread deposit than was first thought.

About a year ago the western limit of the Trinity sands in Oklahoma was mapped as extending only a short distance to the west of Walnut Creek bayou in central Love County, and extending north to the township line running about midway between Ardmore and Marietta. In the fall of 1913 field work was begun in the region about Healdton and to the south, on the assumption that all the surface rocks were Permian. It was found that many of these rocks differed greatly in lithologic character, position, and structural conditions from those of known Permian age. After a careful examination of the rocks and field correlations with those of Cretaceous age, it was decided that much of the surface rock in the area being investigated is Cretaceous. In order to make a more definite comparison, a study was made of the Cretaceous rocks on the Texas side of Red River, directly south of the Healdton field. About 4½ miles southwest of the town of Leon, Okla., is a crossing on Red River known as Rock Bluff Ferry. On the Oklahoma side the area in the big bend of the river consists of a sand-covered, flat plain and terraces sloping gently to the river. On the Texas side the bluff rises abruptly to a height of 100 feet above the low-water level. The section is well exposed. The section was examined for a distance of about 4 miles. The rocks exposed show from approximately the base of the Trinity sand series up into the formation, a distance of 100 feet at the immediate bluff, and in going back from the river a short distance, the Goodland limestone is found overlying the Trinity formation.

The section at Rock Bluff Ferry is a fair average of the Trinity formation in the area under consideration, yet it cannot be taken as a typical section, since the degree of variation from place to place is great.

At the crossing the low-water line is about 710 feet above sea level, and the top of the highest part of the bluff from 100 to 110 feet higher. Beginning at the base, the following section is exposed: At the base 16 feet of cross-bedded, fine to coarse sands with interbedded chert and quartz pebbles. The mass of the material varies in color from light yellow to saffron. The pebbles range from a few, irregularly distributed, to a solid mass varying in size from that of a pea to 3 inches in diameter. The mass of sand is loosely cemented and disintegrates readily into loose sand and gravel. The pebbles are chiefly light-colored, but all colors may be found. Locally the sand contains streaks of red, sandy clay, and in places the sand is blackish on the outside, often showing hardened masses with blackened surfaces.

Above this gravelly conglomerate are about 32 feet of loose pack-sand, white to yellow in color containing many marble-like spots of bright yellow, unconsolidated sand. A little farther to the northwest, at about the same horizon, are found numerous marble-like hard sand-balls consisting of white, rounded grains of sand in more or less concretionary form, and yellow or black on the outside. Sometimes several of these are cemented in one mass.

At this particular location is a lenticular band of red to chocolate-colored sandy shale 3 inches to 1 foot thick. About 5 or 6 feet higher in the pack-sand there is a little clay, in which the color grades from yellow to purple. These 5 or 6 feet of clay, with the sand, make up to a total thickness of about 43 feet. In places the sand becomes gray, green, and brown, while at about 43 feet from the base the sand and clay contain a large amount of limy streaks and irregular concretions. A material of similar nature continues upward for a distance of 25 feet or more to the base of a hard capping conglomerate-pebble bed. Near the top of the sand are some thin layers of gypsum. Hard concretions are also found in the upper part of this series. The bluff is capped with a ledge of conglomerate about 3 feet thick, consisting of fine to coarse oolitic-like grains and pebbles of varying size. The conglomerate is hard, massive, in part cross-bedded, and cemented together with a white, chalky-appearing cement. In general, the mass is given a mottled appearance. This is due to the presence of pebbles, colored pink, red, yellow, purple, greenish, brown, white, clear, and blue, with all variations in shade. Some of the pebbles are rounded, others subangular and irregular, but always with smooth surfaces.

Going to the southward a considerable thickness of sand and local conglomerates is found between the main conglomerate bed and the Goodland limestone.

The following description of a section just west of the Rubottom store, on the west side of section 13, along the east side of the small stream, gives a fair idea of the condition to the north of the above location. In the cut along the stream, sandstone of supposed Cretaceous age rests on a considerable thickness of red shale, which may replace a part of the sand and conglomerate in the section to the south, or it may be the top of the Permian series.

Section along stream west of Rubottom store.

	Feet.
Underlying red shale	30
White to greenish sandstone, with massive, round and kidney-shaped concretions	10-20
Quartzite conglomerate	2
Shaly interval	5
Calcareous quartzite	2
Shaly interval	8
Soft, sandy limestone	2
Sand and gravel	20
Quartzite bed	3

Beginning a few rods north of the above location with the conglomerate bed in the bottom of stream, the following section occurs to the top of the hill:

Section 20 rods north of above section.

	Feet.
Sandy gravel conglomerate (1 pebble 3 inches in diameter)	1-2
Basal part of sandstone, with fine conglomerate cemented with lime. Sandstone weathers out into rough irregular masses	15
White, greenish, shaly sandstone, with many calcareous, irregular surface concretions	10
Deep red to purple sandy shale	7
Yellow sandstone, with interbedded limestone at top, glassy quartzite associated with oolitic quartz and pebbles	24
Heavy conglomerate, weathered out and lying about in large fragments	—

Sections similar to the upper members of those given above may be made at many localities over the area north of Red River. The characteristic rocks over the surface of the area are heavy quartzite conglomerates, chief of which is the one represented at the top of the Rock Bluff section. It is a heavy, massive quartz-conglomerate, with pebbles ranging from a fraction of an inch in diameter to 3 inches or more. The pebbles are all chert and quartz. The basal conglomerates exposed in Rock Bluff do not extend far to the northward. The principal sandstones outcropping, come in between the horizons of the heavy conglomerate, and represent various horizons in the pack-sand series. The outcropping sandstones are irregular masses weathered into rough, kidney-shaped bodies, having a characteristic blocking. These sandstones

are all dark-colored on the outside, and on the inside vary from gray, mottled, soft sandstones to hard, red, irony sandstones, in some cases becoming almost flinty. There are characteristic grains and cleavage planes in the sandstone which group them all in one series. However, there is little reason to believe that the principal sandstone of the area is a distinct sandstone occupying a definite horizon, but locally there may be one or more layers or masses occurring at any horizon within a favorable distance of 100 feet, or at any level throughout the thickness of the pack-sands shown in the above sections. These sandstones are chiefly much hardened or indurated masses. There is, however, one principal level of the sandstone masses which occurs about 35 feet below the heavy conglomerate. In some places the heavy conglomerate rests directly on the masses of sandstone, the intervening pack-sand and associated materials having been removed chiefly by the action of water. In other places the conglomerate and sandstone rest on heavy red shale beds of Permian age. All the intervening materials have disappeared, and the more resistant parts make up a new succession.

In some instances, the heavy conglomerate caps the hills and presents a good section of the series. A half mile to a mile away the same bed of conglomerate is found apparently in place, but 50 to 100 feet lower, the full section of unconsolidated material disappears.

STRUCTURE.

Some structural features are evident in the area of these rocks. In a general way, as stated above, the principal streams lie in the major synclines, and many of the smaller streams are in minor basins or synclines. While the divides are more or less in the nature of anticlines, it is difficult to determine the highest points on the structure. There are no rocks in the area covered by these Cretaceous sediments which can be taken as a key upon which to contour the structure properly. In many places apparent structure is due to the slumping and weathering conditions of the rocks of the Trinity sand series. While many of the rocks outcropping are apparently in place, the best policy to follow is that they are not in such a condition, for the reason that there are few, if any, of the rocks which have not been moved more or less from their original position. In the mapping of any structure in this area, it should be kept in mind that there is a chance of a vertical drop of as much as 100 feet, due to the giving away of the pack-sands. Some structural features exist and on a large scale, but the degree of accuracy is not such that any line of structure can be drawn for a considerable distance and be expected to prove productive. The structure which will prove productive is only on local doming, if the production is at all dependent upon surface conditions.

The principal production of the Healdton and adjoining pools appears to be in the underlying Pennsylvanian rocks. What the structural conditions of these rocks are cannot be stated in advance of drilling. Some of the production is in the Permian Redbeds, but it is very probable that any oil or gas here encountered has migrated into the rocks from the underlying Pennsylvanian.

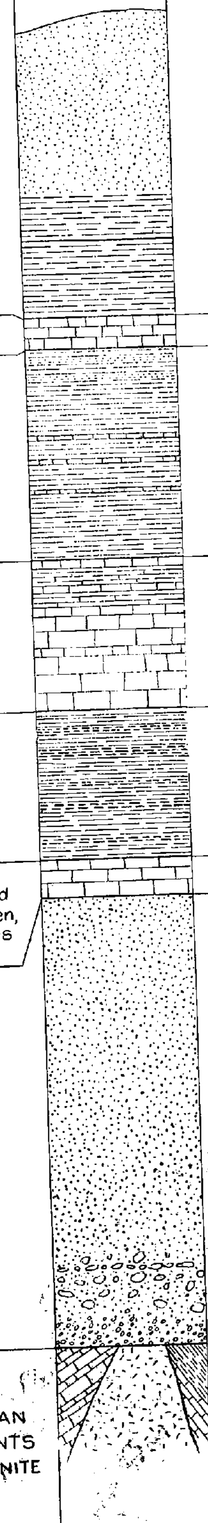
OCCURRENCE OF ASPHALT IN CRETACEOUS ROCKS.

Six miles south and about 2½ miles west of Rock Bluff Ferry, in the north end of Gordon Mountains, near the line between Montague and Cook Counties, Texas, about 4 miles east of St. Jo, considerable asphalt is found. It occurs in the northeast bluff on a high ridge, and is chiefly in a layer of sandstone 1 to 2 feet thick, lying about 5 to 10 feet below the Goodland limestone. The sandstone is highly impregnated with asphalt, and in places it oozes from the rocks in a semi-viscuous state. The overlying sandstone consists of a loosely cemented gray to brownish sand overlaid by soil and fragments, while farther back on the hill the limestone is in place. The asphalt from this locality has been used on the streets of St. Jo.

The limestone ridges are flat-topped and without timber. The margins of the ridges are timbered. An occasional hackberry or oak grows on top of the limestone. Below the asphaltic horizon is a fossiliferous limestone similar to the upper limestone, except for being more shaly and weathering into rounded knobs and ridges, with much loose debris over the surface. These lower limestone hills are in part covered with timber. On the Oklahoma side numerous occurrences of asphalt have been reported, but upon examination of these very few were found to contain any asphalt, the black color of the rocks being due to the highly oxidized state of the contained iron. In some localities, for example, about the Wheeler oil field, and the segregated land in the vicinity of Asphaltum, the surface sandstone which is saturated with asphalt is very similar in appearance to certain parts of the pack-sands in the Trinity series, and it is believed that at least a remnant covering of these sands extends to this distance to the northward. The origin of the asphalt cannot be definitely determined, but it is very likely that the oils giving rise to this deposition have worked up from the rocks older than the Cretaceous. There is very little evidence in the Trinity sands of

CRETACEOUS ROCKS.

FORMATION NAME	COLUMNAR SECTION.	THICKNESS IN FEET.
SILO SANDSTONE Brown friable Sandstone, irony Shale, some thin Coal		200'+
BENNINGTON LIMESTONE. Blue, shelly.		15'-25'
Local beds of Sandstone occur near the top **BOKCHITO FORMATION.** Red and bluish Clays with thin beds of shell Limestone, weather out to reddish hues.		140'
CADDO LIMESTONE. Limy Clay and yellow to white Limestone		50'-150'
KIAMICHI FORMATION. Blue clay-marl with oyster shell - Smooth rolling black lands		50'-150'
GOODLAND LIMESTONE Partly chrystalline, cream colored to white, moderately hard, barren, low Bluffs or Terraces-some places a table-land with thin rocky soil.		25'
TRINITY SAND. Fine, yellow Sand White pack Sands Indurated masses Irony Sandstone Quartz pebble Conglomerates with associated limy layers. Conglomerate base Partly granite pebbles, oil bearing		200'-400'
CARBONIFEROUS, SILURIAN AND CAMBRIAN SEDIMENTS AND PRE-CAMBRIAN GRANITE		



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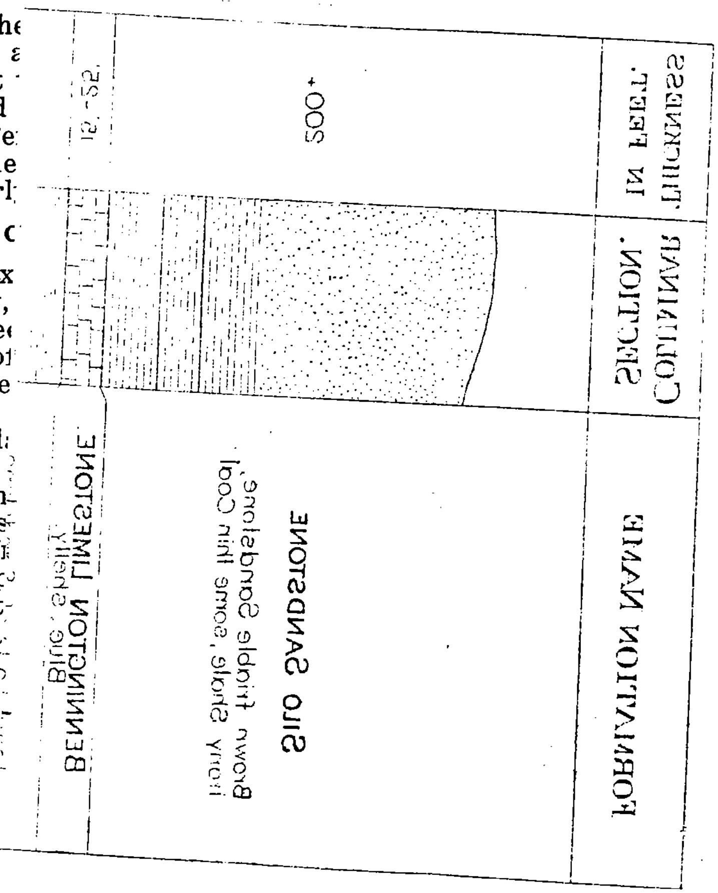

CRETACEOUS ROCKS.

sufficient organic matter to produce any appreciable amounts of bituminous substances.

A cursory examination of the immediate Red River region shows a superficial deposit of unconsolidated sands that are probably of recent origin. They are easily distinguished from the older deposits, because of their loose, unconsolidated character. In the broad stream valleys alluvium covers the older rocks, so that they are inaccessible.

THE CRETACEOUS REGION.

GENERAL STATEMENT.

The surface rocks of the region between the Ouachita and Arbuckle mountains and Red River are of Cretaceous age. Remnants of Cretaceous deposits have been identified in a number of points in western Oklahoma. These deposits consist of light-colored clays and shelly limestone, with a basal conglomerate or chert. The deposits vary from a few acres in extent to several hundred square miles.

The rocks of this region are made up of clays, sands, and thick-bedded limestones, which lie practically horizontal. The surface is low and over large areas is flat and wooded. Where limestone occurs above massive shale or sandstone the escarpments are usually steep and high, and the streams which flow over broad, flat floodplains have steep sides. The rocks have all been gently tilted to the south and southeast. Over the entire Cretaceous area plant growth is very prolific, and as a result all except limestone uplands have been wooded at one time or are still thickly covered. All of each of the following counties are covered by Cretaceous rocks: Marshall, Bryan and Choctaw counties, and a part of Love, Carter, Atoka, Johnston, Pushmataha and McCurtain counties.

The Cretaceous rocks are very fossiliferous, and the younger rocks are of such a character that oil and gas could be formed in them. The Trinity sand, though not containing fossil remains in abundance, does show a few beds of asphalt, and some oil and gas. It seems reasonable to predict future developments of importance within this general region.

STRATIGRAPHY.

Very little work has been done in this region, and with the exception of the detailed data given in the Atoka folio and Water Supply Paper No. 276, both by the United States Geological Survey, our information is general. It has been determined roughly that the formations are fairly uniform throughout this region, and the data at hand will serve until further information can be gathered. The following brief discussion is intended to give a general idea as to the character, thickness, occurrence, fossil forms, and possibilities for oil in each of the Cretaceous formations. The section reads from youngest to oldest.

Geologic section.

		Feet.
7.	Silo sandstone	200
6.	Bennington limestone	10 to 15
5.	Bokchito formation	150
4.	Caddo limestone	150
3.	Kiamichi formation	150
2.	Goodland limestone	25
1.	Trinity sand	300 to 400

1. *Trinity sand.*—The Trinity sand lies unconformably upon the weathered edges of the older Paleozoic rocks to the north. A study of the formation shows it to be a beach or near-shore deposit of a sea that gradually encroached from the south. It is composed of 200 to 400 feet of fine to coarse, pebbly conglomerates and fine yellow to white pack-sands, indurated masses of irony sandstone, some thin layers of shale, with an occasional heavy bed, and locally, limestone with occasional clays. The conglomerate occurs invariably at the bottom and ranges from a thin stratum to one 50 feet in thickness. It is cross-bedded and interstratified with sand and clay. The constituent pebbles, usually quartz or quartzite, range in size from 6 inches in diameter to fine sand. An examination of the material from the base to the top shows that the finer materials become more abundant in the upper part, grading into grits of quartz or chert.

From the conglomerate upward to the base of the Goodland, the sands and clays are homogeneous. These pack-sands and clays vary in color from pure white to yellow, brown, red, greenish, and mottled. The red and yellow mottling seems more prevalent where the formation is more or less argillaceous. The sands break down easily into a loose, sandy soil, which is fertile and heavily wooded.

Topographic forms common to this formation are broad flat valleys and low rounded hills. Fossil remains are practically unknown, except for the frequent occurrence of silicified wood.

The Trinity sand is the only Cretaceous formation that has proved productive. Productive horizons have been struck at the depths of 430 to 550 feet near Madill. The output has been small, but of high-grade oil, ranging from 42° to 46.7° Baumé.

2. *Goodland limestone.*—Lying above the basal Trinity of this region is the Goodland limestone. It is a massive white limestone, 25 or more feet thick. In the region of Ft. Towson, according to reports by drillers, it is 70 feet in thickness. These reports have not been corroborated, and it is thought that the wells started well up in the Kiamichi formation. The outcrop is continuous across the Atoka quadrangle. The limestone dips at a low angle and forms escarpments and terraces above the soft Trinity sand. At the basal contact is an oyster bed of considerable thickness. Abundant fossil remains are found throughout the formation. Robert T. Hill* gives the following description of the Goodland:

> In general, this formation consists of a white, pasty limestone of dull or chalky texture and luster, certain layers of which crumble upon exposure into numerous fragments, generally broken in direction diagonal to the bedding planes. Sometimes the layers are firm and indurated or semi-crystalline, a condition due to secondary alteration of its particles by percolating waters.

3. *Kiamichi formaton.*—This formation consists primarily of dark blue, laminated, calcareous clay, with many beds of impure limestone interbedded. The Kiamichi formation, 150 feet in thickness, lies upon the Goodland limestone. The thin-bedded, siliceous limestones near the top aggregate but a few feet and are seldom exposed. Thirty feet of blue clay marl, and then 20 feet of the same material with oyster-shell beds interstratified, succeed the thin, shaly limestones. The oyster beds are thin, with the shells from very small to 3 inches long.

Exposures are more often found along the lower slopes of escarpments. The upper beds form a more or less continuous outcrop. The weathered surface is yellowish from the oxidized iron.

4. *Caddo limestone.*—The Caddo limestone contains much clay and marl interstratified with semi-crystalline and yellow marly limestone. The formation is 100 feet thick. The lower 60 feet consist chiefly of marly clays. Above this for 20 to 30 feet are marly limestone and chalky limestone interbedded. In this member are some oyster-shell beds very similar to those at the top of the Kiamichi. Upward in the beds the marly layers thin and the limestones thicken and increase in number, until near the top the marls are thin partings between the limestone layers. The top layer is composed wholly of oyster shells.

The Caddo limestone forms "low, northward-facing escarpments and rolling, southward-sloping land." The hard limestones project as ledges in these escarpments.

*Twenty-first Ann. Rept., U. S. Geol. Survey, 1901, pp. 216-217.

5. *Bokchito formation.*—The Bokchito formation, lying immediately above the Caddo limestone is typically exposed along Bokchito Creek. Here it is siliceous fossiliferous limestone, and ferruginous concretions. The approximate thickness is 140 feet. The lower portion is made up of friable sandy clay shale, with inclusions of ferruginous material. Above the 90 feet of sandy material just mentioned are 20 to 30 feet of sandstone. These in turn are succeeded by hard, blue, semi-crystalline shell limestone strata separated by shale lenses. The weathered surface is reddish or yellowish brown in color, with the shells appearing in cross-section, thus showing that the carbonate of matrix and shell are equally resistant to the agents of weathering. The limestones project as ledges and boulders, but the shales are seldom exposed. Topping the formation are 50 feet of clay, sandy shale, and sandstone. The sandstone is much cross-bedded, showing shoal water deposition. The shale concretions and iron and lime nodules often contain the original shells with the nacreous luster still well preserved. Topographically, the formation as a whole is marked by hill slopes and rolling low land.

6. *Bennington limestone.*—The Bennington limestone occurs at the top of the Lower Cretaceous section of this region. In Texas it is 80 to 100 feet in thickness, and composed of calcareous shales, abundantly supplied with fossil remains. In northern Texas and southern Oklahoma the character changes first to shales and limestones interstratified, and then to hard limestone. The thickness also becomes much less, being not more than 10 feet in the Atoka quadrangle. Here it is made up of a hard, massive, dull-blue limestone, composed almost wholly of the remains of a ramshorn-like fossil, *Exogyra arietina* Roemer. Locally, there is a thin, shaly limestone present, which is the equivalent of the Buda limestone of Texas.

The Bennington limestone, although thin, is more often exposed along bluffs, because the rocks above and below are more subject to weathering. These escarpments are always low. Outcrops are also found in flat areas.

7. *Silo sandstone.*—The Silo sandstone is the lowest of the Upper Cretaceous formations. In north Texas near Red River, it is fully 500 feet thick. It consists of 5 layers of brown sands and sandy clays interstratified, showing that it was deposited just off shore, as was the Trinity. The sandstone beds which sometimes contain nodules of brown, siliceous iron ore, are much thicker toward the middle of the bed, while shales, sandy shales, and clays occur above and below.

Within the Atoka quadrangle the upper part is composed

of clays, with the fine sands less abundant and more evenly distributed through the clays. The result is a fairly homogeneous siliceous clay or argillaceous sand. The entire series is approximately 200 feet thick.

The outcrops of the lower part of this formation are usually heavily wooded, but areas occupied by the upper portion are usually open prairie. The topographic forms resulting from outcrops are low, rounded hills and shallow valleys. Few fossils have been found. The formation is admirably adopted for a reservoir for oil and gas, but so far no production has been reported from this horizon.

CORRELATION.

The formations exposed in southern Oklahoma, though differently named from the Cretaceous rocks of Texas, have their equivalents. The correlation shown below is a result of following the formations southward to the Austin quadrangle. A detailed discussion of the Texas formations is given by Robert T. Hill.*

Correlation table of Cretaceous formation.

Names used in Oklahoma.	Names used in Texas.
Silo sandstone	Eagle Ford formation.
Bennington limestone	Buda limestone. Del Rio clay.
Bokchito formation Caddo limestone Kiamichi formation	Georgetown limestone.
Goodland limestone	Edwards limestone. Comanche Peak limestone. Walnut clay.
Trinity sand	Glen Rose formation. Travis Peak formation.

STRUCTURE.

The Cretaceous sandstones, shales, and limestones lie nearly level above the eroded edges of the older formations of the Ouachita and Arbuckle mountains. The general dip is southeastward, with few local foldings. To the present time there have been but a few of these local anticlines or domes located within this area. However, it is thought that future investigations may reveal the presence of a number of others that may be of value.

*Twenty-first Ann. Rept., U. S. Geol. Survey, 1901.

PERMIAN REGION.

NON-RED PERMIAN AREA

GENERAL STATEMENT.

The area of non-red Permian rocks lies in north-central Oklahoma, chiefly within Kay County. The formations to the east consist of alternating limestones and shales, while the western part of the area is underlaid by thick shales. The whole region lies within the physiographic division known as the Great Plains. The general surface slopes to the south and east, while the formations dip about 30 feet to the mile to the west. The result is more or less pronounced eastward-facing escarpments, whose sharpness depends quite as much upon the thickness of the underlying shales as upon the character and thickness of the limestone formation. Another result of the alternating shales and limestones is the deeply incised surface. To the westward, the surface is comparatively level and the streams have broad flat valleys, with thick residual soil and alluvial deposits.

STRATIGRAPHY.

Not all the formations which are included within the area under discussion have been studied and described. Those at both the top and bottom of the section have not yet been worked out in detail. The colors found are chocolate, brown, red, gray, blue, and yellowish among the shales and sandstones, while gray and white limestones prevail.

The sub-surface rocks will receive no mention here, since they are Pennsylvanian and have been discussed under that head. The following is the Permian section exposed, beginning with the youngest formation:

Geologic section.

		Feet.
9.	Unclassified shales, with thin limestone and sandstone members	——
8.	Herrington limestone	18-20
7.	Uncas shale	50
6.	Winfield limestone	10-15
5.	Doyle shale	22-35
4.	Fort Riley limestone	40
3.	Matfield shale	70
2.	Wreford limestone	40
1.	Unclassified series of sandstones, and shales of western Osage County	——

1. *Unclassified series.*—The Permian rocks outcropping along eastern Kay County and western Osage have been as little studied and are as little known as those along the western edge of the non-red area. At this time about all that can be

said is that they are a series of rapidly alternating shales, thin limestones, and occasional sandstones. It is certain, however, that only the upper part of these sediments is Permian. Of the Kansas section equivalent to this, given under the discussion on Pennsylvanian rocks, the following are Permian:

		Feet
3.	Garrison formation	140 to 150
2.	Cottonwood limestone	6 plus
1.	Eskridge shales	30 to 40

A brief discussion of these formations is thought advisable in this connection. The *Eskridge shales* fill the interval between the Neva and Cottonwood limestones. They are massive, greenish brown, and yellowish clay shales, with a few thin layers of limestone irregularly dispersed through them. The thickness is 30 to 40 feet, according to Prosser.

Above the Eskridge shales is the *Cottonwood limestone,* typically displayed near Cottonwood Falls, Kansas. It is approximately 6 feet thick; it is massive, light gray or buff-colored; and it contains few fossils except *Fusulina secalica.* Say.

The *Garrison formation,* so named by Prosser, has been subdivided into the Florena shales and the Neosho member. The Florena shales are composed of "green, chocolate, and yellowish shales, alternating with grayish limestone." It contains a limited fauna throughout. The Neosho member is marked by a ledge of gypsum near its base.

2. *Wreford limestone.*—The Garrison formation is succeeded above by the Wreford limestone. In Kansas, where it has a thickness of 40 feet, this limestone has been carefully described by members of the Kansas Survey. It was named by Hay after a little station south of Junction City on the Missouri, Kansas & Texas Railroad, where it is quarried and burned for lime. It is there described as being distinguished from the other formations by the abundance of chert. In Oklahoma the same general characters obtain. The lower part, however, is much more siliceous and cherty than the upper part. Shales and shaly limestones are more prominent also. Haworth, in discussing this limestone, says that in its southern extension, it is characterized by large, partly siliceous blocks of limestone which weather to a porous, reddish-brown mass, called "sand rock" by the inhabitants.

3. *Matfield shale.*—The thickest single formation of this region is the Matfield shale. It is composed of 70 feet of coarse, arenaceous shale, with red, thin-bedded sandstones rather abundant. Good exposures are rather numerous, with the coarse, red, sandy material predominating because of

peculiar weathering. Lighter colors are probably more abundant, however. As a general rule, the shales are constant in thickness and character throughout the region. The outcrop is narrow, and usually at the base of a Fort Riley scarp.

The sand 275 feet below the top of the Herrington limestone, in the Ponca City field, has been referred by Ohern to the sandstone associated with the outcrops of Matfield shale. The outcrops which occur to the north of this field are composed of thin-bedded sandstones with intercalated beds of sandy shale. The shallowest sand of the Newkirk field probably is at this horizon also.

4. *Fort Riley limestone.*—The Fort Riley in this area consists of about 52 feet of limestone, massively bedded in the lower part, with lenses of chert present. The Fort Riley of Kansas is underlaid by the Florence flint with a thickness of 20 feet, while the Fort Riley itself is 40 feet thick. In the Kay County region the Florence flint has not been identified. It is possible, however, that the flint lenses of the lower Fort Riley may be its equivalent. The upper portion of the Fort Riley is made up of alternating beds of hard, resistant limestone and thin shales and shaly limestones.

The 70 feet of shale lying immediately below has aided in making the escarpments of this limestone probably the most conspicuous of any in this region. These are best shown along the crest of the Newkirk anticline, southeast of Newkirk and south of the Arkansas River. To the north of the river, good exposures are common along the smaller streams.

5. *Doyle shale.*—Lying above the Fort Riley limestone is a mass of clay shales, with occasional arenaceous layers. The thickness varies from 22 feet in the north to about 35 feet in the southern part. Red colors are common, but are probably not more abundant than the lighter colors. Owing to the occurrence of the Doyle on a bench above the Fort Riley, its outcrop is of too great extent to be proportional to its thickness.

6. *Winfield limestone.*—The Winfield limestone which succeeds the Doyle, below, is from 10 to 15 feet thick, the average being about 12 feet. Lithologically, the limestone is massive, gray, with the upper layers more arenaceous and platy. This feature, with the fact that near the base is a 1-foot layer abundantly supplied with small brachiopods, serves to distinguish this limestone readily.

In passing eastward from the outcrop of the Herrington the first limestone encountered is the Winfield. It, too, is well exposed west of the axis of the Newkirk anticline, only outliers being found to the east.

7. *Uncas shale.*—Immediately above the Winfield limestone is a 50-foot shale termed the Uncas shale. In Kansas, the equivalent is a series of thin-bedded, porous limestone beds, followed by 35 feet of shale, lying between the Winfield and Herrington limestones. This limestone is known as the Luta limestone. Detailed study of these formations by Ohern fails to reveal the presence of this limestone. The Uncas shale, so named provisionally from the town of Uncas, is composed of alternating red and light-colored clays. Ohern gives the following section,* and notes that the 3-foot limestone may possibly be the Luta limestone of Beede:

Section 3 miles southwest of Newkirk.	Feet.
Limestone, massive in lower part, thin-bedded above (Herrington)	17
Shale, largely maroon, some red to brown sandstones	44
Massive limestone with clay nodules, abundance of *Myalina* and *Aviculopecten*	3
Shale	7
Thin-bedded limestone, base not exposed (Winfield)	5

In the above section the 54 feet of sediment between the upper and lower limestone comprises the Uncas shale.

8. *Herrington limestone.*—The Herrington is the highest prominent limestone exposed in this region. It is 18 to 20 feet thick, with massive beds below and thin beds above. The basal part is honeycombed where the formation has been long exposed, thus causing a characteristic marking. Characteristic outcrops of the Herrington occur along the west side of the Newkirk anticline, from Ponca City north to the Arkansas River, as a prominent escarpment. Another means for identification is the presence of numerous springs issuing along the upper line of contact.

9. *Unclassified series.*—Lying west of the Atchison, Topeka & Santa Fe Railroad is a great series of shales, with an occasional arenaceous or calcareous layer. These shales extend westward to the contact with the Permian Redbeds. Generally they are gray, yellow, buff, or reddish, friable clay shales. The calcareous members which have been studied in the region of Blackwell are usually buff in color and porous, as if a result of secondary deposition by percolating water. The repeated change from beds of this character to pure limestone with fossils, and back again to a limestone composed of a network of calcite veins, rather tends to disprove this idea. Three of these calcareous layers are typically displayed 6 or 8 miles northeast of Blackwell, around the headwaters of tributaries to Bitter Creek. Elevations over this western

*Ohern, D. W., Bull. Oklahoma Geol. Survey, No. 16, 1912, p. 10.

area range from about 950 to 1,150 feet above sea level. This is the highest and least studied of the non-red Permian formations. The upper portion of the following log shows the character of the sediments:

William Bucholtz No. 1, in SE.¼ sec. 11, T. 27 N., R. 1 W.

Character of rock.	Thickness.	Depth.	Character of rock.	Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Surface soil	15	15	Blue slate	5	405
Sand and gravel	3	18	Lime	10	415
Blue slate	12	30	Blue slate	10	425
Slate and shells—water	10	40	Red rock	5	430
Blue slate	15	55	Lime	5	435
Red rock	10	65	White slate and shells	25	460
Blue slate	10	75	Sand	10	470
Red rock	5	80	Lime—shells and slate	5	475
Blue slate	10	90	Red rock	30	505
Lime	10	100	Lime	35	540
Blue slate	20	120	Red Rork	15	555
Lime	10	130	Lime	10	565
Soft cave	20	150	Slate	5	570
Lime	10	160	Lime	25	595
Blue slate	5	165	Red rock	37	632
Lime	5	170	Lime	18	650
Blue slate	5	175	Blue slate	5	655
Lime	15	190	Red rock	10	665
White slate	15	205	Lime	10	675
Lime	7	212	Red rock	35	710
White slate—shells	28	240	Lime—shells and slate	50	760
Blute slate—shells	15	255	Red rock	25	785
Lime	25	280	Blue slate	45	830
Blue slate	5	285	Sand	5	835
Lime	5	290	Slate	12	847
Red rock	5	295	Sand—water and gas	13	860
Lime	10	305	Clack slate	10	870
Blue slate	30	335	Lime	10	880
Red rock	35	370	White slate	2	882
Lime	2	372			
Blue slate	18	390			
Sand—water	10	400			

STRUCTURE.

The general surface formations dip about 30 feet per mile to the west. The anticlinal folds usually have a steeper dip to the east. This is well shown by the Ponca City and Newkirk anticlines described in bulletin No. 16 of the Oklahoma Geological Survey. Further examination of the region to the west is now being prosecuted by members of the Survey. These results are not yet ready for publication, so that it is only possible to say here that the structure to the west is of much the same type as that already mapped to the east.

RED PERMIAN AREA.

GENERAL STATEMENT.

The Redbeds of central and western Oklahoma are of Permian age, chiefly, and composed of shales, sandstones, gypsum ledges, and an occasional layer of dolomitic limestone. Two lines drawn from near Pawnee, the one northwest to the state line north of Medford, the other south along the Atchison, Topeka & Santa Fe Railroad to a point just west of Shawnee, thence south and west to the western extremity of the Arbuckle Mountains, define roughly the eastern limit of the Redbeds area. The Wichita Mountains occur in this general area and must be considered apart from this discussion. Some other areas in Harper, Beaver, Ellis, Woodward, Texas, and Cimarron counties are covered by rocks much younger in age than Permian. These sediments are probably Tertiary and Cretaceous. They have a maximum thickness of only a few hundred feet, while the Permian rocks vary from a few feet along the foothills of the mountains and along the eastern limit of outcrop, to probably 3,000 feet in the western part of the State.

In general the surface of the Redbeds region is gently rolling prairie. Where two formations of distinctly different characteristics outcrop, the surface is somewhat rugged and broken. In areas where heavy bedded sandstones, such as the Whitehorse sandstones, 225 feet thick, occur, canyons of 100 to 200 feet in depth are common. Topography of this sort, composed of deep canyons and high hills, is common throughout Caddo County. Surface elevations over the Redbeds area range from about 4,000 feet in the Panhandle plains to about 1,000 feet along the eastern and southern limits.

STRATIGRAPHY.

Stratigraphy in the Redbeds is a problem which is difficult of solution because of the uncertainty of data secured. Shales and sandstone layers, usually only a few inches to a few feet thick, thin, grade, and disappear into each other within a few feet horizontally or laterally. The same is true vertically. Because of similarity of beds in lithologic character, it is usually impossible to say, absolutely, whether one bed occupies the same horizon as another. Fossil remains have not been found in sufficient numbers for correlation from one locality to another.

The following brief section gives the rocks exposed over western Oklahoma. The formations are named from top to bottom.

Geologic section.

Quartermaster formation 300 feet.	Soft red sandstones, sandy clays, and shales.
Greer formation 275 feet.	Mangum dolomite member. Collingsworth gypsum member. Cedartop gypsum member. Haystack gypsum member. Kiser gypsum member. Chaney gypsum member.
Woodward formation 425 feet.	Day Creek dolomite. Whitehorse sandstone, 175-200 feet, light red, very coarsely cross-bedded—suitable for building stone. Day Creek shales, 30 feet. In central Oklahoma is a great dolomite formation, 150-225 feet thick in gypsum hills.
Blaine formation 100 feet. Outcrop 1 to 8 miles wide.	Shimer gypsum. Shales, red. Medicine Lodge gypsum, middle portion of anhydrite. Shales, red. Ferguson gypsum.
Enid formation	Shales, sandstones, gypsum, mostly red colored. Thickness, 1,200 to 1,500 feet. Sandstones most abundant in lower part.

The Enid formation is the most eastern exposed and the Quartermaster occurs farthest west. The former comprises all or a part of the following counties: Kay, Noble, Payne, Logan, Oklahoma, Cleveland, Canadian, McClain, Kingfisher, Garfield, Grant, Major, Alfalfa, and possibly a portion of Garvin.

Lying west of the Enid formation is the outcrop of the Blaine. It is the surface rock in Woods, Harper, Blaine, Major, Woodward, Kingfisher, and Canadian counties.

The Greer formation occurs in Grady, Caddo, Washita, Custer, Dewey, Greer, Harmon, and Ellis counties.

The highest formation, the Quartermaster, outcrops in a solid, almost square block in Washita, Beckham, Custer, and Roger Mills counties.

Bordering the Wichita Mountains and over the region to the south toward Red River, are areas in which the above section is not applicable. In fact, the rocks are unnamed and have been very little studied. These rocks are made up of much the same material as those already described, except that they contain a number of conglomeratic beds, and little or no gypsum.

STRUCTURE.

The Redbeds rocks are, as a rule, only slightly tilted, if at all. In the eastern portion of the region the dip is to the north

and west, in the center nearly flat, and farther west gently tilted to the east and south. These statements bear upon the strata farther north, since those in the southern part, nearer the Wichita uplift, have been directly influenced by the warping and folding that took place there.

Owing to the character of the beds structure is very difficult to work out. In the mountain region where conglomerates can be followed, the problem is not impossible. In the regions where the Greer and Blaine formations outcrop and are subjected to solution processes, dips can be found sufficient to prove the presence of any kind of structure. These are not true structural features. They are due to the water dissolving out the underlying heavy ledges of gypsum, causing the beds above to slump down. These features have no significance to the man looking for oil, and are mentioned here chiefly as a warning to those unfamiliar with this topographic feature, which results from weathering. Too much emphasis cannot be placed on the fact that it is best not to place confidence in small outcrops in the Redbeds area. In regions where sandstones outcrop, the cross-bedding or false-bedding, as it is sometimes called, makes it possible to secure strong dips in all directions, and thus show the presence of structure in any area. Further investigation along the whole outcrop will show the strata to be practically level. It seems best, then, to consider all short outcrops which show marked inclination, as due to slumping or cross-bedding.

SUMMARY OF DEVELOPMENT.

As the price of crude oil advanced, and it was found, first in one portion of the State and then another, the people of the Redbeds area became convinced that oil might be found nearer home in paying quantities. Many wells were drilled as a result. So far as can be determined, none have given a good showing of either oil or gas, even where the proper formations were encountered below the Permian rocks. The table here given shows briefly the history of this development.

Table of development in the Redbeds area.

Name.	Location.	Depth.	Remarks.	Horizon at which begun.
Alva	½ mi. E. of Alva	3,500	Passed Redbeds at 1,100 feet. Gas showing at 3,300	Upper part Enid formation.
Enid	Near Enid	2,215	OutofRedbedsat1,000ft. Dry	Upper part Enid formation.
Waukomis	Near Waukomis	2,135	Dry. Redbeds to 850 fet.	Upper part Enid formation.
Watonga	----		Several drilling. All dry	Upper part Woodward form.
Newcastle	8 mi. SW. of Oklahoma City	2,500	Extent of Redbeds unknown	Middle of Enid formation.
El Reno	----	3,200	Redbeds to 1,750 feet. Dry	Upper part Enid formation.
Clinton	Near Clinton	2,507	All Redbeds. Dry	Upper Greer formation.
Willow	W.½ SW.¼ sec 24, T. 7, N., R. 21 W.	2,135	Redbeds to 850 ft. Shallow because near mountains	Top of unclassified Redbeds.
Burt Switch	SW. of Frederick	1,800	Dry	Dune sand covers surface.
Verden	Near Verden	1,200	Still in Redbeds. Dry	Middle Greer.
Cement	SW.¼ sec. 6, T. 5 N., R. 8 W.	1,700	Extent of Redbeds unknown	Top of Greer formation.
Erick	1½ mi. SE. of Erick	----	Dry	Top of Greer or base of Quartermaster.
Mulhall	Mulhall	1,917	Dry. Redbeds to 1,675 feet	Middle of Enid formation.
Apache	SE.¼ sec. 1, T. 4 N., R. 12 W.	1,300	Slight showing. Redbeds to 405	Base of unclassified Permian, Arbuckle limestone below.
SW. of Alden	Sec. 6, T. 5 N., R 13 W., Caddo Co.	648	On edge Wichita Mountains. Dry. Redbeds to 498	Base of unclassified Permian, Arbuckle limestone below.
Ninnekah	7¾ m. S. of Chickasha	1,470	Dry. Redbeds to 1,470	Top of Greer formation.
Colony	SW.¼ sec. 5, T. 10 N., R. 13 W.	1,003	Dry. Still in Redbeds	Whitehorse sandstone.
----	SE.¼ sec. 20, T. 11 N., R. 13 W.	1,942	Dry. Still in Redbeds	Whitehorse sandstone.
Oklahoma City	3 wells near Oklahoma City		Dry	Lower part Enid formation.

Several factors preclude the idea that oil and gas will be found in the Permian. There are no fossil remains or carbonaceous shales from which the hydrocarbons might have come. If, on the other hand, we accept the chemical theory for the origin of oil and gas, the highly heated igneous intrusions necessary to cause the chemical reactions are wanting. It seems unlikely that all of the wells so far drilled would have been put down in a haphazard fashion, without any regard for structure. If it be true, then, that the geology has been worked out in detail even in a few cases, the fact that all wells are dry strengthens the contention that the formation is unfavorable for the occurrence of oil and gas in large quantities.

In a few scattered cases small showings of oil and gas have been reported. In most cases which were tested out, the oil proved to be an iron compound and the gas either air or nitrogen (no good) gas. In all of the other cases where the oil or gas were no longer present, if they ever were, surface conditions showed that the small finding had probably migrated to this point by following fault zones, joint planes, or fractured portions of the rock.

The red color of the rock is in itself proof that they do not contain much oil or gas. Oil or gas is probably the distillate from animal or vegetable matter, or both. Organic matter changes red iron oxide to the darker-colored compounds, usually black or green. The red color of the iron, with the almost total absence of fossil remains, proves conclusively that life was not abundant during this period. Careful study reveals the fact that the amount of life necessary to produce this change in color is much less than would be required to produce oil and gas in commercial quantities, so that as long as red is the predominating color, it is certain that from within the rock itself there is little chance of either oil or gas. If the reader will call to mind any or all of the producing horizons, it will be remembered that the sands or sandstones are light colored or brownish, and that the shales above and below are gray, blue, or black—any color but red.

The nature of the Redbeds themselves precludes the idea that these hydrocarbons could have migrated to any great distance. As mentioned before, the presence of thousands of feet of sediments composed chiefly of fine-grained clay shales would prevent migration of these bituminous compounds and at the same time keep the oil at such a depth as to be inaccessible.

The only areas which give any promise whatsoever are the regions fringing the mountains, and a narrow band along the eastern border. In both of these areas the underlying oil-bearing strata can be reached by the drill. In the western region, along the foothills of the Wichita and Arbuckle mountains, the probabilities seem greater, since the oil and gas of the older strata have a better chance to work up into the base of the overlying Permian, because these oil-bearing rocks have been steeply tilted. Between the mountain ranges, and south to Red River, the older rocks are only a few hundred feet beneath the surface. In these areas, as has been mentioned previously, there is the added advantage of being able to work out the structure with a fair degree of accuracy. Some development has taken place which is very promising. This will be discussed when the various fields are considered.

In conclusion, the prospects for future development in this general region, as evidenced by formational characteristics and by past drilling records, are not the brightest.

WICHITA MOUNTAIN REGION.

GENERAL STATEMENT.

The Wichita Mountains lie in southwestern Oklahoma, in Comanche, Jackson, Greer, and Kiowa counties. The long axis of this uplift lies in a northwest-southeast direction, and extends from Lawton to Granite, a distance of 60 miles. The trend is in line with the Arbuckle Mountains, and the two uplifts are probably connected underneath the covering of Redbed material. These mountains have had practically the same history as have the Arbuckles, except that the Redbeds have covered more of them. Both groups are said to be of the same age as the Appalachian uplift.

STRATIGRAPHY.

The same formations occur in both the Wichita and Arbuckle mountain groups, but in the former much less of the section is exposed. Of the sedimentary rocks only the Reagan sandstone, Arbuckle limestone, and Viola limestone remain uncovered by Permian sediments. The central portion and a few scattered outliers are chiefly igneous.

Older rocks.—For a brief discussion of the outcropping sedimentary rocks, the reader is referred to the discussion on the Arbuckle area. A discussion here of the Reagan sandstone and the Viola and Arbuckle limestones would be useless repetition.

The igneous rocks of this region may be separated into four groups or classes: gabbro, granite, granite-porphyry, and diabase dikes.

It is the consensus of opinion that very little or none of the hydrocarbons are common to any of the rocks of this region. If we accept the organic theory for the origin of oil, it is easily

seen why these formations are not petroliferous. The value of the granite, gabbro, and limestone lies chiefly in their use for building, ballasting purposes, and as concrete filler.

Permian.—The Redbeds which surround the mountains are composed of light, gray, blue, and reddish shales, with occasional local conglomerates and sandstones. The conglomeratic members are white, or light-colored, and the constituent particles vary from very small to several inches in diameter, with the smaller sizes much more abundant. This portion of the Permian has been little studied, and so is unnamed.

A careful examination of the horizon at which the oil occurs at numerous points along the foothills of the Wichitas from Gotebo to Lawton points to the contact zone or near it as the immediate source. It seems probable that the oil in this locality is not originally from the Permian, but from the older beds which are hidden.

In the region north of Lawton a number of shallow wells have been drilled in the Permian shales to about the top of the Arbuckle limestone horizon, and small amounts of oil have been encountered. A study of surface indications and of the age, character, and probabilities of such a formation would preclude the idea of this limestone being the source of the oil. It seems likely that here, as in the case mentioned above, the oil has migrated for some distance along the zone of contact between the Permian and older rocks, and that the real source is the unexposed Pennsylvanian sediments. In some of the wells recently drilled the claim has been that the oil came from the limestone or shales or sandstone some distance below the Permian. This might be possible, since oil under pressure will escape in any direction which furnishes an outlet. It is probable that in these cases the small amount has worked its way to this point along fractures, faults, or joint planes, as a result of the lateral and overhead pressures. Seldom, if ever, would oil be secured in paying quantities under such conditions.

STRUCTURE.

The gabbro and granite areas are found to be oriented in a direction approximately N. 60° to 70° W. In the strike of the chief ranges and peaks the jointing is more pronounced. Joints are especially prevalent in the western part of the Wichita group. Conspicuous jointing occurs both in a northwest and southeast and a north and south direction. The latter jointing is probably the more noticeable.

Folding and faulting in the sedimentaries is very noticeable, being on a somewhat larger scale than that of the mountains to the east.

ARBUCKLE MOUNTAIN REGION.

GENERAL STATEMENT.

In south-central Oklahoma are the Arbuckle Mountains, about 60 miles long by 10 to 40 miles wide. The topographic forms are a result of erosion, for the most part. That is, the harder strata stand out as hills and ridges, while the soft strata occupy the slopes and the valleys. The structure plays an important part in the arrangement of these hills, ridges, and valleys. The entire region slopes from the northwest to the southeast, having an elevation of about 1,350 feet above sea level in the northwest, and approximately 700 feet at the southeast corner. Generally the slope is gentle. The area occupied lies within Garvin, Murray, Carter, Johnston, Coal, and Pontotoc counties. The rocks exposed range in age from pre-Cambrian to Pennsylvanian. They were deposited during pre-Pennsylvanian times under water which varied in depth and in length of duration. During the earlier periods thick deposits of limestone were laid down. Later deposits show more shallow water and shorter periods of time in which conditions were favorable for homogeneous deposition. Some time during the Pennsylvanian period the area was lifted above water in places and remained covered in others. The crustal stresses which made the region dry land by uplifting also broke, folded, faulted, and twisted the formations until they are steeply inclined. As soon as land appeared, agents of denudation began to work rapidly. The result was a deposit of conglomeratic material. The erosion which took place then and later has exposed the granite core of this upfold, which had been in itself twisted and warped into a large number of minor flexures. Over the upturned edges of the older rocks which dip away from the granite cores, the Franks conglomerate was laid down.

STRATIGRAPHY.

In the following geologic section exposed in the Arbuckle Mountains it is deemed advisable in some cases to give three or four of the more characteristic fossil forms. The section is given with the youngest formation at the top.

Geologic section.

			Feet.
12.	Franks conglomerate		
11.	Glenn formation		—
10.	Caney shale		—
9.	Sycamore limestone		1,600
8.	Woodford chert		200
			550
7.	Hunton limestone	Bois d' Arc limestone	
		Haragan shale	0- 90
		Orthostrophia strophemenoides, Meristella arcuata, Phacops logani.	0- 166
		Henryhouse shale	
		Chimneyhill limestone	0- 223
		Spirifer radiatus, Dalmanella elegantula.	0- 53
6.	Sylvan shale		
	Diplograptus, Climacograptus.		60- 300
5.	Viola limestone	Upper: *Strophomena wisconsinensis, Hebertella insculpta, Rhynchotrema capax.* Middle: *Diplograptus pristis, Climacograptus typicallis, Trinucleus concentricus.* Lower: *Rafinesquina deltoidea, Platystrophia, Bumastus trentonensis.*	500- 700
4.	Simpson formation		
	Macleura magna, Orthis tricenaria, Hebertella bellarugosa, Plectambonites multistriata.		1,200-2,000
3.	Arbuckle limestone		
	Billingsella, Ophileta, Bathyurus.		4,000-6,000
2.	Reagan sandstone		
	Cambrian trilobites and *brachiopods.*		500
1.	Granite		

1. *Granite.*—The surface area of the granites of the Arbuckle Mountain region comprises about 80 square miles. All of the commercial granite of the region lies on the southwestern flank of the exposed portion of the Arbuckle Uplift. This district is not mountainous in the sense of being of high elevation, but consists of a gently rolling plain, which slopes to the south at a low angle. The granite is of two chief types, a coarse-grained and a fine-grained, pinkish-gray biotite-granite. The two types are much alike except in texture. Granite is exposed in the East and West Timbered Hills but has neither the areal extent nor the quality to be of commercial value.

2. *Reagan sandstone.*—This is coarse sandstone with shales and sandstones in the upper part. The basal member, which is variable in occurrence and thickness, is arkosic and granitic. Above this member is a coarse quartz sandstone, with occasional overlying green and red sands and shales. The thickness varies from a few feet to 500 feet. The upper calcareous layers contain Middle Cambrian fossils.

3. *Arbuckle limestone.*—The Arbuckle limestone has here much the same character that it has farther west. These sediments are chiefly massive limestones, which aggregate 4,000-6,000 feet in thickness. The limestone is white to light blue, with many layers of thin, dark-colored shale near the base. Abundant fine white quartz-conglomerate is found near the contact with the Reagan sandstone. This limestone covers an area of 385 square miles. Owing to the orogenic movements of Pennsylvanian time, it has been broken and highly faulted over large areas. Its faulted and unfaulted contacts with igneous and sedimentary rocks measure 134 and 122 miles, respectively. The exposures are broad, treeless, and rolling, forming rocky uplands.

4. *Simpson formation.*—The Simpson formation consists of three massive, pure sandstone members, separated by shales, siliceous limestone, and sandy shales. The thickness varies from 1,200 to 2,000 feet. The sandstones are white or light gray, with the grains small but fairly uniform. The shales are friable and chiefly glauconitic. The limy layers have preserved the lower Ordovician fauna rather poorly, while in the sandstones and shales fossil remains are very rare or entirely wanting.

This formation is of special economic value as a source for good glass sand, rich asphalt deposits, and possibly undiscovered oil pools. It is impossible to say definitely as to the possibilities for encountering oil in a formation which is so closely folded, which has undergone such severe crumpling and faulting, as is evidenced by slickensides in the calcareous members. It is probable that from a formation in which there are such large asphalt deposits a large amount of the volatile hydrocarbons has escaped. It might be possible, however, to find areas in which the oil is still retained. In fact, it has been rumored that a small amount of oil has been found in some shallow wells drilled into the Simpson.

The Simpson formation outcrops are much scattered over this uplift, occurring chiefly in long narrow bands. One of the longest of these begins at a point 6 miles west and 1½ miles north of Tishomingo, and extends northwest to the middle of the north line of T. 3 S., R. 3 E. Here it is faulted out. In sec. 31, T. 2 S., R. 3 E., it again appears, and continues in a north and westerly direction to a few miles south of Hennepin. Other outcrops of importance occur in the eastern one-half T. 2 S., R. 3 E.; southeast of Sulphur for 6 or 8 miles; around the town of Hickory; north and east of Roff; and the eastern tier of sections of T. 1 S., R. 6 E., along with the southwestern three-fourths of T. 1 S., R. 7 E. The outer limits of this area extend northward and southward for a short distance into the adjoining townships. This area is just north of Belton and east of Connerville. Further investigation may show that certain portions of the areas mentioned, as well as some not enumerated, would be worth drilling. In most cases it is probable the hole drilled would not need to be very deep in order to test out one of the three sands present.

Four hundred feet down from the top of this formation is a 90-foot sandstone; 400 feet below this a 100-200-foot sandstone; and several others lower down, varying from 5 to 100 feet. The character and thickness of these sands connected with the fact that some oil has been found, and that asphaltic deposits covering large areas and over 100 feet thick have been prospected within them, all indicate that further investigation should be made.

5. *Viola limestone.*—Five hundred to 700 feet of limestone lie above the Simpson formation. This has been subdivided into upper, middle, and lower, because of differences, lithologically and paleontologically. The lower part contains many chert nodules; the middle is dense and fine, with its lower part buff shale; and the upper is coarsely crystalline limestone. This stone is crushed for ballast, crushed stone, chicken feed, etc., at Fitzhugh. Large, rounded, grassed hills characterize Viola topography.

6. *Sylvan shale.*—The Sylvan shale is black to greenish in color. Its thickness is from 60 to 300 feet. The Ordovician fauna is not very abundant. Outcrops occur in wooded valleys.

7. *Hunton formation.*—Reeds, after working over this formation carefully, has subdivided it into four parts, as follows:

	Feet.		Feet.
Bois d'Arc limestone	0- 90	Av.	60
Haragan shale	0-166	Av.	100
Henryhouse shale	0-223	Av.	90
Chimneyhill limestone	0- 53	Av.	35

The Bois d' Arc of Reeds equals the upper Hunton of Taff, the Haragan and Henryhouse shales equal middle Hunton, and the Chimneyhill is equivalent to the lower Hunton. The faunas are distinctive and well preserved.

8. *Woodford chert.*—Conformable above the Hunton lies the Woodford chert. The few fossils at the base point to probably Devonian age. No fossils have been found within the formation, which is made up of alternating cherty layers, shale, and small concretions. Numerous blackjacks mark the outcrops.

9. *Sycamore limestone.*—The Sycamore limestone is appar-

ently a lentil occurring only in the western portion of the mountains. At the western extremity the thickness is 200 feet, in the middle 50 feet, and toward the northeast it disappears entirely. The rock is light bluish to yellow or buff, with joint plains frequent. Near the middle are two carbonaceous shaly members separated by limestone, from which a limited fauna closely related to that of the Caney has been collected.

10. *Caney shale.*— The Caney shale is estimated as being as much as 1,600 feet thick. The basal part is marked by black carbonaceous shales, with some calcareous and argillaceous segregations. These concretions are often fossiliferous. The fauna is probably Mississippian.

11. *Glenn formation.*—This formation includes all of the shales and sandstones above the Caney in the Pennsylvanian. The town of Glenn, from which the sediments take their name, is located in the Ardmore quadrangle on the outcrop. The Glenn is composed chiefly of friable blue clay shales and thin-bedded brownish or drab sandstone. Rarely, outcrops of calcareous material are found. Owing to the fact that the beds are generally difficult to keep separate and distinct, information concerning structure within this formation is limited. It is also practically impossible to say as to the thickness because of this lack of data. The best that can be said is that these sediments are comparatively thick. Fossils are fairly abundant, and those at the base have been identified as being of Pennsylvanian age.

The formation dips south away from the center of the mountains. It is quite probable that this same series of shales, sandstones, and calcareous layers may lie under the Healdton, Wheeler, and Loco fields. If so, the supposition favors this formation as being the productive horizon.

12. *Franks conglomerate.*—The Franks conglomerate is the youngest formation exposed over any part of this area. It ranges in thickness from zero to several hundred feet, and covers outcrops of rocks from lower Ordovician or possibly Cambrian age to Pennsylvanian. The component particles, which are usually light gray, buff, or pinkish in color, vary in size from comparatively fine sand to pebbles 3 inches in diameter. The Franks conglomerate lies unconformably upon older formations.

STRUCTURE.

In a general way, the term dome has been applied to the Arbuckle region, but this must be understood as being expressed in simplest terms. Lateral thrusting has caused many

minor folds to be formed. In regions of extreme deformation the strain has proved too great, so faults have resulted. One has a throw of probably 6,000 feet, others are less. Good examples of tilting, folding, and faulting may be noted almost anywhere over the area.

MISSISSIPPIAN REGION.

GENERAL STATEMENT.

The northeastern portion of the State lies within the geologic division known as the Mississippian region. All or a part of the following counties are included: Ottawa, Craig, Mayes, Delaware, Adair, Cherokee, Wagoner, and Sequoyah. Parts of the Vinita, Wyandotte, Pryor, Siloam Springs, Tahlequah, and Muskogee quadrangles are embraced within these counties. This area is the southwestern extension of the Ozark uplift of Missouri and Arkansas. The rocks as a whole are limestones, with some shales and sandstones present. In the vicinity of Spavinaw is a red granite dike 75 feet wide by 1,500 feet long. At several places along the west and south there are small irregular patches of Pennsylvanian rocks. These are described as the Morrow and Winslow by Taff in the Tahlequah folio, and have been previously mentioned in this discussion.

The general level of the surface is 1,100 feet above sea. The tributaries of the larger rivers cut deep, narrow valleys in the limestone. The slopes as a rule are steep, rocky, and well rounded. In a few instances these deep incisions have reached rocks older than Mississippian age.

The formations of this area are of the right nature to be petroliferous. The Burgen sandstone would make a good reservoir, and the Chattanooga shales, alone, would probably furnish a sufficiently impervious cap rock. The shaly members of the Tyner would also act as cap rocks. A number of places have been located where the structure is very favorable, but so far no production has been recorded. It is a generally accepted idea among drillers that the "Mississippi lime" is the lowest point at which oil or gas may be found. A number of wells have been drilled in the area of Mississippian sediments, but only strong flows of salt water have been encountered. The prospects for oil and gas do not seem to be good in this area.

STRATIGRAPHY.

The Mississippian rocks of Oklahoma have been studied very carefully by L. C. Snider, assistant director of the Oklahoma Geological Survey, and most of the information given here is a result of his efforts. This is especially true in instances where lists of the fossils have been given, but not associated with any one's name.

The following formations named from the top down comprise the section of Mississippian sediments:

Geologic section.	Feet.
4. Pitkin limestone	5 to 70
3. Fayetteville shale	100 to 120
2. Mayes formation	Thin to 100
1. Boone formation	100 to 350

1. *Boone formation.*—The greater part of the Mississippian area of northeastern Oklahoma is covered by the Boone formation. This consists of limestone and chert 100 to 350 feet thick. The basal portion is marked by a 30-foot limestone, the upper part of which is free from chert, crinoidal, and light-colored. In the Siloam Springs quadrangle the crinoidal layer is 10 to 15 feet thick, with some shaly limestone below it. In most localities the limestone and chert alternate, with the layers 1 to 2 feet thick. In other cases the chert is irregularly disseminated through the limestone as nodules and lenses. In the Tahlequah quadrangle, locally, dark-colored limestone and greenish shales prevail at the bottom of the formation. These thicken from 6 feet, north of Tahlequah, to 40 feet in the Siloam Springs quadrangle, and then thin rapidly to the north and northwest. They are just below the horizon of the St. Joe member of Missouri, and the fauna shows them to be of Kinderhook age.

The fauna indicates the mass of the Boone to be Burlington-Keokuk.

So far as the writer is able to determine, no production of consequence, if any at all, has come from the Mississippian rocks. Some have contended that wells in the region of Muskogee and Wagoner are producing from this, or a lower horizon, but the data are not sufficient to determine fully this point.

Below the rocks of Mississippian age a series of older sedimentaries have been uncovered by erosion. The Devonian is represented by the *Chattanooga shale,* which in texture and composition closely resembles that of the same age in Arkansas, Tennessee, Kentucky, Indiana, and Ohio. It is black, carbonaceous, and uniform in character. According to Snider* and Siebenthal† the thickness varies considerably over different areas, and may be said to be from 15 to 90 feet. Outcrops are found at the following places: East of Neosho, on Spring, Honey, Buffalo creeks, and along the bluff of Illinois and Cowskin rivers. The *Sylamore sandstone member* lies at the base of the Chattanooga shale. In some deep wells near Vinita and Grove, it is claimed this formation has been reached.

Older than the Chattanooga is the *St. Clair marble* of Silurian age, which is exposed in the southeastern part of the Tahlequah quadrangle. Rocks of this age are not exposed in adjoining quadrangles, and occur here only as a result of a fault.

The oldest formation exposed in this geologic division is the *Burgen sandstone,* a white, fine-grained sandstone varying from 5 to nearly 100 feet, according to Taff in the Tahlequah folio. The formation is generally considered non-fossiliferous, but a few poorly preserved Orthoceras have been found on the surface. The *Tyner formation* lies immediately above the Burgen, and consists of a series of greenish shales, with some limestone and sandstone interbedded. The fossils of the thin sandstone and shale are of Lorraine (Ordovician) age. The contacts with the Chattanooga shale above and the Burgen sandstone below are unconformable.

2. *Mayes formation.*—Lying unconformably above the Boone formation, and usually separated from it by a thin shale member, is the Mayes formation of the Chester group. In the Tahlequah and Muskogee quadrangles it consists principally of dark-gray to black limestone, separated by thin bands of black shale. The thickness is variable, but in general this formation thickens rapidly to the north, until in the Pryor quadrangle it attains a maximum thickness of 100 feet along Grand River.

3. *Fayetteville shale.*—Lying conformably above the Mayes formation is a series of shales varying from 100 feet in thickness near Ft. Gibson to 120 feet in the Tahlequah quadrangle. The formation consists of blue to black clay shales, with thin limestones which are usually lenticular. Near Wedington a sandstone member which measures nearly 40 feet in thickness, thins to the westward and disappears near the middle of the quadrangle. The formation as a whole thins to the northward, but the limestones thicken and become more persistent.

Southeast of Choteau, where the thickness is 90 feet, a limestone 12 feet thick occurs near the base, with a middle layer abounding in *Productus pileiformus* and *Productus cestriensis.*

In the Vinita quadrangle it is difficult to distinguish be-

*Snider, L. C., Bull. Okla. Geol. Survey, No. 9, 1912, p. 36.
†Siebenthal, C. E., Bull. U. S. Geol. Survey, No. 340, 1907, p. 189.

tween the different horizons, and their correlation is not yet determined.

4. *Pitkin limestone*.—The Pitkin limestone is variable in thickness over different areas. Within the Muskogee quadrangle 50 feet is the usual thickness, with little variation, either above or below, while in the Tahlequah quadrangle the variation is from 5 to 70 feet. The Pitkin thins rapidly to the north. In the Pryor quadrangle it is usually less than 20 feet and seldomly over. According to Snider, it is locally absent north of the center of the Pryor quadrangle, and the Pennsylvanian sandstones are found in contact with the Fayetteville shale. To the south the formation consists of thin, light blue to brown layers, interbedded with massive, fine-textured streaks.

The fauna of the Pitkin closely resembles that of the Fayetteville shale below.

STRUCTURE.

The surface rocks dip gently to the west and southwest. The formations, however, are not so nearly level as they otherwise would be if it were not for the folds and faults which have broken them, to a marked degree in some cases. The structural features have been worked out in the southern part by the United States Geological Survey, but have not been studied to the north sufficiently to locate them with accuracy.

OUACHITA MOUNTAIN REGION

GENERAL STATEMENT.

In southeastern Oklahoma, as in the northeastern part, the mountain uplift extends across from the adjoining state. This range of mountains is bounded on the north and west by the Choctaw fault, and on the south by the Cretaceous region, and comprises the south half of Latimer and Leflore counties, the eastern three-fourths of Pushmataha, the northern two-thirds of McCurtain, southeastern Pittsburg, and northeastern Atoka counties. The Ouachita Mountains extend from the northern part of the Atoka quadrangle to central Arkansas, near Little Rock, a distance of 200 miles.

The area, as a whole, consists of long, low mountains and high ridges oriented southwest-northeast. The rocks have been closely folded and faulted, so that high altitudes mark the more resistant sandstone regions, while steep-sided, flat-bottomed valleys mark the shale outcrops. The valley slopes often rise abruptly 50 to 250 feet. The hills increase in height to the east until they reach an elevation of about 3,000 feet near the State line. The chief points of elevation are: Jackfork, Kiamichi, Winding Stair, Pine, Potato Hill, and Williams mountains. Throughout this region of rough topography there is little land under cultivation. The result is a sparse population.

The rocks are chiefly shales and sandstones, with the former more abundant, although the latter is apparently the thicker. This is due to peculiarities of weathering.

The extreme folding and faulting in this region makes most of the area undesirable territory to test out for oil and gas. It seems probable that the formations have been broken to such an extent that any volatile hydrocarbons must have escaped. Only a few areas have been located in which bituminous deposits have been present. One of these is near Page in Leflore County, another near Antlers in Pushmataha County, and still others of importance occur in the McGee and Impson valleys. The first two named deposits contain a too great percentage of fixed carbon to be of value, even for paving purposes. All of these deposits occur along fault zones, but, by no means, have all faults deposits. A careful summing up of the known data seems to stamp this territory as unfavorable for oil and gas. It is possible, however, that in some gentle fold or sealed in by a fault there may be sufficient petroleum and gas to pay for drilling. To make any definite locations at this time is impossible, owing to the small amount of geologic information extant.

STRATIGRAPHY.

The rocks found in this region are all of Ordovician and Silurian age. The section is as follows, beginning at the top:

Geologic section.

	Feet
4. Jackfork sandstone	3,800-5,000
Brown and drab sandstones, shales, and sandy shale.	
3. Standley shale	6,100
Fissile shale and thin, drab sandstone.	
2. Talihina chert	1,150
Flint and chert above, chert and clay middle, and combined with lentils of limestone at the base.	
1. Stringtown shale	600
Black and blue shale, with cherty beds.	

1. *Stringtown shale*.—The lowest formation exposed is the Stringtown shale. It is made up of black, fissile, cherty shales, with greenish clay shales below. The total thickness is more than 600 feet. Much of the material exposed is slatelike and

hard. Exposures are frequent in the western part of the uplift, along the lower slopes and on flat plains. Upper Ordovician *graptotiles* have been formed in the black, slaty shale of the upper part.

2. *Talihina chert.*—Over this area above the Stringtown, is the Talahina chert, about 1,200 feet in thickness. Generally, it is composed of three poorly defined members. The highest of these, 300 feet thick, is composed of chert and shale, with the layers usually less than 6 inches in thickness. Some limestone is present. The middle and upper members grade into each other, so that a line of demarcation cannot be definitely drawn. This member is also about 300 feet thick, with fissile shales and thin, cherty layers throughout. The bottom member is estimated to be 600 feet thick. It is composed of black, gray, white, and greenish cherts and flints, 6 inches thick. Limestones sometimes occur in the section.

Many reports of lead have come from the Ouachita Range, based chiefly upon stories that Indians secured lead to make bullets. Recently a lead mine of considerable importance has been opened up in eastern McCurtain County. It seems probable, from the information that can be secured, that this ore comes from the Talahina. Another metallic mineral which occurs in the Arkansas novaculite (upper Talahina) as small lumps and nodules, though not in sufficient quantities to be classed as an ore, is manganese.

This cherty horizon usually forms low, smooth, round-knobbed ridges.

3. *Standley shale.*—Immediately above the Talihina chert is the Standley shale. Lithologically, it consists of 6,100 feet of siliceous chert, greenish clay shale, sandy shale, and some thick sandstone. The sandy chert, clay, and greenish clay shales occur near the bottom of the formation. Higher are the brown and drab sandstone members from 20 to 100 feet thick, separated by shales or shales and sandstones interstratified, 140 to 2,000 feet thick. The sandstones, as a rule, are so soft that they weather evenly with the clay shales. As a result, outcrops are found on level plains and in wide valleys, such as that of the Kiamichi River and Impson, Jackfork, Chickasaw, and McGee creeks. Standley, the small town from which the name is taken, is located in the Kiamichi Valley.

4. *Jackfork sandstone.*—Topmost of the formations exposed in the Ouachita Mountain region is the Jackfork sandstone 3,800 to 5,000 feet thck. The period of sedimentation was evidently long and fairly continuous, since the greater part of this formation is brown and gray sandstone. The layers,

even-textured and fine-grained, range from very thin to fully 50 feet in thickness, with the shale partings thin and seldom exposed. Outcrops are marked by high, strong, rough land. Three good exposures are located near the west end of the Ouachita range, forming Rich, Kiamichi, and Jackfork mountains. The formation takes its name from the last mentioned.

STRUCTURE.

A preliminary study shows that the structure of this region is more complex than in any other portion of the State. The surface is also more broken, due to the combined effects of these crustal stresses and the hard, resistant character of the Jackfork sandstone. Some of the topographic features reach such height as to be worthy of the name of mountains. The strata are upedged and in many cases completely overturned.

SUMMARY.

Oklahoma ranks second in the United States as a petroleum producing state, and among the first in the production of natural gas. The main fields lie in the northeastern part of the State. Other widely separated areas are productive, chief of which is the Healdton field brought in during the latter part of 1912, and now having about 300 wells yielding either oil or gas, or both.

The production in the Oklahoma fields is controlled by the structural features. "Oil-trends," "oil witches," and prospecting instruments are not to be relied upon. In the location of wells a knowledge of the geologic conditions and structural features is essential.

Certain areas in the State are to be eliminated from the probable oil and gas territory. The geologic conditions in the Ozark, Ouachita, Arbuckle, and Wichita mountain regions, and a considerable part of the Redbeds region, are such that the finding of oil or gas in paying quantities is very improbable.

The Pennsylvanian series contain the chief oil and gas producing rocks of Oklahoma. In the south-central part of the State Permian rocks are locally productive. Some production is found in the basal portion of the Trinity sand of the Cretaceous rocks. The oil and gas found in the Permian and Cretaceous probably had their origin in the underlying Pennsylvanian rocks. Showings of oil and gas may be found in any of the sedimentary rocks. Asphalt deposits and oil seepages often serve as aids in the proper location of test wells.