Petroleum and Natural Gas In Oklahoma

By

L. C. SNIDER, A. M.,

Assistant Director of the Oklahoma Geological Survey

Oklahoma City, Okla.

THE HARLOW-RATLIFF COMPANY

1913

ALLIED PRINTING TRADES UNION LABEL COUNCIL
93

PREFACE

This hand book is written with the view of putting within reach of all interested, a comprehensive but brief review of the oil and gas industry of Oklahoma, and the prospects for the future development of this industry. A large portion of the book is taken up with descriptions of the producing fields and discussions of the conditions in these fields. The geology of the State is considered with reference to the occurrence of oil and gas in the developed areas and with reference to the probable or possible occurrence of these substances in other portions of the State. The methods of prospecting for oil and gas and the use of geology as a guide for prospecting are considered rather fully. Some items of general interest, such as brief notes on transportation and refining, are included. In the consideration of the oil and gas of the different fields it is necessary to refer constantly to the geologic conditions which exist in the area. For the benefit of those who have had no training in geology brief discussions of the nature and mode of origin of rocks, and of the structure or position in which the rocks are found are given. All the geologic terms used in the book are explained in these sections.

Development maps showing the state of development in the early part of 1913, are given for all the important pools. The information for these maps has been obtained from the maps of the Gulf Pipe Line Company and of the Tulsa Mapping Company. The character of the rocks passed through in drilling in the different pools is illustrated by means of typical well logs. The statistics are taken from Mineral Resources of the United States published by the United States Geological Survey.

INTRODUCTION

The daily output of oil in Oklahoma has a value of more than $1,000,000 a week. Natural gas to the value of more than $135,000 is marketed every seven days. The total value of oil and gas is now running at about $70,000,000 a year. These figures more than any words will impress on the mind the commercial value of Oklahoma's oil and gas industry. To this amount should be added the values of refinery products and natural gas gasoline as well as that of the scores of industries which draw on our natural gas for fuel. The value of our raw products and of the industries which subsist directly upon them swell the value of these commodities to an enormous total and make the oil and gas industry one of the first in the State.

The present demand for information on oil and gas in Oklahoma is enormous. Few, if any, men are better qualified to supply this information than the author. Mr. Snider has written this book and compiled statistics during such times as he was free from official duties. His information has been drawn in large measure from publications of the Oklahoma and United States Geological Surveys. This has been materially supplemented by the personal knowledge of the author, acquired during five years of service for the State. During his field and office work Mr. Snider has had excellent opportunity to become conversant with the oil and gas geology of Oklahoma as a whole, and also with geologic and operating conditions in each particular field.

In the preparation of this work the author has had in mind to supply general information to those actively engaged in drilling and developing proven territory; to guide in a general way those who are courageously "wildcatting" in the various parts of the State; and to inform the general public and especially the prospective investor as to conditions as they now exist. The book is a valuable aid to landowners who may or may not believe that oil and gas underlie their possessions.

I have read a large part of Mr. Snider's manuscript, and, at his invitation, have carefully scrutinized his discussions of the geology of the several oil and gas fields, and criticized his statistical data. All are believed to be in strict accord with present knowledge. Mr. Snider's clear, concise, and lucid style, his close familiarity with the geology of the State, his intimate knowledge of operating conditions in each community, and his firm grasp of the oil and gas business, all conspire to commend his work to the public.

D. W. OHERN.

Norman, Oklahoma, August 26, 1913.

ILLUSTRATIONS

TABLE OF CONTENTS

I.

GENERAL GEOLOGY

NATURE AND MODE OF FORMATION OF ROCKS.

Rocks are divided into three great classes—igneous, sedimentary, and metamorphic. The igneous rocks are those which were formed by the action of heat (*ignis*, Latin for fire). They have cooled into their present form from a liquid or molten condition. The igneous rocks are generally hard and crystalline and do not, as a rule, occur in layers or beds. There are very many types of igneous rocks of widely varying appearance and texture, but granite is probably the most common and best known variety and may be considered as the type of the igneous rocks of Oklahoma where they occur only in the Arbuckle and Wichita mountains and in a very small area along Spavinaw Creek in Mayes County.

The sedimentary rocks—as is indicated by their name—are those which were deposited as sediments in water. We know that ages ago all the territory now included in Oklahoma was covered by the ocean for vast periods of time. Gravel, sand, and soil were washed down by the rivers from the surrounding land and deposited as layers of sediment on the ocean bottom. These sediments in many places were piled up to thicknesses of thousands of feet before the ocean was finally withdrawn and the area of Oklahoma became land. Since the rocks of practically all of Oklahoma are sedimentary and since all the oil and gas occur in these rocks, an understanding of the method of their formation and their relations is important.

The sedimentary rocks consist of shales or mud rock, sandstone, limestone, chert or flint, and conglomerate or pudding stone, named in the order of abundance. The conglomerates, sandstones, and shales were formed by the gravel, sand, and mud respectively which were washed down from the surrounding land into the ancient ocean and settled to the bottom. The limestone was built up principally of the shells of sea animals. When the animals died these shells sank to the bottom and accumulated there. For the most part the shells were partially dissolved and were ground up by the wave action into a lime mud which preserved no trace of the shell structure. In many cases, however, the shells were preserved entire and some of the limestones of northeastern Oklahoma and of the Arbuckle Mountains are largely made up of well-preserved fossil shells. Fossil shells are also found in shale, and the shells or their impressions in sandstones. The mode of origin of flint or chert is not definitely known. It is certainly formed by the action of water, but the exact method is in dispute, and was probably different for different deposits.

It is easily seen that the gravel and sand, which now form the conglomerates and sandstones, would be deposited near shore or where there was sufficient action by waves or currents to carry the coarse material in suspension, while the finer particles of mud would be carried out farther and deposited in more quiet waters. Some lime from shells would be deposited with the gravel, sand, and mud, but the quantity would be so small in comparison with that of the other materials that it could scarcely be noticed. It would be only in clear, relatively quiet water that pure, or nearly pure, lime mud would be formed.

From the way in which these different rocks are formed, it is evident that all three kinds of rock would be forming at the same time, that is, at the same time that gravel and sand were being deposited near shore, clay mud would be deposited farther from shore where the waters were more quiet, and lime mud would be forming farther out in the quiet, clear water. This is shown in figure 1. When the sea level is at *AB*, gravel is deposited near shore and sand from *A* to *a*, mud from *a* to *b* and lime mud from *b* to *c*.

The different materials would naturally grade into each other laterally, that is, some fine sand would be de-

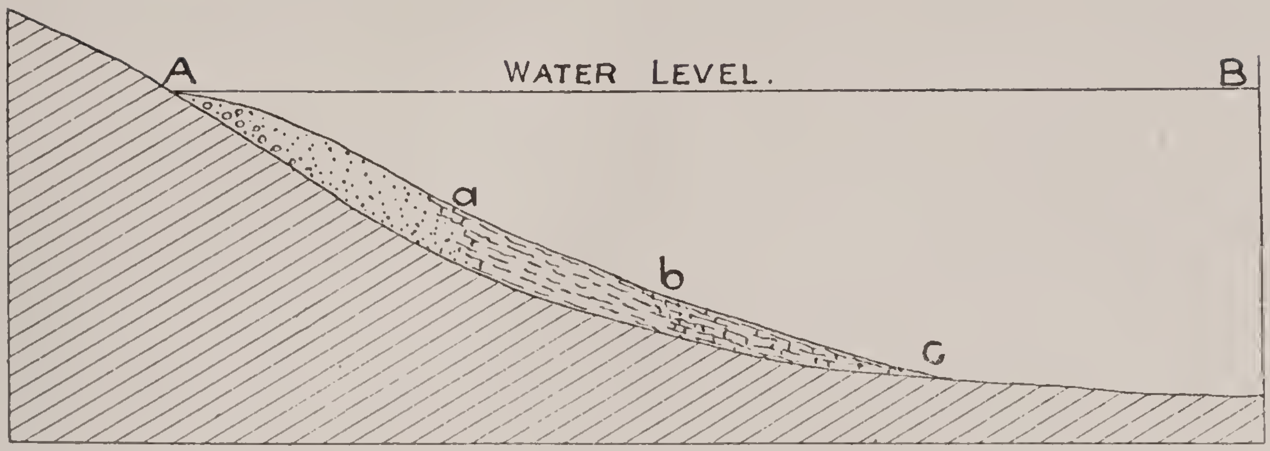


Fig. 1.—Diagram illustrating the simultaneous deposition of sand, mud, and lime mud near a shore.

posited with the mud and some mud and extremely fine sand with the lime mud. It is also evident that changing conditions such as deepening of the water, elevation of the land, or a change in the direction of the ocean currents

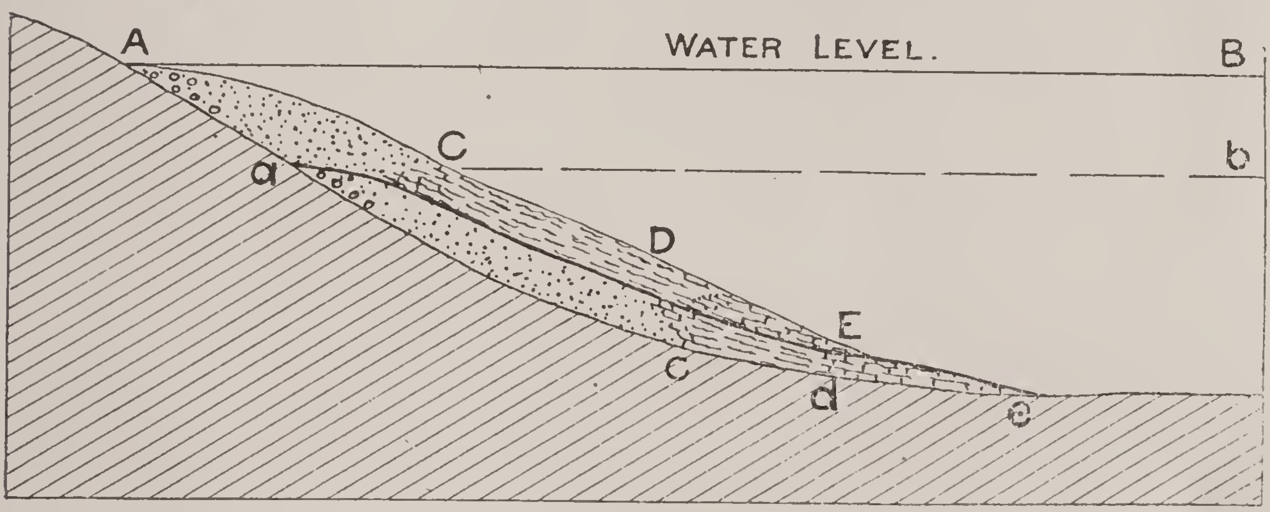


Fig. 2.—Diagram illustrating the effect of change of sea level on the succession of deposits at a given place.

might cause a change in the nature or the distribution of sediments. Thus in figure 2, when the water level was at *ab* gravel or sand would be deposited over the area *ac*, mud over *cd*, and lime mud over *de*. A change in level bringing the water level to *AB* would cause sand to be deposited over *AC*, mud over *CD*, and lime mud over *DE*. We might thus have a layer of sand overlaid by a layer of mud or of lime mud, and mud overlaid by lime mud. A change of shore line in the opposite direction would deposit sand above mud, mud above lime mud, and lime mud farther out on the sea bottom. Any succession or number of successions of the three or any two of the three might be produced by varying conditions.

A greater change in the level of the sea might cause a great area of the sea bottom to become land, and the layers of gravel, sand, mud, and lime mud would then become hardened by the pressure of the overlying layers and by chemical changes and would be cemented to form conglomerate, sandstone, shale or slate, or limestone respectively.

As soon as the region became land the air and the water would begin their work of breaking down and carrying away the rock. While both agents are active the water is the more important. Running water is the great agent for carrying rock material from the land surface. Water also assists in the removal of rock by dissolving it and carrying it away in solution. The cementing material of sandstones is dissolved and the sandstone crumbles into sand which is easily washed away. This action would soon form hills and valleys so that a rough land surface would be developed. A further change in the sea level might bring this surface below the sea when it would again receive deposits as before. The earlier and later deposits

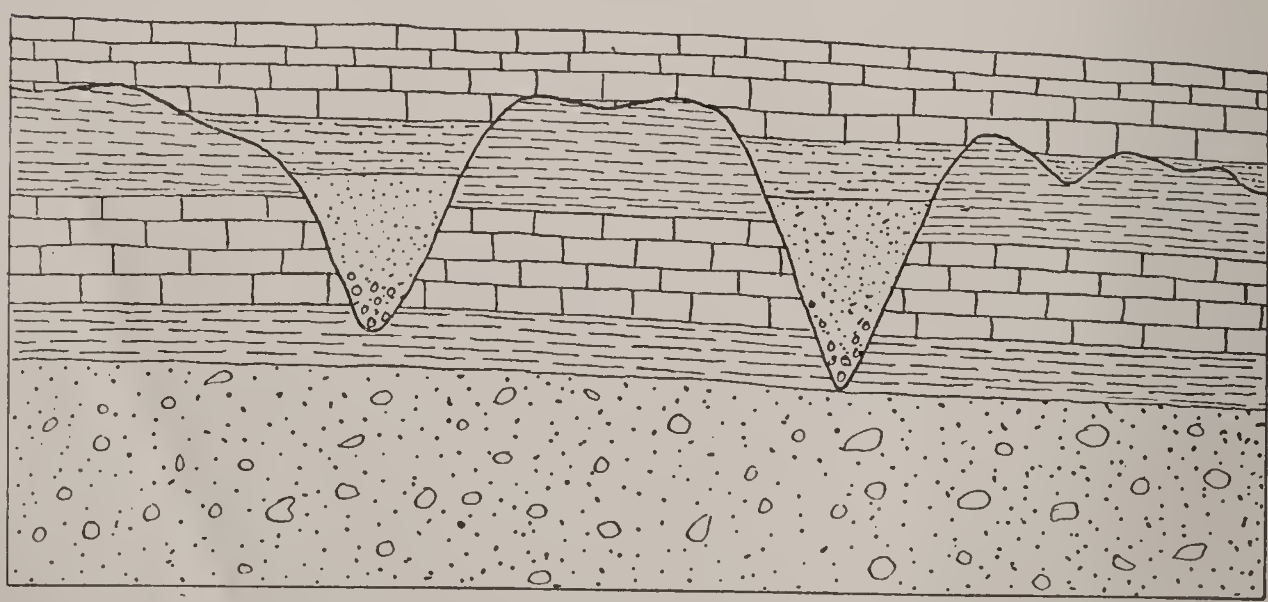


Fig. 3.—Diagram showing an unconformity.

would, however, be separated by a break or uneven surface—the old land surface—which condition is known as an *unconformity*. These conditions are illustrated in figure 3 where the irregular line *AB* represents an unconformity.

STRUCTURE OF ROCKS.

From the description of the mode of formation of the sedimentary rocks, it is apparent that the rocks would be deposited in a horizontal or level-lying position or would be slightly inclined if deposited on a sloping sea bottom. It is seldom, however, that rocks which have been exposed as land for a long time remain in this level position. The earth is apparently growing smaller and this contraction causes wrinkles or folds to appear in the rocks of the surface in the same way that the skin of an apple becomes wrinkled as the apple dries up. These folds are not caused by pressure from beneath but from the sides. The method of their formation may be shown by grasping a number of sheets of cardboard or heavy paper by the ends and then pressing the hands together. A slight pressure will make only a simple bend in the paper so that a portion of it is inclined to the rest. A stronger pressure will force the

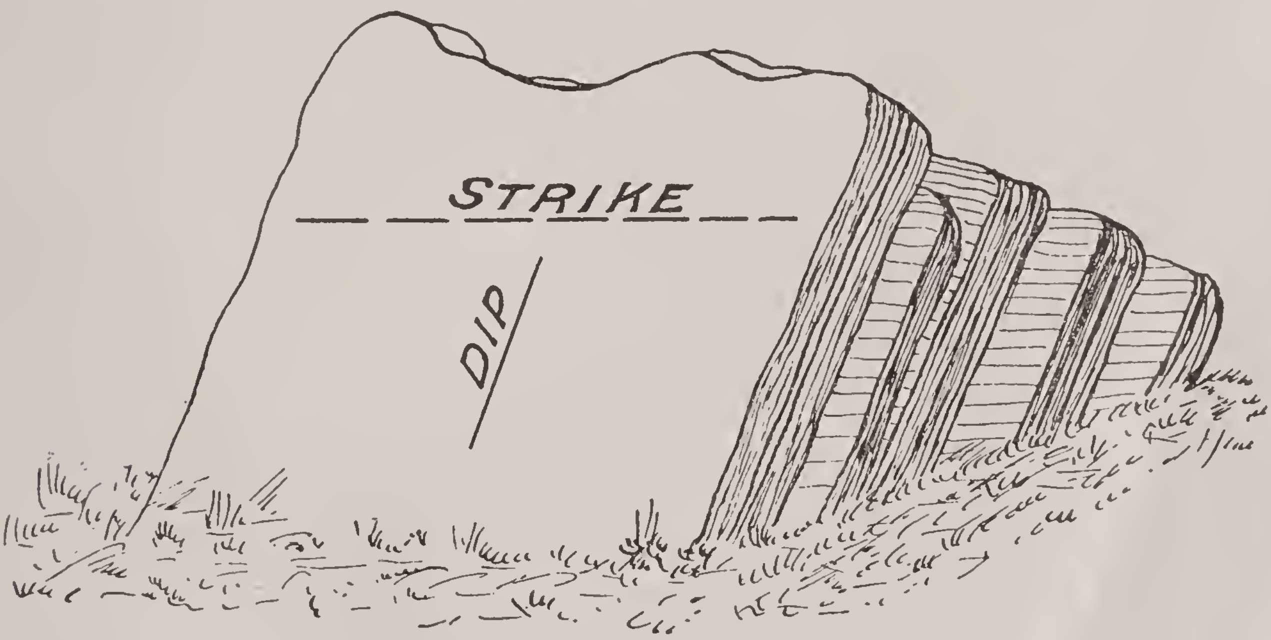


Fig. 4.—Diagram illustrating dip and strike.

paper into a well developed fold—a trough or crest as the case may be—and a still stronger pressure may cause more than one fold to be formed. If the paper is very stiff and the pressure sufficiently great some of the sheets may break and the broken ends be shoved past each other.

As has been said, the rocks which form the surface of the earth have almost everywhere been subjected to this lateral pressure and have been more or less folded, so that they are not level-lying but have an inclination or slope away from the horizontal. This slope or inclination is called the *dip*. The line along which a bed comes to the surface is the *outcrop* and the general direction of the line, at right angles to the dip is the *strike* (Fig. 4). Where the surface rocks dip in one direction for a long distance the structure is known as a *monocline*. When the dip changes in short distance, that is when the rocks are in folds, two forms of structure may result, an upfold or arch, known as an *anticline* and a downfold or trough, known as a *syncline*. (Fig. 5). Both anticlines and synclines are usually much longer

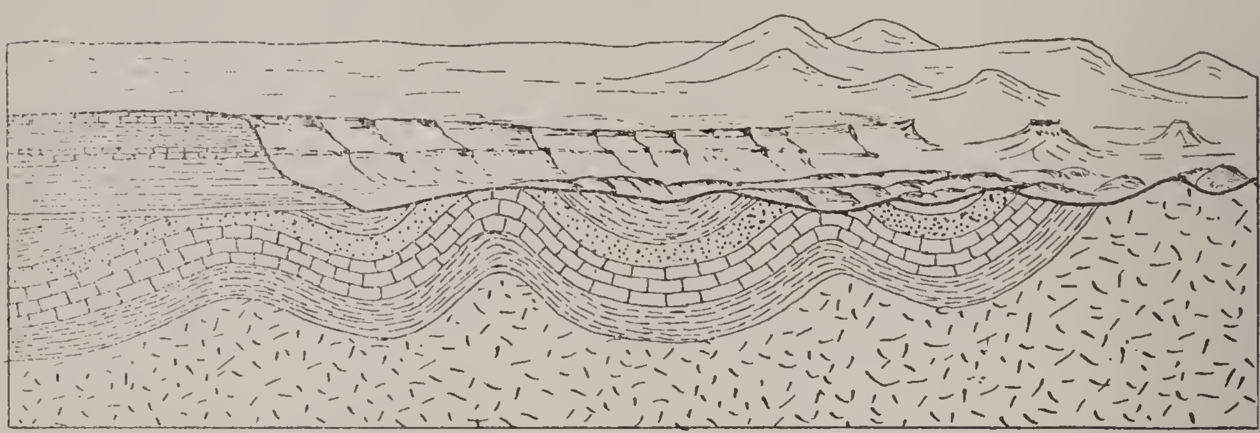


Fig. 5.—Diagram illustrating anticlines and synclines in section with landscape behind. (U. S. Geol. Survey.)

than they are wide but in some cases the length and breadth are about equal. An anticline of this sort is called a *dome* and a syncline is called a *basin* or *saucer-shaped* structure. Any one of these types of folds may vary greatly in size—some folds are much less than a mile in length, while others are many miles in both length and width. The steepness of the dip also varies. In some cases the rocks are standing on edge or have been overturned and in others the dip is so slight as not to be visible, so that the elevation of the ledge of rock must be determined at different places to find the direction and amount of the dip.

In some localities where the folding is very sharp, or where the rocks are under a stretching force rather than a pressure, the rocks have broken along some lines and the rocks on the opposite sides of the break have moved upward or downward with reference to each other. In some cases the blocks have slipped laterally along the break as well as up or down. Such a break as this is called a *fault.* (Fig. 6).

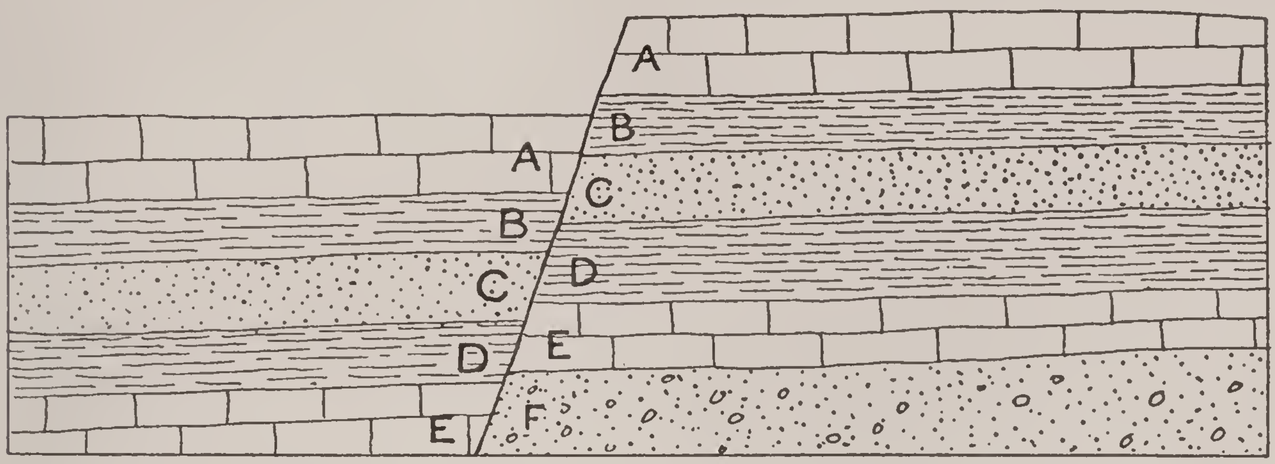


Fig. 6.—Diagram of fault.

So far as our knowledge goes at present, the structure of the rocks is of prime importance in the accumulation of oil and gas and the meaning of the terms anticline, syncline, monocline, dome, and fault should be well understood by anyone interested in prospecting or in developing oil and gas fields.

The origin of the present surface forms, the hills and valleys, can not be considered fully in this connection, but it may be said here that the surface features very seldom bear any definite relation to the structure. The hills do not necessarily correspond to the anticlines nor the valleys to the synclines and a straight bluff does not usually indicate a fault, although it may do so. The presence of a fold is not shown by the elevation of the surface but solely by the dip of the rocks. This fact is well shown in figure 5.

AGE OF ROCKS.

As a matter of convenience geologists have divided the rocks forming the outer portion of the earth's crust into a series of groups according to their age. The oldest of the sedimentary rocks are those which were deposited first and which occur lowest in the geologic column or section. Each of the great groups or systems is marked by the fossils or traces of animal and plant life which it contains. By means of these fossils, rocks of a certain age can be distinguished anywhere they are found, since the fossils of any system are different in many respects from the fossils of the systems above and below it. Names are applied to these systems of rocks—the name usually being taken from the locality where the rocks are best developed or where they were first studied. In this book little reference is made to the age of the rocks, but it is almost impossible to discuss the geology of a region without at least mentioning the names of the principal systems exposed in that region. In the main oil and gas region the rocks are of Pennsylvanian age, the name indicating simply that the rocks are of the same age—were deposited at relatively the same time—as the coal bearing rocks of Pennsylvania. The rocks of the extreme northeastern portion of the State, east of Grand River, are of Mississippian age, that is they are of the same age as the rocks which were first studied in the United States along the Mississippi River in Missouri, Iowa, and Illinois. The rocks of the western half of the State are of Permian age. The term Permian comes from the name of a province of Russia where these rocks are well developed and where they were first studied. In the Arbuckle, Wichita, and Ouachita mountains rocks of ages older than the Mississippian are exposed, but these areas are so small and unimportant from our standpoint that the names of the systems need not be given. In a narrow belt along Red River, rocks of Cretaceous age are exposed. This name is taken from the Latin word for chalk because rocks of this age form the famous chalk cliffs of England. In the extreme western part of the State rocks of a much younger age than those mentioned occur which are known as Tertiary.

In connection with the discussion of oil and gas in the State, the Mississippian, Pennsylvanian, Permian, and Cretaceous rocks are important. The Mississippian rocks are the oldest of these and are composed principally of limestone and chert. They are known to drillers as the "Mississippi Lime." They outcrop in the northeastern part of the State, as has been said, and, dipping to the southwest, pass back under the sandstones and shales of the Pennsylvanian which contain the important deposits of oil and gas. Coming in to the west of the Pennsylvanian rocks and lying above them are the younger Permian rocks which, in Oklahoma, consist almost entirely of red sandstones and shales and are known as Redbeds. To the south, between the Arbuckle and Ouachita mountains the Pennsylvanian rocks pass under the Cretaceous rocks which are still younger than the Permian Redbeds. These Cretaceous rocks contain some oil and gas but so far no large pools have been developed in them.

The systems of rocks are divided into smaller groups known as formations. A formation is defined as a mappable unit, that is a layer of rock or group of layers which extends entirely across the area under consideration and has sufficient width of outcrop to be mapped. Formations may consist of single ledges or beds of rock but commonly are made up of two or more closely related beds.

The separate beds are sometimes called members. Thus, the principal oil sands of the main oil and gas field may be considered as members of the Cherokee formation. The formations and members are usually named from the place where they are best developed or where they were first studied. The Pitkin limestone which outcrops east of Muskogee and Ft. Gibson is an example of a formation consisting of only one kind of rock. The Ft. Scott formation, known to the drillers as the Oswego, is usually called the Ft. Scott limestone, but really consists of two limestones separated by a shale. Formations may vary in thickness from a few feet to thousands of feet. Thus the Chattanooga shale in northeastern Oklahoma is not over 50 feet thick while the Arbuckle limestone in the Arbuckle Mountains is over 5,000 feet thick. Formation names are a great convenience since they provide a means of designating certain beds of rock without repeating extended descriptions. They are necessarily used extensively in the description of the geology of any region.

II.

NATURE AND ORIGIN OF PETROLEUM AND NATURAL GAS

NATURE OF PETROLEUM AND NATURAL GAS.

Natural gas, petroleum, and asphalt or mineral paraffin are all closely related substances forming the different phases of a series of chemical compounds composed of hydrogen and carbon. The simpler compounds of this series are gases while the more complex are liquids and solids. Neither gas, oil, nor asphalt are simple compounds but are mixtures of different members of this series of hydrocarbons. This condition is responsible for the large number of products obtained from petroleum since, in refining, the compounds can be separated from each other and as they form a continuous series almost any number of products can be made by separating the petroleum into different fractions by distillation. This matter is considered more fully under the section on refining.

As has been indicated, natural gas is a mixture of simpler members of the hydrocarbon series which are gaseous at ordinary temperatures. Gas occurs in greater or less quantities with all petroleum. It is colorless, and has a slight odor. The heavier members of the gaseous hydrocarbons are very nearly related to the lighter members of the liquid ones and may be changed to liquids by pressure at low temperatures. This accounts for the manufacture of gasoline from natural gas which is becoming an important industry. The gas which is given off from oil wells, known as casing-head gas, is composed of the heavier gaseous hydrocarbons and is especially adapted to the manufacture of gasoline.

Petroleum is composed of the hydrocarbons that are liquid at ordinary temperatures and pressures and of the hydrocarbons that are solid ordinarily but which are dissolved in the liquid hydrocarbons. The physical properties of petroleum from different fields and even from different wells in the same field vary widely. Some oils are thin and contain considerable volatile constituents, while others are thick and viscous. In color the oils range from almost colorless through a variety of tints of brown and green to black. The Pennsylvania oils are mostly of an amber color, those of Oklahoma are generally dark green to black and those of California are generally dark reddish brown to black. The specific gravity ranges from 0.771 to 1.06 according to Redwood. That is, the weight of a given volume of oil varies from 0.771 to 1.06 times that of an equal volume of pure water. In general the lighter colored oils have the less specific gravity and produce, when refined, the greater amounts of burning oil and less of the heavy lubricating oils and residuum.

The proportion of the lighter oils, gasoline and kerosene, to the heavier oils which are fitted only for lubricating and fuel oils varies very widely. The nature of the base or solid hydrocarbons dissolved in the oil also varies. Oils are known as asphalt or paraffin-base oils according to which substance predominates in the base. Some oils contain either a pure paraffin or a pure asphalt base but much more commonly the two substances occur in the same oil. The Pennsylvania, Lima-Indiana, and Mid-continent oils are principally paraffin-base oils, while those of California are commonly asphalt-base oils.

The properties and composition of the Oklahoma oils are considered more fully in the section on that subject.

CONDITIONS OF OCCURRENCE OF PETROLEUM AND NATURAL GAS.

GENERAL STATEMENT.

All the known deposits of oil and gas occur in sedimentary rocks, and the majority of the occurrences are distant from areas of igneous rocks. Deposits of considerable size have been found in all sorts of sedimentary rocks but limestones and sandstones contain oil and gas much more commonly than do shales. This is probably only because the limestones and sandstones are more open and porous and so offer an opportunity for the oil and gas to collect. So far as observations go it is in the pores and small spaces of the rocks that these substances occur and there are probably no "lakes" of oil—that is no large caverns filled with oil. The advantage of "shooting" oil wells depends on this fact. Often when a small quantity of oil is found in a well, drilling is stopped and a heavy charge of nitroglycerine is lowered to the bottom of the well and discharged there. This has the effect of shattering the rock and opening it up so that the oil can flow through more rapidly and greatly increases the production of the well.

Almost invariably there is a layer of a tight, close-grained rock immediately above the porous rock. This is known as the cap rock.

In the Oklahoma field the principal oil and gas pools are closely related to the presence of certain structures, notably the anticlines and monoclines. It cannot be said that all the developed fields are on anticlines or that every anticline contains oil and gas in sufficient quantity to pay for drilling. In some of the developed fields the structure is so gentle that it can be determined only by extremely careful detailed work so that the relation of the accumulation to the structure cannot yet be definitely stated.

In some regions, in Mexico for example, the occurrence of oil seeps or springs seems to be definitely related to the presence of large bodies of oil beneath the surface. No oil seeps of this kind, however, are known to occur in Oklahoma except possibly near the Arbuckle Mountains. All the important deposits of oil and gas occur in rocks which contain abundant organic remains or are closely associated with rocks containing such remains.

Oil and gas are usually but not always associated with strong heads of salt water.

There is no apparent relation between oil fields and streams, coasts, mountains, or other surface features unless these features result from the structures that control the accumulation of the oil.

It should be repeated that these statements are general and are intended to apply only to commercially important bodies of oil and gas and especially to the conditions in the Oklahoma field. Small quantities of either oil or gas or both together or of closely related substances may be found under almost any conditions, but the statements made above will hold for the principal deposits and especially for those of Oklahoma.

THEORIES OF ORIGIN OF PETROLEUM AND NATURAL GAS.

Several theories as to the origin of oil and gas based on the nature of the substances and on the conditions of their occurrence as given in the preceding sections have been formulated. The theories of origin fall into two groups—the inorganic and the organic. The inorganic theory holds that oil and gas have been formed by the reaction of certain inorganic or mineral compounds in the earth's crust. So far as known the inorganic substances from which oil and gas could be formed can exist only at high temperatures. This makes it necessary to believe that the oil and gas were formed at considerable depths beneath the surface or near intrusions of igneous rocks. Either of these ideas makes it necessary to account for the transference of the oil and gas of the principal fields of the world for great distances since practically all of the deposits are found at a less depth than 4,000 feet and also at considerable distance from igneous intrusions. The additional fact that all the great deposits are found in sedimentary rocks is hard to explain under this theory. These and other considerations have prevented the general acceptance of this theory, although there are some authorities that do not find the difficulties insurmountable and accept this theory for the origin of oil and gas.

The generally accepted theory of the origin of oil and gas is that both substances have been formed by slow decay of organic (plant and vegetable) matter buried in the rocks. Substances greatly resembling crude oil have been produced by heating fish and other organic substances in closed vessels under considerable pressure and at low temperatures for a considerable length of time. It is thought, then, that the plant and vegetable matter buried with the rocks as they were deposited have been slowly changed to oil and gas by the effect of low temperatures and high pressures acting through very long periods of time. Some of the facts that seem in accord with this theory are the occurrence of the oil and gas in the sedimentary rocks and their absence in the igneous rocks; also the occurrence of fossils in the sedimentary rocks containing the oil and gas or in closely associated rocks. The distance from mountain ranges or large bodies of igneous rocks at which the principal fields occur and the absence of any indications that the rocks near by have been subjected to the degree of heat which seems to be required by the inorganic theory, are additional evidence in favor of the organic theory. In regard to the origin of the oil and gas of Oklahoma, the organic theory seems to be much more satisfactory than the inorganic.

Another feature to be considered in connection with the origin of oil and gas is the question as to whether these substances have originated in or near the rocks in which they now occur or whether they have migrated into them from other rocks at greater or less distance. Both oil and gas occur in the rocks under great pressure and are usually kept from escaping to the surface by layers of shale or other very close-grained rock through which it seems that neither substance can pass. It is impossible that the oil and gas now in the sands of the Oklahoma field could have moved into these sands from beneath without passing through considerable thicknesses of shale, and if conditions were such as to force the oil and gas through this shale, it seems difficult to account for them coming to within a few hundred feet of the surface and then stopping. The same difficulty is encountered in trying to account for the lateral movement of oil and gas. The sands in which they occur sometimes cover an area of several hundred square miles, but at some distance from the pools they pinch out and give place to other rocks, usually shales. In fact, most of the sands of the Oklahoma fields can be regarded as immense pumpkin-seed-shaped masses of sand buried in the shales with which they are associated. It seems just as impossible that the oil and gas should have moved sideways through the shales for any great distance as for it to have moved upward. The evidence then seems to favor the idea that the oil and gas have originated in the sands where they now occur or in the shales and limestones very closely associated with them.

ACCUMULATION OF PETROLEUM AND NATURAL GAS.

Observation of the developed oil fields in Pennsylvania, Ohio, and West Virginia convinced many of the observers that there is some definite relation between the accumulation of oil and gas and the structure of the rocks. It was determined that the principal oil and gas pools lay along the crests of the anticlinal folds; therefore, the theory of accumulation based on these observations has become known as the anticlinal theory. This theory has been of great value in locating prospective oil and gas regions, but the attempt to apply it to other fields where the geologic conditions are not similar to those where it was originally applied has not always been successful. Various changes have been made in the theory, but the fundamental part of the theory—that the accumulation of oil and gas depends on the structure—is still generally accepted.

The anticlinal theory is, in brief, that oil and gas were originally widely disseminated throughout the formations in which they are found, or in contiguous formations, and their segregation is believed to be due to the different specific gravities of oil, gas, and water. If a porous stratum contains all these substances, when it is tilted by geologic causes, they will arrange themselves according to specific gravity; the gas, being lighter, will be driven into the higher parts of the stratum (toward the crest of the anticline), the oil will be floated on top of the water, while the water occupies the lower portions of the stratum (those nearest the syncline).

According to the anticlinal theory, then, four factors are necessary for the accumulation of quantities of oil and gas: a source of the material (that is, rocks which in their original level or nearly level condition contained the oil and gas or the substances from which they are formed); a porous stratum in which considerable quantities of the substance may collect; some structure tilting the rocks so that the oil, gas, and water may arrange themselves according to their specific gravities; and finally a layer of impervious rock above the porous layer to prevent the oil and gas from escaping to the surface. These conditions are represented in the accompanying figure.

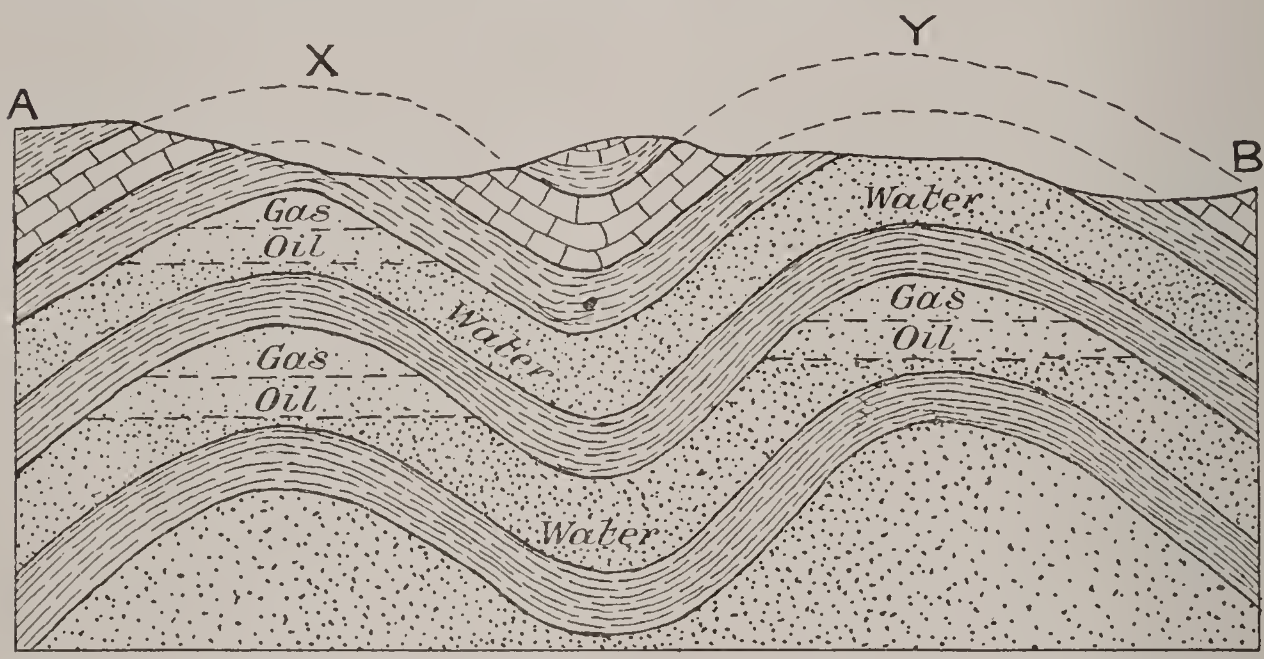


Fig. 7.—Diagram representing the accumulation of oil and gas in anticlines.

In this figure, as in all others in the book, the sandstone is represented by the dotted pattern and the shale by the closely ruled pattern. The line *AB* represents the present land surface and the broken lines represent the strata which have been removed by erosion. The oil and gas are shown collected in the sandstones under the crests of the anticlines at *X* and *Y*. At *Y* the shale has been removed from over the upper sandstone, allowing the oil and gas to escape.

As work progressed in areas outside the Pennsylvania and West Virginia fields it was found that the variations of structure made it necessary to modify the anticlinal theory in some respects. The presence of a true anticline has been shown not to be necessary for accumulation, but any structure or tilting of the rocks which will cause the oil, gas, and water to arrange themselves in the order of their specific gravities will suffice for the accumulation if the oil and gas are sealed in from the surface. On this account a recent writer (F. G. Clapp, Economic Geology, Vol. V, No. 6), has proposed a new classification of oil fields based on structure as follows:

I. Where anticlinal and synclinal structure exists.
   (a) Strong anticlines standing alone.
   (b) Well defined anticlines and synclines alternating.
   (c) Monoclinal slopes with change in dip.
   (d) Terrace structure.
   (e) Broad geanticlinal folds.
   (f) Overturned folds.
II. Domes or quaquaversal structures.
III. Sealed faults.
IV. Oil and gas sealed in by asphaltic deposits.
V. Joint cracks.
VI. Surrounding volcanic vents (or igneous intrusion).

Almost all the important fields belong to some division of Class I, among them being the Appalachian, Mid-Continent, Illinois, Indiana, Wyoming, Colorado, northern Louisiana, northern Texas, and some of the California fields in this country, and the Russian, Austrian, Burma, and Borneo fields in the eastern hemisphere. Of the different subclasses, the second is probably the most common, containing with a few minor exceptions the Appalachian field in Pennsylvania, West Virginia, and eastern Kentucky, the southern Indiana and Illinois field, the Kansas and Oklahoma fields, the Caddo field in northern Louisiana, the north Texas fields, and those of Colorado, Wyoming, and Montana. The conditions in these fields are shown diagrammatically in figure 7.

Subclasses *c* and *d* may be considered together since *d* is only an extreme type of *c*. These structures are sometimes called arrested anticlines since the forces were apparently the same as those forming anticlines, but not strong enough to reverse completely the normal dip of rocks with a monoclinal structure, but merely to lessen the dip locally or to flatten the rocks out. The conditions are shown diagrammatically in figure 8. Some of the important pools of northern Oklahoma represent this type of structure although most of them belong to subclass *b*.

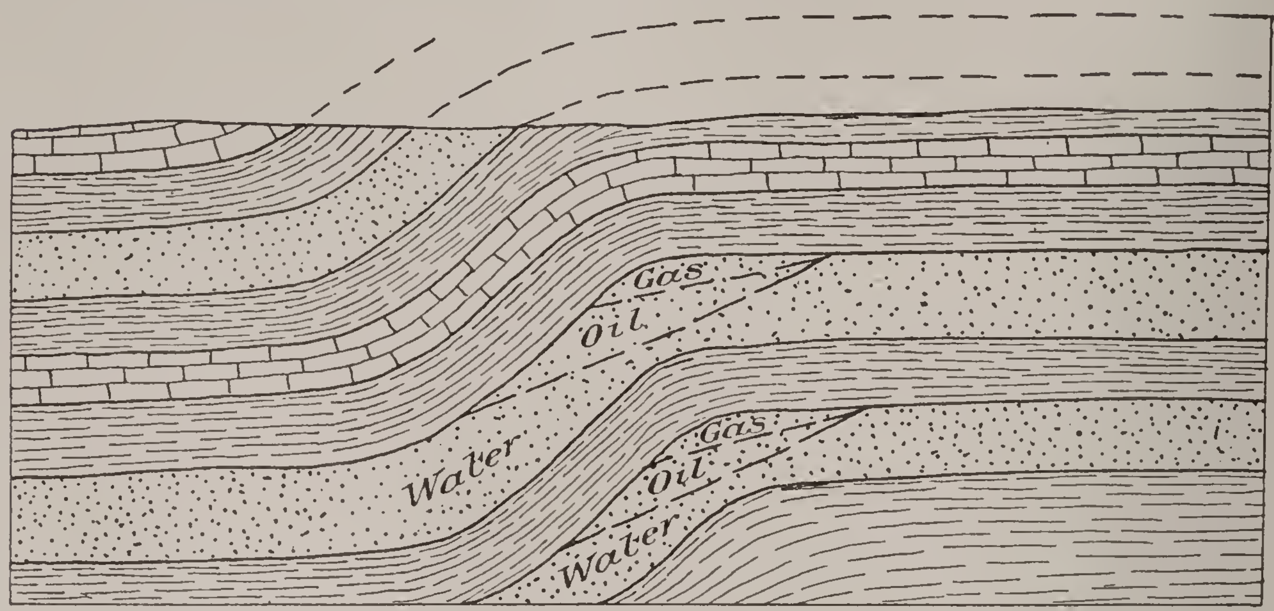


Fig. 8.—Diagram showing the accumulation of oil and gas in a terrace or arrested anticline.

The last two subclasses are probably not represented in Oklahoma. The fields in Ohio and Indiana around the Cincinnati arch or geanticline belong to subclass *e*.

Class II is represented by the pools in the coastal plain of Texas and Louisiana. Class III occurs in some of the California fields. It is possible, although scarcely probable, that this condition occurs in the Ouachita Mountains in the southeastern part of Oklahoma. The conditions are represented in the diagram of a fault (fig. 4). Oil contained in the sandstone layer would be sealed in by the fault passing through the overlying shale layer, and would collect near the fault line if the sandstone dipped away from the fault, which would usually be the case on one side or the other. Faults of this type exist in the region mentioned and the asphalt deposits prove that oil was once present in the rocks, but whether it all escaped or whether part of it is sealed in along some of the faults is problematic. Class IV is possibly represented in Oklahoma by some small deposits giving rise to the oil springs or seeps in the Arbuckle Mountain region. It is not at all probable that the deposits are large enough to be of any value.

Class V is not very important, occurring, so far as known, only in Canada. Class VI does not occur in Oklahoma. Some of the large Mexican fields probably belong to this class.

It seems to the writer that one other condition should be included in this list, which, while not strictly a structural condition, should have the same effect as inclined strata on accumulation. This is the local thickening of sands or the occurrence of short, thick lenses of sand in shale. The conditions are shown diagrammatically in the accompany-

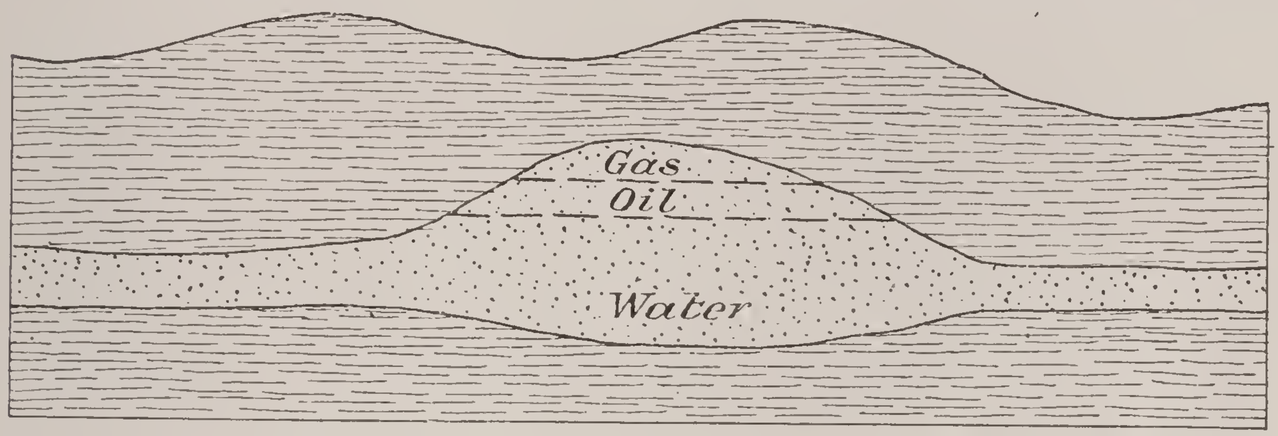


Fig. 9.—Diagram illustrating the accumulation of oil and gas in a lens of sandstone in shale.

ing sketch (fig. 9). In this case the oil and gas would certainly collect in the top of the arch made in the shale by the lens of sand, the gas at the top and the oil lower down. This local thickening of the sands or occurrence of such lenses may or may not give any surface indications of their presence and may account for some oil and gas pools where no surface structure can be made out, as in the Cretaceous area along Red River in southern Oklahoma.

A factor which is of extreme importance in the consideration of accumulation by any type of structure is the difference in porosity of the same sandstone in different localities. If a sandstone is studied along its outcrop it will be found to vary somewhat in character from place to place. In one place it may be composed of fairly large grains of sand loosely cemented together, while a short distance away it will be very fine-grained and well cemented so that there is very little pore space. It is only reasonable to presume that such variations also exist in the sandstones underneath the surface, and this variation is believed to account for the occasional finding of dry holes which are in proven territory and which may be entirely surrounded by producing wells. It is supposed that the dry holes encountered a non-porous or tight place in the sandstone, while the producing wells penetrated more open, porous places. The variation in production of wells of equal depth located near each other is explained in the same way. In general the more open and porous the sand, the greater the amount of oil contained and the more rapidly the oil can be given up from the sand around the bot-

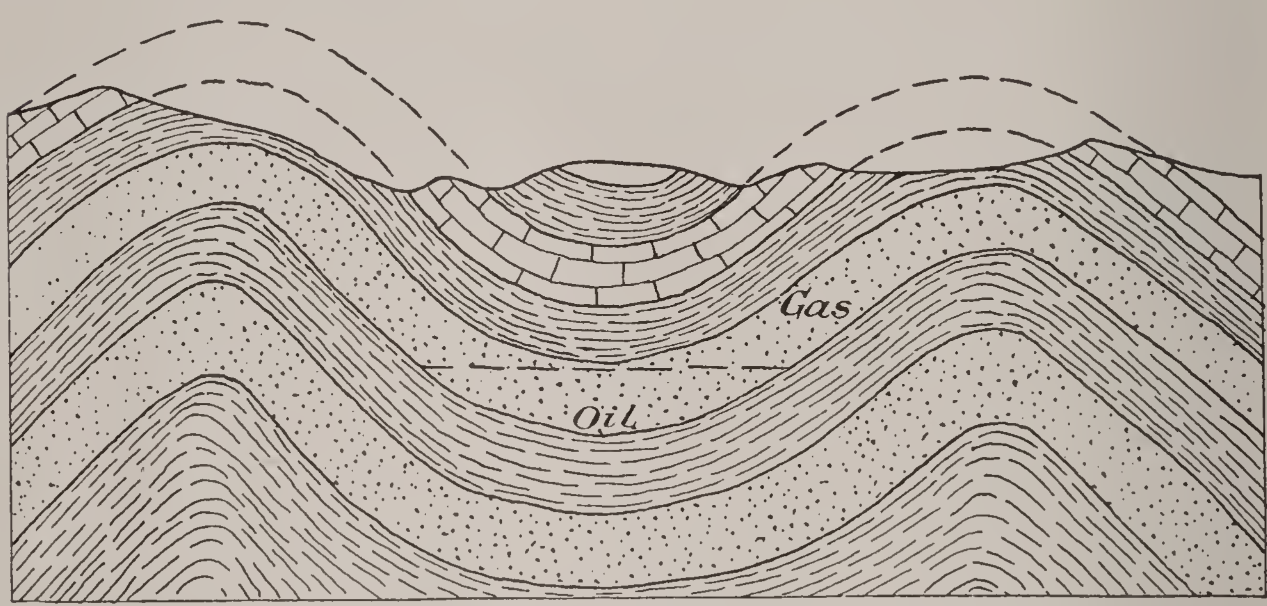


Fig. 10.—Diagram illustrating the accumulation of oil in syncline in the absence of water.

tom of the well. This also accounts for the fact that very often wells of phenomenally large initial production are not as long-lived as those with a smaller production, since the more rapidly the oil can pass through the sand the sooner will the supply be exhausted. The shooting of oil wells is based on the same fact, as the effect of the shooting is simply to loosen up the sand so that the oil can pass through it more readily.

Still another feature needs to be considered in this connection. All the statements previously made concerning the effect of structure on accumulation are based on the presence of water with the oil and gas. When no water is present the oil and gas, instead of being collected in the anticlines or corresponding structures, seek the synclines or lower parts of the structure governing the accumulation, the oil in the bottom of the syncline and the gas higher on the slope as shown in the accompanying diagram. This condition is not known to exist in Oklahoma, although it probably does.

III.

PROSPECTING FOR PETROLEUM AND NATURAL GAS

From what has been said concerning the conditions of occurrence of oil and gas, and the generally accepted theories of their origin and accumulation, certain general rules concerning the prospecting for these substances can be deduced. The knowledge of conditions in developed fields is a great aid in determining the relations of the oil and gas pool to the nature of the rocks, both the surface rocks and those encountered in drilling, as well as to the structure of the rocks and to the surface features. The value of geology as an aid to prospecting is considered at some length.

Nature of the rocks.—Many people are strongly of the opinion that the rocks immediately on the surface are related to the occurrence of oil and gas below, and there is quite a strong prejudice in favor of starting wells on top of limestone. In regard to this matter it may be said that the developments in the different fields of the country and even of the different pools in Oklahoma prove that this idea is without foundation.

It has already been noted that all the important deposits of oil and gas occur in sedimentary rocks, limestones, sandstones, or shales. No deposits are known in igneous rocks or in rocks that have been so metamorphosed by heat and pressure that their original nature has been destroyed. In Oklahoma this fact is of importance in small areas since most of the surface rocks are sedimentary. In the Arbuckle and Wichita mountains, however, there are some areas of several square miles in which the surface rocks are granite and closely related rocks. In these areas there is absolutely no use of prospecting for oil and gas.

It is practically certain that holes started on the granite would encounter no other kind of rock no matter how deep the drilling was carried. There are no areas of intensely metamorphosed rocks in the State, but in a small area in McCurtain County the rocks are so crumpled and broken that there is no probability that they contain oil or gas at present, even if they did so before they were disturbed.

In an area of sedimentary rocks a little consideration will make it possible to select the more favorable areas from the less favorable. Whether the organic theory of the origin of oil and gas be accepted or not, the fact remains that all important deposits of either substance are found in rocks which are strongly charged with organic matter or which are closely associated with such rocks. This is usually shown by the presence of fossils and by the prevailing dark colors of the rocks. The dark blues and greens and the blacks are due to the presence of iron in the reduced form, the reduction being due to the presence of organic matter, or in some cases the color is due to the organic matter itself. In rocks in which very little or no organic matter is present the iron is in the oxidized form—iron rust—and gives the rocks a prevailing red color. A large area of red rocks which are of considerable thickness cannot but be regarded as a most unlikely region for oil and gas prospecting.

This fact eliminates a large portion of Oklahoma as prospective territory. With the exception of the comparatively small area of the Wichita Mountains all the State west of a line drawn north and south so as to pass through Oklahoma City or a short distance to the east is underlaid with red rocks. Along the eastern margin the red rocks are thin and deep drilling will penetrate them and reach the underlying dark-colored rocks. This is also true in the region around the Wichita Mountains, between the Wichitas and Red River and between the Wichitas and the Arbuckles. Some oil and gas have been found in this region and are often made the basis for the statement that the Redbeds rocks do contain oil and gas. However, a study of the logs of the wells of any of the pools in this region will show that the oil and gas occur in rocks below the red rocks or so near their base that the source of supply is undoubtedly in the underlying non-red rocks. In the absence of more drill records it is impossible to fix the exact limit of the possible productive area in the Redbeds region, but it is safe to say that all the area north of an east-west line through Chickasha and Anadarko and west of a line drawn through Oklahoma City and Enid is extremely improbable territory for oil and gas.

Relations of oil and gas pools to topographic features. —The statement is often made that the indications in a certain territory or on a certain tract of land are favorable for oil and gas because the land is near or lies parallel to a river or mountain range or some other topographic feature. The statement that all oil and gas fields lie parallel to some coast or stream is necessarily true, but is of absolutely no value in prospecting. For example, the fields or pools in northeastern Oklahoma having an east-west trend are nearly parallel to Arkansas River and those bearing north and south are parallel to the Verdigris. In fact, it would be practically impossible to locate a pool so that the trend would not be in a measure parallel to some stream in the vicinity. At the same time unproductive tracts would show exactly the same relation. The only case in which the course of a stream would really be related to the trend of an oil or gas pool would be where the course of the stream is controlled by the structure of the rocks and where the same structure is related to the accumulation of the oil or gas. In this case the shape or the trend of the oil pool would be due to the structure instead of to its following the course of the river. It may be said, therefore, that the presence or absence of a stream in a given area or the relation of a tract of land to its course is no indication as to the occurrence of oil and gas unless the course of the stream is controlled by the structure and in this case the indications may or may not be favorable on a given tract.

The relations of pools to mountain ranges are of the same nature as their relations to rivers. The structure of the mountain range often provides the necessary conditions for the accumulation of oil and gas and hence the long axis of the pool is often parallel to the direction of the ranges. The relation of the pool, however, is to the structure and not to the mountain range itself. If the rocks making up a mountain range are igneous or strongly metamorphic there will be no oil or gas in them any more than there will be in rocks of the same kind at a distance from the mountains, and if the rocks and the structure are favorable for accumulation in a region there will be oil and gas no matter what the relation to a mountain range may be.

In Oklahoma the principal pools are at some distance to the west and southwest of the Ozark Mountains. It is possible that the structure was produced in the oil region by the same set of forces which produced it in the mountains, but the territory cannot be considered as a part of the Ozarks. The location of the pools in southern Oklahoma is almost certainly due to the thinning of the Redbeds near the Arbuckle and Wichita mountains and in this sense they may be said to have a relation to the mountains. The location and the trend of the individual pools, however, is quite independent of the structure of the mountains, or the trend of the separate ranges or groups.

In general, hills and valleys cannot be depended upon to give any indication as to the presence of oil and gas. In many developed pools, wells started on the hills are just as productive as those started in the valleys and vice versa. Other pools are on practically level land. There is no more ground for saying that a certain location should be a good place for prospecting because the surface looks like that of a developed pool than for saying that the same region is without oil and gas because the surface is very unlike that of another developed pool, or that it is very like another region which is known to be dry. In some instances the distribution of the hills and valleys depends on the structure and here, of course, the surface configuration may give some indication as to the more probable places to prospect. In the coal fields of the east-central part of Oklahoma the anticlines are often worn down into valleys while the synclines stand up as ridges and hills. In this region it is wiser to prospect in the valleys than on the hills if no further investigation is made. Even in this locality, however, there are so many exceptions to the general rule and so many hills and valleys that are without relation to the structure that it is much better to work out the structure definitely before locating a test well than to depend upon the character of the surface alone.

"Oil trends."—An idea that was held generally in the early days of the industry and which still has a number of adherents is that oil occurs along certain well developed trends or lines and that territory anywhere along certain well developed trends is favorable for prospecting. It is believed by many people that the country will eventually be developed between the Oklahoma field and the Gulf field in Texas and Louisiana. It is apparent that if this idea were carried to an extreme almost any region could be considered as probable territory since by connecting all the oil fields of the world by lines it would be hard to find a locality that would not be reasonably near one of these lines. There is no more reason for considering the region between the Oklahoma and Gulf fields as all being favorable for prospecting than for considering all the territory between the Oklahoma and California fields or between the California and Pennsylvania fields in the same way. The oil in the Gulf and California fields occurs under very different conditions from those of the Oklahoma fields. The rocks in the former fields are much younger than those in Oklahoma, and if the productive rocks of Oklahoma are present at all in the Gulf and California fields they are buried under thousands of feet of younger rocks.

When a single field is considered it is evident that the trend of the whole field will be in the same direction as that of the outcrop of the rocks containing the oil and gas. For instance, in the northeastern Oklahoma field the oil and gas is all contained in a thickness of about 1,000 feet of rocks and these rocks outcrop from north to south and dip to the west. It is evident that oil and gas can be found in a belt to the west of the outcrop in which the oil-bearing rocks lie at a depth of less than 3,000 feet. The development of the field as a whole will therefore be in a north-south belt. In the region around the Arbuckle and Wichita mountains the favorable conditions occur in a northwest-southeast belt and the field as a whole will show a similar trend. There is, however, no reason for presuming that oil and gas will be found in Cleveland County, for instance, because it lies on a line between the Cushing and the Loco fields or between the Kay County and the Wheeler fields. If the geologic conditions in Cleveland County can be shown to be similar to those of any one of these fields or even if they were different and still favorable for the occurrence of oil and gas it may be considered favorable territory for prospecting, but the fact that it lies between productive fields is positively no evidence either for or against it.

The individual pools may extend in any direction to that of the field as a whole, in spite of the common idea that all lie in one direction. For example, the northeastern Oklahoma field has a general north-south trend as has been said, but the individual pools may trend in any direction. The Coody's Bluff-Alluwe and the Hogshooter pools extend north and south, the Delaware-Childers pool east and west, the Copan and the Dewey-Bartlesville pools northeast and southwest, the Henryetta-Schulter and Morris pools northwest and southeast, and the main portion of the Glenn pool is almost circular. The direction of the long axis of a pool depends usually on the structure and in any region the majority of the folds are likely to have their long axes in the same direction, so that it is probable that the majority of the pools will trend the same way. There are, however, almost always exceptions to this rule, and the development of a pool cannot be certainly predicted on the basis of that of other pools in the vicinity unless it is known that the structure is the same.

Oil seeps.—Among the features that are often cited as indications of oil and gas are the so-called oil seeps which occur in practically all parts of the State. True oil seeps are undoubtedly proof of the presence of oil or asphalt, but such seeps are rare in the State and are known to occur only in the Arbuckle Mountains, in the Redbeds around these mountains and the Wichitas, and in the Red River limestone region. The oil field at Wheeler is located near one of the largest of these oil seeps. The appearances which are reported as oil seeps in other parts of the State have all proved to be due to other substances than petroleum. In the majority of cases the "seeps" have proved to be merely thin scums of iron oxide on the water. This gives the appearance of a thin layer of kerosene, but is easily distinguished from it. If an attempt is made to skim off the "oil" the scum breaks and separates into angular pieces. If the water is stirred up the crust or scum will be broken up and will settle to the bottom. The behavior of a true oil scum is of course quite different. Further tests which are quite easily made and which establish definitely the identity of the scum are those with acid, preferably hydrochloric, and carbonbisulphide, both of which can be easily obtained at any drug store. If some of the water with as much of the scum as possible be collected and placed in a bottle or glass and a little hydrochloric acid added a scum due to iron will dissolve and give a brown colored solution. This may be tested still more definitely for iron by adding a little of a solution of potassium sulpho-cyanate to the brown liquid. A brilliant deep red color is produced if iron is present. This red color is a very delicate test for iron and will often show its presence when the brown color of the hydrochloric acid solution is very faint. It should be said that the potassium sulpho-cyanate is very poisonous and care should be taken in using it. A few drops of a strong solution is all that is necessary to make the test. The solution to be tested should not be very strong with the acid. A film of pure oil is not affected by the acid and will give no test with the potassium sulpho-cyanate unless the water with it is strongly charged with iron. On the other hand, if carbonbisulphide is used instead of the acid an iron film or scum is not affected in any way, but any oil present is dissolved in the bisulphide and gives it a dark brown color. The bisulphide and the oil settle to the bottom of the bottle with the colorless water on top. These tests can be made at an expense of a few cents and a few minutes of time and should always be made before any great expense is incurred in the investigation of a supposed oil seep. In nine cases out of ten any scum or film on water (outside of the oil region where the streams are covered with waste oil from the wells) will be of iron and not of petroleum or other oil.

Iron also causes another appearance which is often mistaken for an indication of oil. Some of the iron compounds are black and when wet have a greasy appearance. Irony sands are found in several localities in the State, especially in the Redbeds region, that appear oily when they are wet. The test by the hydrochloric acid is sufficient to show that this appearance is due to iron since a weak solution of the acid will dissolve the black coloration and leave ordinary sand while the solution becomes brown. The further test with the potassium sulpho-cyanate can be made if desired, but is really not necessary.

In considering a seep it should be borne in mind that crude oil is usually a thick liquid and dark in color so that the thin oily films due to iron do not at all resemble a covering of crude oil, although they do somewhat resemble one of kerosene or coal oil. The latter, however, is a refined product of the crude oil and is never found as such in nature. A few seeps of a dark substance having the appearance of crude oil have been reported from localities in western Oklahoma and some samples have been examined. In general these "seeps" are found in the bottoms of canyons and can usually be attributed to the decay of vegetable matter which is washed down into the canyons at times of heavy rains. The amount of the oily substance is very small and the seeps occur only in times of wet weather.

Asphalt deposits.—Deposits of asphalt are often considered as indications of oil and gas and in some circumstances they are undoubtedly so. From what has been said regarding the nature of petroleum it is evident that wherever a quantity of oil with an asphaltic base is exposed to the air, the lighter, volatile substances will evaporate and a residue resembling the residuum of the refining process will be left. The deposits of asphalt in Oklahoma are generally regarded as being residual bodies of this nature. It is thought that erosion has carried away the overlying rocks so that the oil could get to the surface or that the structure, the folding and faulting, has broken the rocks so that deep seated bodies of oil could work out to the surface. The presence of asphalt, then, may be regarded as proof that the rocks containing them, or some of the lower rocks, at one time contained considerable quantities of oil. The question then arises as to whether all of the oil has escaped or whether some of it still remains in the rocks where it can be reached by the drill. It is reported that in Mexico one of the principal guides in prospecting is the presence of seeps of a very heavy asphaltic oil called mineral pitch or brea. As has been said the field at Wheeler, Okla., is near a large asphalt seep. It seems that in some cases therefore all of the oil has not escaped, but that important deposits still remain beneath the surface. However there is no record, to my knowledge, of important finds of oil or gas near asphalt deposits which are composed of solid asphalt. The fact that the asphalt is solid seems to indicate that it has been exposed long enough for all lighter oils to escape and that the process of asphalt formation is entirely complete. This seems to preclude the presence of large bodies of oil in the rocks near at hand. The most of the deposits of asphalt in the Arbuckle Mountains and in the Ouachitas are of this type. Very little can be said as to the prospects in the underlying rocks or in the asphalt-bearing rocks at some distance from the asphalt occurrences since the prospects would depend on so many features that could be determined only by a detailed investigation of the locality.

The use of instruments in prospecting for oil and gas.—So far as is known there is no instrument that is of the least service in locating deposits of oil and gas except the ordinary surveying instruments which are used in determining the structure of the rocks. There is no substance known that is either repelled or attracted by oil or gas. In spite of these facts there are many communities in the State that have paid "oil witches" considerable sums of money to have them locate drilling sites by the means of some sort of instrument. In a certain case to the writer's knowledge one of these witches received $25 each for locating three wells. One of the wells was located on an outcrop of the granite of the Arbuckle Mountains and the other two were in places where the granite was probably not over 100 feet beneath the surface. In another community in the western part of the State a negro with a considerable amount of paraphernalia was successful in obtaining small sums of money from several parties for locating wells. These wells were located on sand hills where the Redbeds would be encountered at a depth of probably less than 100 feet and where these beds are at least 1,500 feet thick. This operator is reported to have told some of the men who accompanied him that at one place they were walking over the largest lake (or pool) of pure gasoline that the world has ever known. Since the world has never known any gasoline whatever to be found in a pure state in the rocks the lake need not have been very large to have fulfilled the description.

A little consideration will make it plain that if a man had an instrument or substance that would locate definitely deposits of oil and gas it would not be necessary for him to do locating at the rates charged by such men. The possession of such an instrument would enable one man to locate sufficient wells to flood the market and to destroy the petroleum industry in a year or two. If such a substance or instrument existed it would be to the advantage of large oil companies to pay the owner enormous sums of money to refrain from locating more wells. It is certainly safe to say that men claiming such power are plain fakers.

Geology as an aid in prospecting for oil and gas.—From the discussion of the theories of origin and accumulation of oil and gas and the notes already given on the nature of rocks it is evident that one great aid which geology can give the oil prospector is in the selection of general areas in which the geologic conditions are such that prospecting has some chance of being rewarded. Thus in Oklahoma a knowledge of the general geology of the State enables one to eliminate a large portion of the State from the probable producing territory. The geologic conditions in the Ozark, Ouachita, Arbuckle, and Wichita mountains, and over a large part of the Redbeds area are such that the finding of oil and gas is very improbable, and the knowledge of this fact enables the operator and prospector to concentrate their efforts on more favorable territory.

When the general territory in which the conditions are favorable for accumulations of oil and gas has been determined the next proposition is to decide just which localities in this general region are the most favorable, and here, too, it is often possible for the geologist to give some aid. It has already been said that in Oklahoma the accumulations so far as they have been carefully investigated are dependent on the structure and that most if not all of the pools are on anticlines, or some closely related type of structure involving a change of dip of the

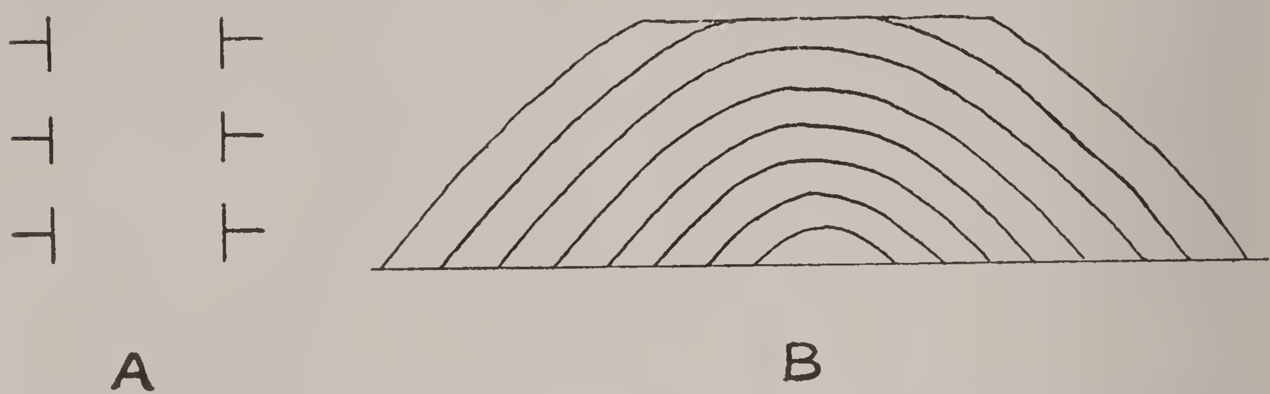


Fig. 11.—A. Map record of dip and strike showing anticlinal structure. B. The structure of the area shown in A in cross section. (Chamberlin and Salisbury.)

rocks. The problem of the geologist then is to determine carefully the structure of the rocks which contain the oil and gas. It is easily seen that where there are no unconformities in the rock column the layers of rock underground will lie parallel to those at the surface, so that the determination of the structure of the surface rocks will also determine that of the oil-bearing rocks beneath. This condition is the one that exists in the oil and gas fields in Oklahoma and is the only one that will be considered fully. The methods of determining the structure of the underlying beds when they are not parallel to those on the surface are noticed briefly.

In some cases where a fold is small the structure can easily be determined by observation without any aid from instruments. The first essential is to determine the succession of rocks, that is, to observe which of the strata exposed in the region under observation is the lowest and the nature and appearance of the successively higher strata. Then the dips should be observed at different places along the outcrop of some ledge which is continuous throughout the area. These dips and the direction of the strike should be noted on a map and the fold will be shown.

The accompanying diagram (fig. 11) shows how the dips and strike may be recorded on a map very easily. The short lines with both ends free indicate the direction of the dip. The structure which is indicated by this record of dips and strikes is shown in the second part of the figure.

If the rocks dip toward each other so that the lines with the one free end point toward each other, the structure is synclinal or trough-like and can be represented by *B* of figure 11 turned upside down.

It should be understood that the determination of the structure is very often not as simple as indicated in the above description. In many localities it is hard to find a stratum which is continuous over a considerable area and this stratum may not be well exposed in a large number of places. The dip may also be so slight as not to be apparent to the eye. In this case instruments for the determination of the elevation of the ledge at different localities must be used. For rough work the aneroid barometer can be used for this purpose. This is an instrument which resembles a large watch in appearance. The face has a scale graduated in feet of elevation and a needle pointer as an indicator. The air is partially exhausted from the central chamber of the barometer and a flexible diaphragm forms the back of this chamber. The air pressure varies at different heights above sea level and this variation is shown by the pointer which is attached to the flexible diaphragm by means of a system of levers. The aneroid permits of very rapid work, but, as the air pressure varies with the condition of the atmosphere as well as the height above sea level, it is an instrument that can be used only where it can be checked with the elevations determined by some more accurate method or where the structure is sufficiently pronounced that the results will not be greatly affected by the minor variations of the barometer.

For accurate work levels on some ledge of rock must be run with some surveying instrument, such as an alidade or a transit. In regions where the structure is very gentle this is the only method which can be depended upon to give accurate results. Skilled manipulation is required for the instruments and this method of determining the structure should not be attempted by anyone not acquainted with the use of the surveying instruments.

A more accurate method of showing the structure, than the simple method shown in figure 11, is by drawing contours on some formation, usually a consistent ledge of sandstone or limestone. The elevations of a large number of points on the surface are determined and when the thicknesses of all the formations of the area are known the exact elevation of the chosen bed at all of these points can be easily calculated. An example of a map of this kind is shown in Plate IV, which is a structural map of the Ponca City anticline with the contours drawn on the top of the Herington limestone. The contours represent differences of 20 feet in elevation. It may be seen that the contours show not only the location of the fold, but also its form. That is, that the anticline is much steeper on the east side where the contour lines are crowded closely together than on the west side where they are spaced more widely.

Where there are important unconformities in the rocks between the surface and the oil-bearing rocks, the structure of the latter is not necessarily the same as that of the former. In this case the structure in localities where there has been some drilling may be ascertained by determining the elevations of the mouths of several wells and the depth in these wells at which the sand whose structure is in question is found. By platting these logs to the same scale the structure of the oil-bearing sand can usually be made out. In localities where no drilling has been done, the problem can be attacked in other ways, but the methods involved are too technical to be considered in this work, especially as this condition is not known to occur in the probable oil territory of Oklahoma.

Locating of wells.—After the more favorable localities of an area have been selected by means of a determination of the structure, the next question which arises is that of the exact location of the well. This will depend somewhat on the nature of the structure found. If the structure is an anticline whose sides have an equal or nearly equal dip the first well should normally be located on or near the crest or line where the dip changes. This is especially true in an undeveloped territory as it would be much better to strike a good flow of gas than to take chances of going too far down the slope of the anticline and strike the oil sand below the oil belt. In a broad, low anticline the well may be located at a somewhat greater distance from the crest than on a narrow, sharp one. Where the anticline is unsymmetric, that is where one

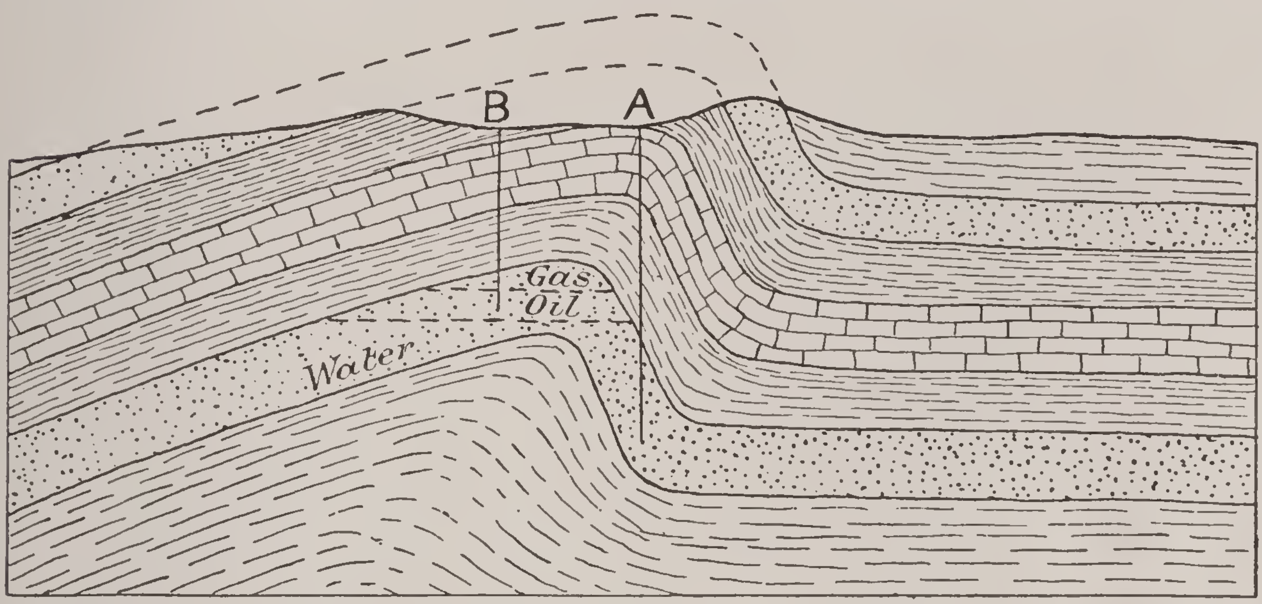


Fig. 12.—Diagram illustrating the accumulation of oil and gas in an unsymmetric anticline.

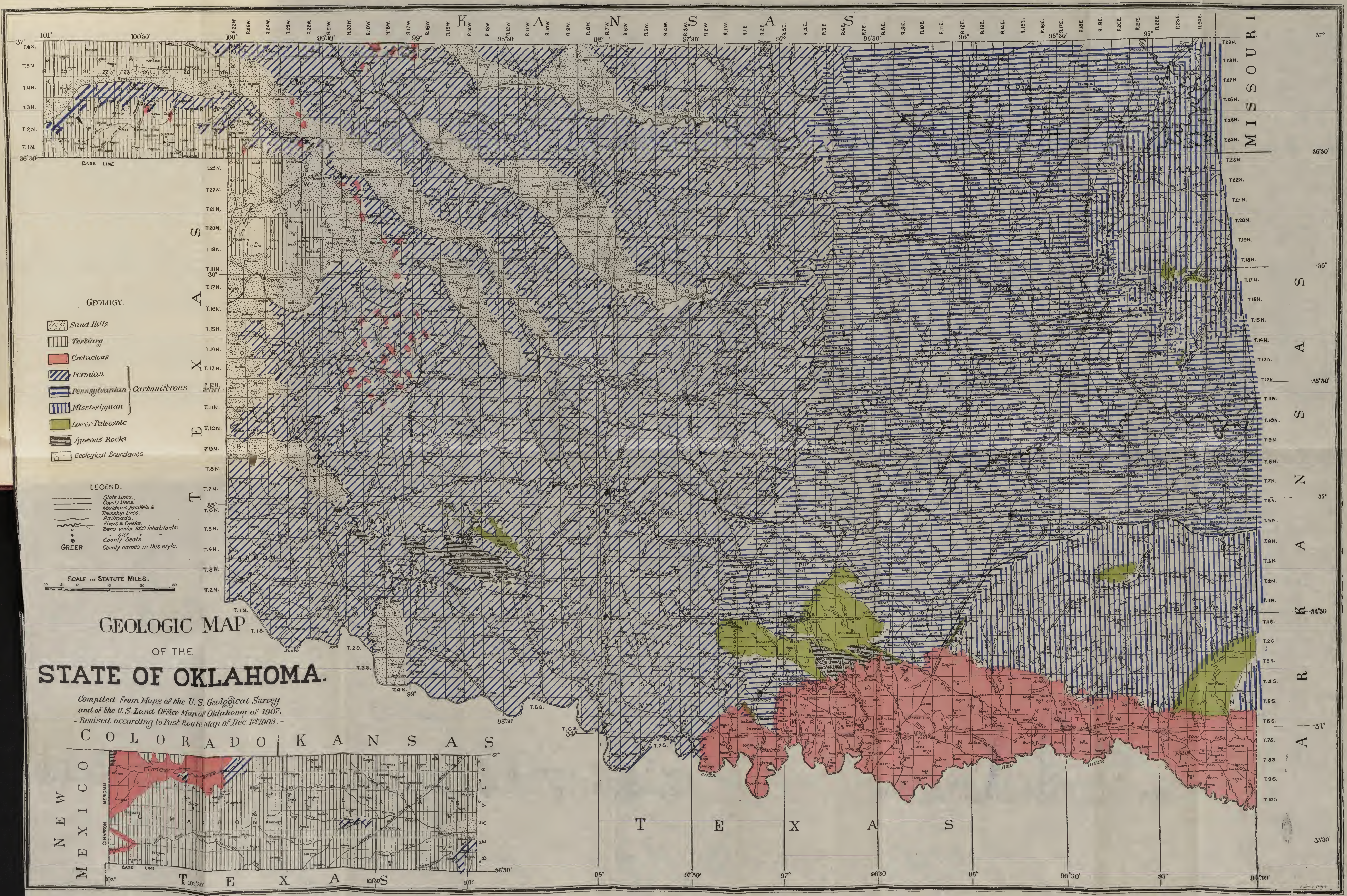
side dips much more steeply than the other, the well should be located down the slope of the gentler side. The reason for this is apparent from the accompanying diagram (fig. 12). It is readily seen that, in an anticline of this sort, the crest moves down the dip of the gentler side with increasing depth. Consequently a well, *A*, started on the crest at the surface would be a considerable distance down the slope of the steeper side by the time it had reached the depth of the oil-bearing sand, and that to encounter the oil-bearing sand at the crest of the fold in it, the well would have to be started down the slope on the gentler side of the anticline, say at *B*. It is also apparent that the width of the oil belt is much greater on this side of the anticline than on the other. The distance from the crest at which the well should be started depends on the steepness of the slope of the sides and the depth to the supposedly oil-bearing sand. These factors, of course, must be worked out for each fold individually.

If the structure is a terrace or arrested anticline instead of a true anticline the location of the well should be somewhere near the top of the steep slope, i. e., near the line of change of dip. The exact location should be determined by one acquainted with the structure and the section to be encountered in drilling, since there are several factors which affect the location which can be determined only by an examination of the vicinity and a knowledge of the general geology.

Depth to which prospect or test wells should be drilled.—After a well has been located, a consideration of the depth to which it should be drilled before it should be abandoned as dry is an important consideration. In some cases this cannot be determined, but usually the sands which are possibly oil or gas-bearing and which are likely to be encountered in the drilling, as well as their approximate depth below the surface, can be approximately determined. Drilling should not stop until the horizon of the lowermost sand which is liable to be encountered is reached. For example, in the great oil region of Oklahoma, the northeastern part of the State, the oil and gas-bearing rocks outcrop to the east of the development and dip under the surface to the west. From a knowledge of the rate of dip and the distance of a locality to the west of the outcrop of the sands, or from a place where their depth is known, the depths of the possibly producing sands of the locality in question can be prophesied with a fair degree of certainty. The dip through the oil and gas region mentioned has been found to be quite uniformly 30 feet to the mile. Supposing then that a well is started 20 miles west of a proven pool, the sands in the new well will be encountered at depths approximately 600 feet greater in the new well than in the pool to the east, if the mouths of the wells are at about the same level. A sand which lies at 500 feet in the old pool should be expected at about 1,100 feet and a sand found at 1,200 feet in the old pool should be found at about 1,800 feet in the new location. Any difference in the elevations of the wells should be added to the difference in the depths of the sands in the two localities as determined by the dip, if the new well is higher than the old, and subtracted if it is lower. There is always a possibility that the sands of the developed pool do not extend under the new location and also that sands will be found in the new location which were not present in the old. The principal producing sands of the northeastern Oklahoma fields, for instance, the Bartlesville and Cleveland sands, are known to be continuous over large areas and can be depended upon with some degree of certainty. Drilling in any locality should be carried to a sufficient depth to reach the lowest productive sand, unless this depth is so great as to be impracticable. Even if production is found in the higher sands the deeper sands should be tried out in some wells at least.

The advantage of knowing the position of the productive sands and the depth at which they are to be expected is shown by two examples that recently came to the writer's knowledge. In one case a well was drilled a considerable distance farther east than any work previously done by those connected with the undertaking. The hole was carried to a depth of about 2,000 feet in search of the Bartlesville sand, when, in fact, this sand was passed through at a depth of about 700 or 800 feet and about one-half of the hole was in the Mississippi lime and the rocks beneath it. In another case a well was started even lower than the one just mentioned, so that it was not over 100 feet to the Mississippi lime. The hole was drilled to a considerable depth in the hope of striking the sandstones which are productive farther to the northwest. What is probably the lowest of these productive sands, outcrops as a range of hills a few miles to the west of the location of the well. In either of these cases even a general knowledge of the geology of the region would have saved the parties drilling the wells considerable sums of money.

Value of wild-catting.—In some places it is practically impossible to get much aid from geology in determining whether or not a certain locality, in a region which is in general an oil and gas region, is particularly favorable for development. Some of these cases are where the surface rocks are so soft that they weather down without giving good exposures; in places where the accumulation is in lenses of sand which are included in shale without giving any surface indications (fig. 9); and in places where the accumulation is largely controlled by variations in the coarseness of the sand. The possibility that these conditions may occur gives considerable justification for what may be termed rank wild-catting, although the chances for finding production are much less than in localities where the structure can be made out and the more probable places selected. Even in such places a knowledge of the general geology of the region should be of great assistance to the prospector in deciding whether or not he wishes to take the chance of drilling in the unproved territory.


GEOLOGIC MAP
OF THE
STATE OF OKLAHOMA.
Compiled from Maps of the U. S. Geological Survey
and of the U. S. Land Office Map of Oklahoma of 1907.
- Revised according to Post Route Map of Dec. 1st 1908. -
GEOLOGY.
Sand Hills
Tertiary
Cretaceous
Permian
Pennsylvanian
Carboniferous
Mississippian
Lower Paleozoic
Igneous Rocks
Geological Boundaries
LEGEND.
State Lines.
County Lines.
Meridians, Parallels & Township Lines.
Railroads.
Rivers & Creeks
Towns under 1000 inhabitants.
" over "
County Seats.
GREER
County names in this style.
SCALE IN STATUTE MILES.
K A N S A S
M I S S O U R I
A R K A N S A S
T E X A S
C O L O R A D O
N E W M E X I C O
SEMINOLE
RIVER
RED RIVER

IV.

THE GEOLOGY OF OKLAHOMA

GENERAL STATEMENT.

The surface rocks of practically all Oklahoma are sedimentary and, except in relatively small areas, are not greatly disturbed. The northeastern corner of the State is part of the Ozark Mountain region and the rocks dip to the southwest, west, and northwest away from the center of the uplift. Most of the rocks in this area are of Mississippian age. The general westward dip continues to the west into the area of the Pennsylvania rocks, and into the Redbeds area for some distance. In the western part of the Redbeds the rocks are very nearly level or dip slightly to the east. In the southern part of the State are three mountain groups, the Ouachita, Arbuckle, and Wichita mountains. These mountain uplifts are composed of older rocks than the Pennsylvanian and Permian. They are much folded and often faulted. These older rocks extend out under the Pennsylvanian and Permian to the north and west. To the south of the Ouachita and Arbuckle mountains is an area of much younger rocks which dip slightly to the southeast and lap over the upturned edges of the older rocks of the mountains.

From the standpoint of its geology, then, the State is divided naturally into certain districts or provinces and it seems best to discuss them as nearly independently of each other as possible. The districts and their boundaries are as follows:

(1). The Ozark Mountain region, or Mississippian area, in northeastern Oklahoma, including approximately the territory east of Grand River and north of the Arkansas.

(2). The Sandstone Hills region, or Pennsylvanian area, including east-central and north-central Oklahoma.

(3). The Ouachita Mountains in the southeastern part of the State, including most of the area south of the Ardmore branch of the Chicago, Rock Island & Pacific Railway and east of the main line of the Missouri, Kansas & Texas Railway.

(4). The Arbuckle Mountains in the south-central part of the State.

(5). The Red River limestone region or the Cretaceous area including the territory between the Arbuckle and Ouachita mountains on the north and Red River on the south.

(6). The Wichita Mountains in southwestern Oklahoma.

Fig. 13.—Map of Oklahoma showing the Ozark Mountain region.

(7). The Redbeds, including most of western Oklahoma.

These areas are described in the order named. They are all indicated on the general geologic map (Pl. I) as well as by small figures in the text.

OZARK MOUNTAIN REGION.

As has been said, the northeastern part of the State is the southwestward extension of the Ozark Mountain uplift and the rocks are in general the same in character and relations as those exposed in the adjacent parts of Missouri and Arkansas. The portion of the State included in this area is shown by figure 13.

Stratigraphy.—The oldest formation of rock exposed in the Oklahoma region is a white sandstone (the Burgen) of which a thickness of about 100 feet is exposed, with the base not shown. Above this is a series of shales, sandstones, and limestones, 60 to 100 feet thick, making up the Tyner formation. Then comes a black slaty shale varying from 5 or 10 to 40 feet in thickness. These three formations are all older than the Mississippian and outcrop only in the deeper valleys such as those of Illinois and Barren Fork rivers and their principal tributaries and some of the larger branches of Grand River. Some of the larger areas are shown on the general geologic map (Pl. I), but the smaller ones cannot be shown on a map of this scale.

Above the Chattanooga black shales lies the Boone formation, named from Boone County in Arkansas. This formation consists of from 100 to about 400 feet of limestone and cherts or flints. The formation is usually called the Boone chert on account of the chert contained. It covers all the region except the narrow outcrops of the older rocks in the deeper valleys, which have been mentioned and a narrow belt around the margin of the region which is covered by the younger rocks to be described shortly. The Boone chert is a very resistant formation and weathers into rugged hills usually covered to a depth of several feet with angular chert fragments. This fact has given the region its well known popular names of the Flint Hills and Cherokee Hills.

Above the Boone chert is a formation of dark colored shale with some limestone, the Fayetteville formation, and above this the Pitkin limestone. Both formations were named from towns in Arkansas where they were first studied. In the region of Muskogee each of these formations is about 100 feet thick, but they thin to the north and east. In the vicinity of Pryor Creek both together are not over 50 feet thick. The Pitkin especially is variable in thickness and thickens and thins irregularly. These two formations or their equivalent* outcrop in a belt

*It is probable that the names Pitkin and Fayetteville cannot be used on the west side of the region in Mayes, Craig and Ottawa counties on account of minor changes in the character and thickness of the rocks but the the variations are not sufficient to be of importance in this connection.

from the Arkansas line westward to Muskogee and thence northward along Grand River to the Kansas line. The belt along the south side of the region is much broken by faulting.

The section of the rocks in this region is shown in figure 14.

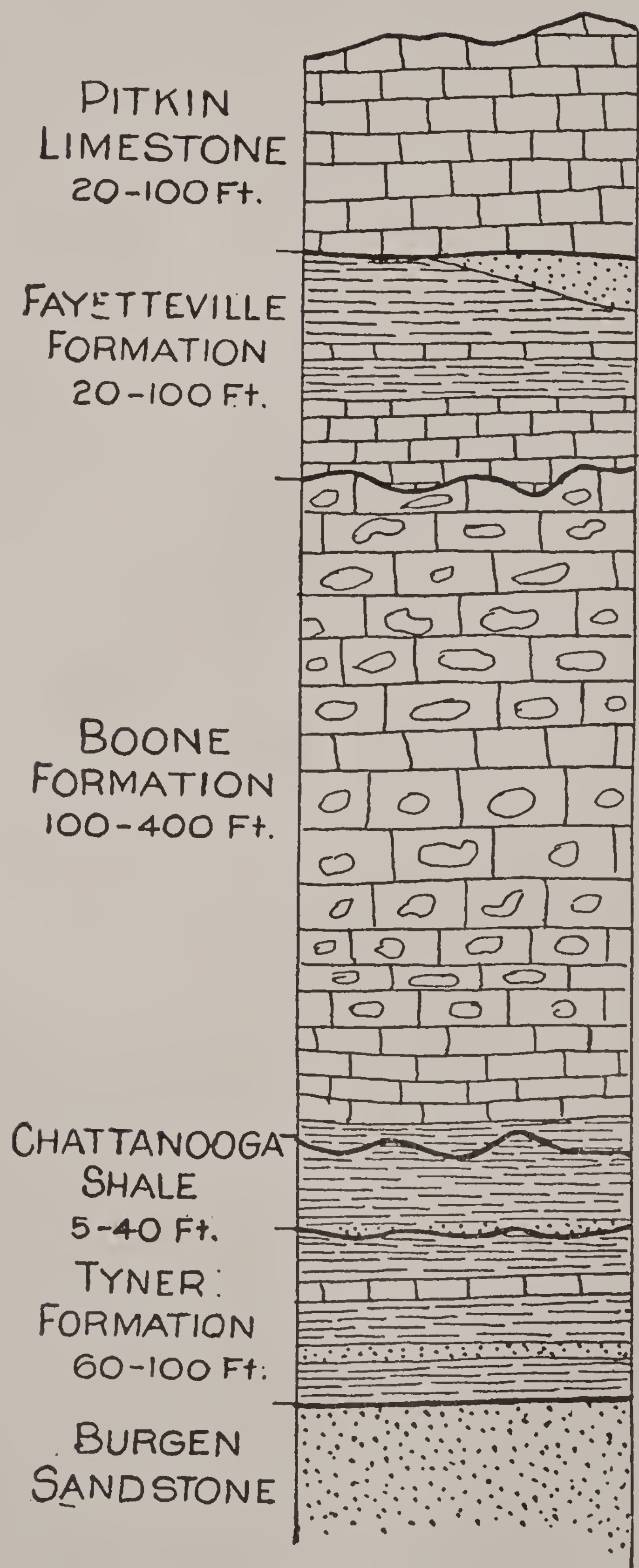


Fig. 14.—Columnar section of the rocks in the Ozark Mountain region in Oklahoma.

Structure.—In general the rocks of this region dip to the west and southwest at low angles. This general dip is very often broken by folds and faults, so that in very little of the area do the rocks lie level. Much of the area has not been worked in sufficient detail to give the locations of the folds and faults, but the extreme southern and northern portions have been reported on by the United States Geological Survey and the outlines of the folds and faults are pretty definitely known. The detailed description of the structure so far as known is reserved for the description of the counties in which the folds or faults occur. The discussion of the prospects for oil and gas is given in a succeeding section.

THE PENNSYLVANIAN AREA OR SANDSTONE HILLS REGION.

Introduction.

This area as already outlined and as shown on the map (fig. 15), occupies a broad L-shaped area on the

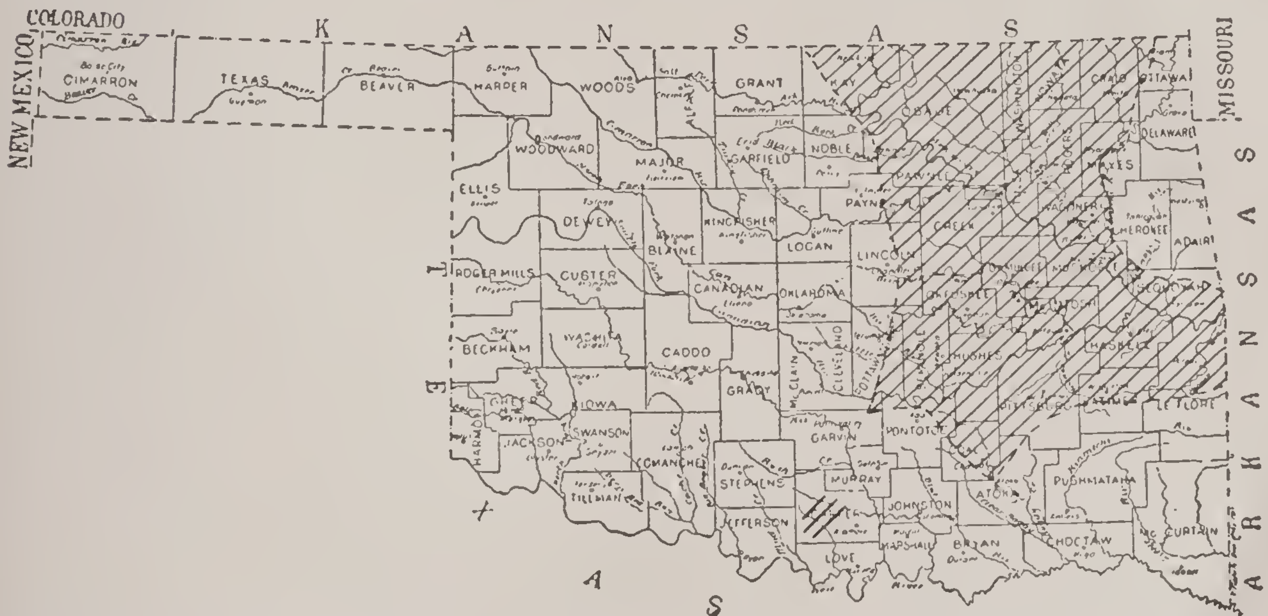


Fig. 15.—Map of Oklahoma showing the Pennsylvanian or sandstone hills region.

south and west sides of the Ozark Mountain region. The western limit is the Redbeds area, and the southern the Arbuckle and Ouachita mountains. Northward the area extends on into Kansas and eastward into Arkansas. The area contains all or parts of the following counties: Ottawa, Craig, Nowata, Washington, Osage, Pawnee, Payne, Lincoln, Creek, Tulsa, Rogers, Mayes, Wagoner; Muskogee, Cherokee, Sequoyah, Adair, LeFlore, Latimer, Haskell, Pittsburg, McIntosh, Hughes, Okmulgee, Okfuskee, Pontotoc, Seminole, Murray, Pottawatomie, and Lincoln.

The rocks of this area are shales, sandstones, and limestones of Pennsylvanian age. In the northern part of the area, north of Arkansas River, there are several limestones, but these thin out and disappear to the south, and only two or three of them cross the river. To the south of the Arkansas practically all the rocks are sandstones and shales. These are much thicker than the rocks to the north of the river and present an entirely different section. It is necessary, then, to discuss the two portions of the area separately.

The Sandstone Hills region north of Arkansas River.

General statement.—The surface of this area slopes gently to the southeast. The alternation of hard and soft strata dipping gently to the west and southwest gives rise to a stairstep topography. The outcrops of the shales make broad flats or valleys, while the outcrops of the sandstones and limestones make pronounced eastward-facing ridges or escarpments. Going west each ridge or escarpment is slightly higher than the one to the east. The greater part of the drainage is into Arkansas River through the Verdigris and its branches. Since this area contains some of the most important oil and gas fields the nature and stratigraphy of the rocks are given rather fully.

Stratigraphy.—The formations exposed in this area with their descriptions are as follows, beginning with the lowest:

(1). The Cherokee formation consists of a group of shales, sandstones, limestone lenses, and coal beds. At the Kansas line the formation is about 500 feet thick, but it thickens rapidly to the southward and in the vicinity of Muskogee the rocks of the same horizon are included in two formations, the Winslow and Boggy which are to-

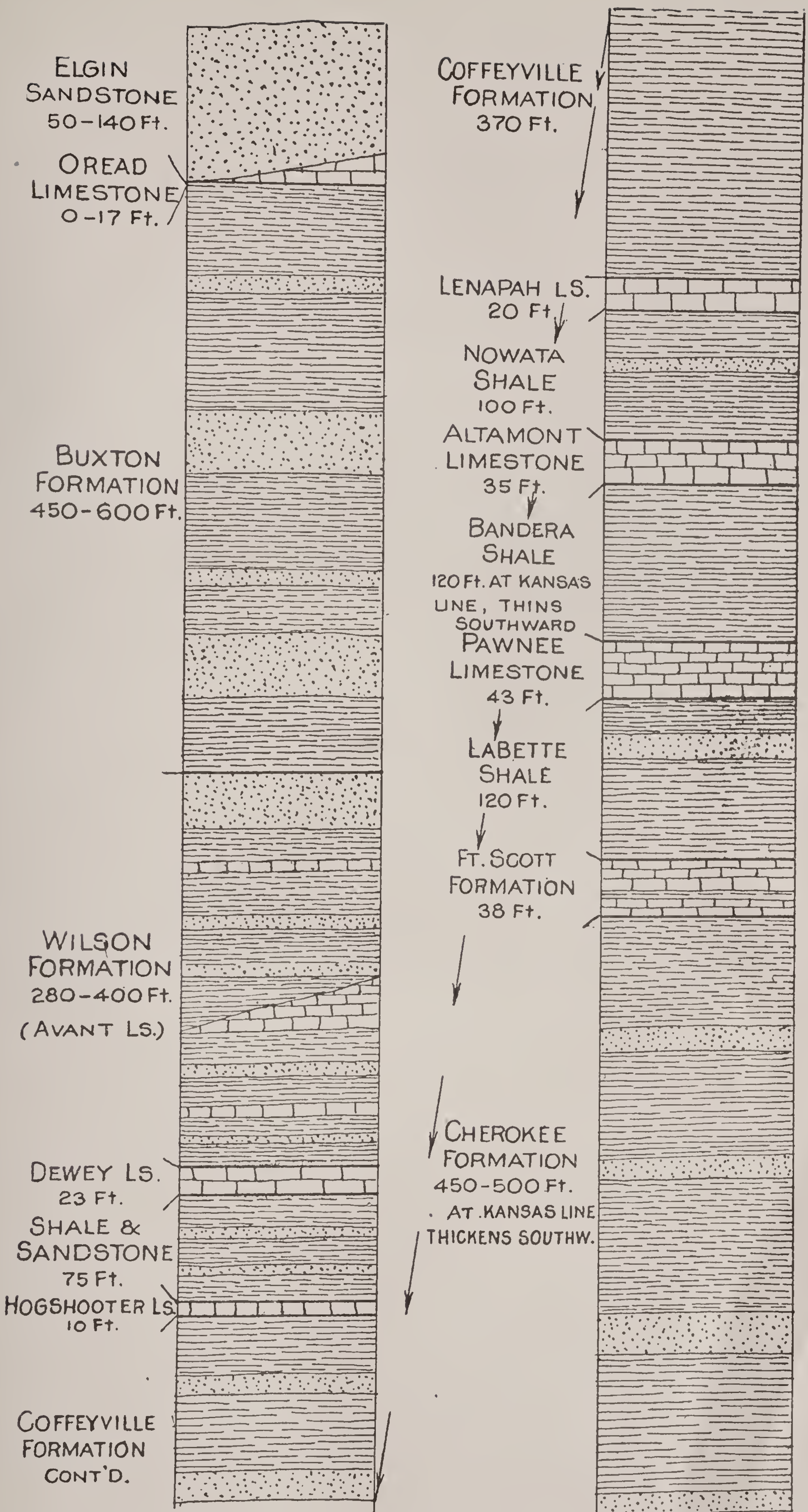


Fig. 16.—Columnar section of the Pennsylvanian rocks in northeastern Oklahoma.

gether about 1,500 feet thick. A columnar section of the rocks exposed in the northern part of the area as far west as the longitude of Cleveland and Pawhuska is shown in figure 16.

The outcrop is a belt of rather level land about 12 or 15 miles wide until it approaches the Arkansas, where it widens rapidly and extends eastward along the south side of the Ozark region. This formation is very important in the discussion of the oil and gas since it contains several of the important oil producing sands in the main field. The Bixler, Markham, Barnett, Bartlesville, and Burgess sands, named in descending order, lie in the formation. Of these the Bartlesville is of most importance. The heavy sandstone outcropping east of Welch, at Bluejacket, and northwest of Vinita is probably the Bartlesville. It has been recognized far to the westward beneath Osage County and to the southwestward in the oil fields of Tulsa, Creek, Pawnee, and other counties.

(2). The Fort Scott formation consists of a lower limestone 10 feet thick separated by about 8 feet of shale from an upper limestone 20 feet thick. The whole thickness is thus 38 feet. The formation is known to the drillers as the "Oswego lime." In Oklahoma its outcrop forms a pronounced escarpment from the Kansas line, northwest of Welch in Craig County, southwest past Centralia, Chelsea, Claremore, and Catoosa to Arkansas River.

(3). Above the Fort Scott formation is a shale 120 feet thick known as the Labette shale. From Nowata northeastward a heavy sandstone occurs toward the top of the formation. It is not improbable that this is the outcrop of the so-called Holland sand which is productive of oil in the vicinity of Ochelata.

(4). The Pawnee limestone is about 40 feet thick. It outcrops along the west side of Verdigris River south from Nowata. At Talala the shale above the Pawnee pinches out and the Pawnee and the higher Altamont limestone unite to form the Oolagah which continues to the southward. The Pawnee and Altamont in the northern part of this area and the Oolagah in the southern part are known to the drillers as the "Big lime."

(5). The Bandera shale lies between the Pawnee and the Altamont limestones. At the Kansas line it is 120 feet thick, but it thins rapidly to the south until it is only 40 feet thick at Nowata and disappears about Talala.

(6). The Altamont limestone is uniformly about 30 feet thick. It outcrops to the east of Nowata and southward along the Verdigris. South of Talala it unites with the Pawnee to form the Oolagah.

(7). The Nowata shale is about 100 feet thick at Nowata and thickens gradually to the south. A few thin sandstones are present in the formation, some of which are probably oil-bearing to the westward.

(8). The Lenapah limestone is about 20 feet thick at Lenapah and on the bluff in Nowata, but is not known to extend southward from that place. Its extension to the west under the younger formations is conjectural.

(9). The Coffeyville formation is composed principally of shales, but sandstones become prominent toward the south. The formation thickens from the Kansas line to the south, the average thickness being about 370 feet.

(10). The Hogshooter limestone is about 10 feet thick. It outcrops along Hogshooter Creek about 9 miles east of Bartlesville. It is not usually recognizable in logs of wells to the west, possibly because it is thin-bedded and is not noticed by the drillers and possibly because it does not extend far to the west.

(11). About 75 feet of unnamed shales and sandstones lie immediately above the Hogshooter limestone. The sandstones are thin and lenticular.

(12). The Dewey limestone is about 23 feet thick. It is well exposed in Bartlesville, near Dewey, and to the eastward and is prominent on the bluffs west of Ochelata and Ramona.

(13). The Wilson formation consists principally of shales with thin sandstone and limestone lenses. The principal sandstone lens is about 30 feet thick and lies about 100 feet below the top of the formation. It is well exposed at the village of Torpedo in the eastern part of Osage County. The principal limestone is exposed near Avant, and is known as the Avant limestone member.

(14). The Buxton formation of southern Kansas thickens southward into Oklahoma where in Osage County it embraces over 550 feet of sediments. A generalized section follows:

	Feet
Shale, sandy shale, and sandstone	140-155
Sandstone, exposed near Nelagony	50
Limestone, lentil	20
Shale, sandy shale, thin sandstones	100
Sandstone, exposed near Bigheart	140
Shale, and sandstone	180
Average total	630

The 50-foot sandstone of the above section is prominently exposed in the vicinity of Nelagony and is known to extend thence in both directions along the strike for a considerable distance. The limestone of the section is a lens and has but little linear extent.

The sandstone at the base of this section is really composed of several distinctive sandstones separated by shale beds. All the beds, however, are closely associated, especially at Bigheart, where they are well developed, several being thick and massive. They are known to extend from the eastern border of Osage County near Bartlesville southwest across this county and probably into Creek County.

(15). The Oread limestone overlies the Buxton formation in Kansas and extends 10 or 12 miles into Oklahoma where it pinches out. It is 17 feet thick at the Kansas line.

(16). The Elgin sandstone overlies the Oread or the Buxton where the Oread is absent. This sandstone extends southward across Osage County to Arkansas River were it caps the hills in the vicinity of Cleveland. Just south of the Kansas line near Elgin, Kans., the Elgin sandstone is 140 feet thick, and is made up of an upper and lower member, separated by shaly sandstone. To the southward the Elgin becomes thinner and consists usually of but a single member, which is in most places massive, containing practically no shale. From the central part of Osage County south to Arkansas River the Elgin is between 50 and 75 feet thick.

(17). The beds outcropping in western Osage County have not been studied nor mapped in detail and have not been divided into separate formations. Of these beds little is known except that a series of rapidly alternating shales, thin limestones, and occasional sandstones intervene between the base of the Wreford limestone and the top of the Elgin sandstone. The entire series approximates a little less than 700 feet thickness. It consists chiefly of shales, but thin limestones are very abundant, and sandstones are not lacking. A succession of sandstone beds about 60 feet thick lies about 300 feet above the base of the series. Of this succession some individual beds have a considerable thickness as shown in exposures along Buck Creek in the north-central part of the county. It is probably the same series that is seen farther to the southwest, east of Fairfax. Some of the higher of these beds are probably Permian in age.

Structure.—The general structure of the Pennsylvanian rocks north of the Arkansas River is a monocline with a westward dip averaging 30 feet to the mile along the Kansas line. The rate of dip farther to the south is not known exactly, but does not seem to be greatly different. The general westward dip is often broken by gentle folds which give local east dips. In some cases the folding is so gentle that no eastward dip is observed, but the rocks lie nearly level for some distance and then dip to the west with a greater dip than the average. There is thus a smaller monocline or arrested anticline superimposed on the large one. Some of the anticlinal folds are so short as to be classed as domes. It should be emphasized that the structure in this area is very gentle except around the margin of the Ozark region. In some cases the dips are great enough to be observed with the eye or measured by a clinometer, but ordinarily several elevations of a given ledge or horizon must be determined and the dip calculated from the difference in elevations. The streams cutting the rocks often give opportunities for these determinations. In many places detailed mapping and determination of as many elevations as possible by means of an alidade or transit is necessary before the structure can be made out. In some of the oil pools it is possible that there is no structure, but that the accumulation is due to short lenses of sand or local thickenings in the bodies of sandstone. The way in which these may effect the accumulation has been noticed in the section on theories of accumulation.

Practically all of this area has been surveyed by the United States and Oklahoma Geological surveys, but the results are to be published by the United States Survey and have not yet been made public. Consequently very little can be said as to the details of the structure. Such facts as are known are given in connection with the descriptions of the various oil pools and under the different counties.

The Sandstone Hills region south of Arkansas River.

General statement.—The area of Pennsylvanian rocks south of the Arkansas differs from the area to the north principally in the almost complete absence of limestones and the greater abundance of sandstones which are much thicker than those to the north of the river. These sandstones give the region as a whole a very rough surface and the name, sandstone hills region, is more applicable to this portion of the Pennsylvanian area than to the northern portion.

Stratigraphy.—While the rocks are the southern continuation of those north of the river they are so different that it was necessary for the United States Geological Survey to use an entirely different set of names in the coal fields of the Choctaw Nation which were studied several years ago. These names apply particularly to the southern part of the area under consideration, especially to the coal fields. There is consequently a large area in Okmulgee, Okfuskee, McIntosh, Hughes, Seminole, and Pottawatomie counties where very little geologic work has been done and where there is considerable doubt as to the exact stratigraphy of the rocks and as to the names to apply to them. From the small amount of work that has been done, however, it appears that the succession of rocks in this belt is in general the same as for the extreme southern part of the area, and also that there is a general thinning of the strata, especially of the sandstones. The thickening from north to south takes place in practically all the rocks, but is especially pronounced in the case of the Cherokee formation. As has already been observed this formation, which is less than 500 feet thick at the Kansas line, is represented in the region of Muskogee by two formations, the Boggy and Winslow, which are together 1,500 feet thick. Farther south the Winslow—the lower of the two formations—thickens enormously and in the vicinity of McAlester and Coalgate is represented by several formations having a combined thickness of over 6,000 feet. The entire section of the McAlester-Coalgate region is shown graphically in figure 17.

The formations are as follows, beginning at the bottom:

(1). The Wapanucka limestone, 100 feet thick, which forms the "limestone ridge" near Atoka and south and southeast of McAlester.

(2). The Atoka formation, 3,100 feet thick, consisting of clay shale, sandy shale, and sandstone, which is generally thin-bedded and friable.

(3). The Hartshorne sandstone, 150 feet thick, consisting of brown sandstone with local beds of shale. This formation outcrops as a low, wooded ridge near the outcrops of the lower workable coals.

(4). The McAlester shale, 1,800 to 2,000 feet thick, consisting of blue and black shale, and sandstone of varying thickness, interbedded with several veins of coal, two of which are workable.

(5). The Savanna sandstone, 1,000 feet thick, consisting of thick-bedded sandstone and shale. Outcrops as prominent ridges near Savanna and McAlester and to the north and east. Thins out and disappears to the northward.

(6). The Boggy shale, 2,000 to 2,600 feet thick, consisting of shale, shaly sandstones, and brown sandstones with local, thin, siliceous limestone and coal near the base.

(7). The Thurman sandstone about 200 feet thick consisting of brown sandstone, shale and chert conglomerates.

(8). The Stuart shale, 90 to 280 feet thick, consisting of blue and black clay shale with some sandstones.

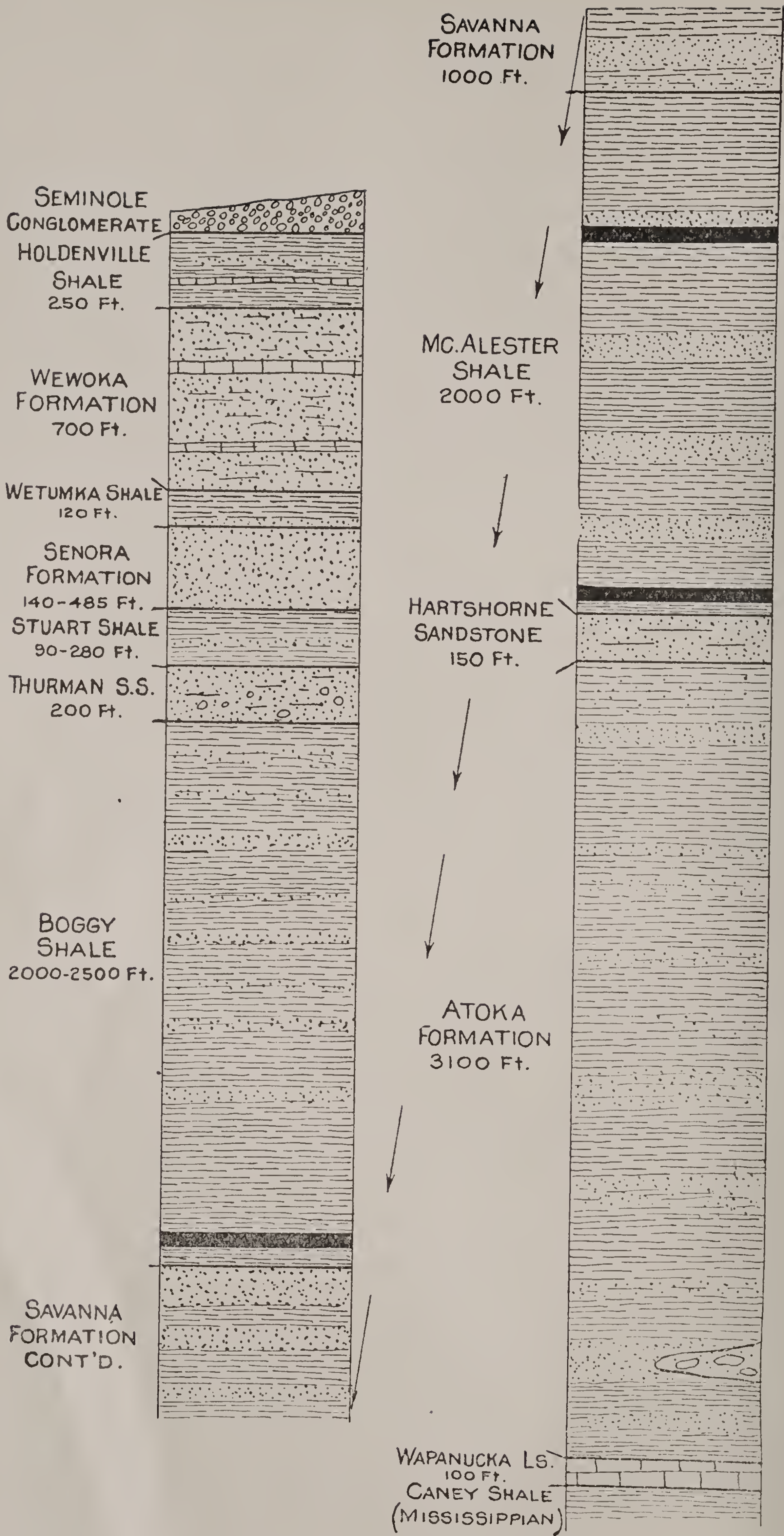


Fig. 17.—Columnar section of the Pennsylvanian rocks in the region south of Arkansas River.

(9). The Senora formation, 140 to 485 feet thick, consisting of brown sandstone generally thick bedded.

All these formations up to and including the Senora are believed to represent the interval occupied by the Cherokee formation near the Kansas line. See fig. 16.

(10). The Wetumka shale, 120 feet thick, consisting of clay shale above and sandy shale and thin sandstone below.

(11). The Wewoka formation, 700 feet thick, consisting of massive, brown, friable sandstone, with interstratified soft, blue clay shale, and some limestone.

(12). The Holdenville shale, 260 feet thick, consisting of blue and yellow clay shale with thin, siliceous limestone and sandstone beds.

(13). The Seminole conglomerate, 50 feet thick in the region studied, but thicker to the north, consisting of a conglomerate of white chert in brown sand, succeeded by brown sandstone.

Above these rocks and outcropping to the west are some higher unnamed shales and sandstones. These, however, can be considered as forming the lowest portion of the Red-beds since some of the members have the red color which becomes general a little higher in the section. It should be repeated that these formation names apply, as yet, only to the extreme southern portion of the area, but that they will probably be found to be applicable northwards almost to Arkansas River. At any event the rocks of the region between that worked out and the Arkansas consist of sandstones and shales, and it is thought that some, if not all, of the formations defined to the south have been recognized almost as far north as the Arkansas.

Structure.—The structure of the portion of this area immediately south of the Arkansas is like that of the area north of the river, a monoclinal dip to the westward, interrupted occasionally by gentle folding. To the south, however, the folding becomes more intense and finally culminates in a very strongly folded and faulted area in the region to the north of the Ouachita Mountains. The structure of the northern portion of the area has not been worked out, but that of the southern portion has been worked out in connection with the survey of the coal fields of the Choctaw Nation. The principal folds of the coal fields have been described by J. A. Taff in the nineteenth and twenty-first annual reports of the United States Geological Survey. These papers give the only account of the structure of the coal fields which has been published. The description of the structure given under the various counties in which the folds occur is taken in large part from these papers. The data for the accompanying map (Pl. II), which shows the approximate location of the axes of the principal folds, are also taken from the maps of the two papers mentioned. It should be borne in mind that a map of this scale cannot show the structure with sufficient accuracy to justify one in attempting to locate favorable drilling sites from such a map without a thorough examination of the field. The map should be useful as a guide for field investigations and should save much preliminary work in locating the folds of this region. It is thought best to give the description of the individual folds in connection with the discussion of the counties in which they occur, in the pages near the end of the book.

THE OUACHITA MOUNTAIN REGION.

General statement.—The Ouachita Mountain region occupies the extreme southeastern part of the State, as shown on the accompanying map (fig. 18). The Ardmore Branch of the Chicago, Rock Island & Pacific Railway forms the northwestern boundary; the main line of the Missouri, Kansas & Texas Railway the western; the belt of level-lying Cretaceous rocks, the southern; and the State of Arkansas the eastern boundary of the area in Oklahoma. The area is really continuous with a large area in Arkansas.

Stratigraphy.—The rocks exposed are principally shales and sandstones, ranging in age from Ordovician to upper Mississippian. The formations are as follows, beginning with the lowest:

(1). The Stringtown shale, 600 feet thick, consisting of black and blue shales with a bed of cherty shale.

(2). The Talihina chert, 1,150 feet thick, consisting of flint and chert of various colors with some cherty and clay shales.

(3). The Standley shale, 6,100 feet thick, consisting of bluish and greenish shales and massive and thin-bedded drab sandstone.

(4). The Jackfork sandstone, 3,800 feet thick with the top eroded, consisting of brown and drab sandstones, shaly sandstones and thin shale beds.

Structure.—The structure of the region is very complex. The rocks are very strongly folded and faulted and many of the folds are overturned.

Detailed geologic work has been done in considerable of the region by the United States Geological Survey, but the results have not been published and are not available. Nothing can be said, therefore, as to the exact location of the folds and faults. The structure which causes all the rocks of the area to be strongly tilted, combined with the resistant properties of the thick Jackfork sandstone, causes this region to have the roughest surface of any portion of the State. The hills are sufficiently high to be known as mountains and names have been given to some of the principal groups. Among these are the Jackfork, Kiamitia, Winding Stair, Pine, Potato Hill, and Williams mountains. Most of these mountains are formed by the Jackfork sandstone, but some of them are due to the Talihina chert or its equivalents. Owing to its extremely rough surface the region has little agricultural land and is very thinly settled. Roads and transportation facilities are very poor.

ARBUCKLE MOUNTAIN REGION.

Location and stratigraphy.—The Arbuckle Mountain region is situated in the south-central part of the State. The area is shown on the accompanying sketch map (fig. 18) with that of the Ouachita and Wichita mountains. The uplift occupies parts of the following counties: Garvin, Murray, Carter, Johnston, Coal, and Pontotoc. The rocks exposed range in age from pre-Cambrian to Pennsylvanian. The section is as follows, beginning at the base:

Fig. 18.—Map of Oklahoma showing the Ouachita, Arbuckle and Wichita mountain regions.

(1). The Tishomingo granite which forms the core of the mountains and outcrops in two areas, one east and one west of Washita River.

(2). The Reagan sandstone, from 0 to about 500 feet thick composed largely of granite fragments with some shale in the upper portions, of Cambian age.

(3). The Arbuckle limestone, 4,000 to 5,000 feet thick, composed almost entirely of thick and thin-bedded limestone of Cambro-Ordovician age.

(4). The Simpson formation, 1,200 to 2,000 feet thick, composed of sandstones, shales, and limestones of Ordovician age.

(5). The Viola limestone, 500 to 700 feet thick, composed of almost pure limestone of Ordovician age.

(6). The Sylvan shale, 60 to 300 feet thick, composed of green and black clay shales of Ordovician age.

(7). The Hunton limestone, 0 to 300 feet thick, composed of two limestones and an intervening shale of Siluro-Devonian age.

(8). The Woodford chert, about 650 feet thick, composed of black shale with thin layers of chert, probably of Devonian age.

(9). The Sycamore limestone, 0 to 200 feet thick, composed of dense blue limestone, probably of Mississippian age.

(10). The Caney shale, about 1,600 feet thick, composed of black and blue shales of Mississippian age.

(11). The Glenn formation, of undetermined thickness, a complex of shales and sandstone of Pennsylvanian age outcropping on the southern side of the mountains, especially in the Ardmore Basin.

(12). The Franks conglomerate, ranging from nothing to several hundred feet in thickness, composed of rounded pebbles and bowlders of limestone from the older rocks of the uplift. The conglomerate was deposited in Pennsylvanian times and lies uncomformably on the upturned edges of most of the older rocks.

History.—The rocks composing the Arbuckle mountains were deposited in pre-Pennsylvanian times in water which varied in depth from time to time and portions of the area were above the water for comparatively short intervals. During Pennsylvanian times the area was uplifted into the shape of an immense dome. As soon as the uplift commenced, the forces of weathering began their work of tearing down the exposed rocks and transporting them back to the ocean. By the end of Pennsylvanian times probably as much as two miles thickness of material had been removed from above the granite core of the mountains. Toward the end of this period the sea again advanced over the area and the Franks conglomerate was built up from the bowlders of limestone which covered the old land surface. Later the lower parts of the Redbeds was deposited around the edges of the mountains, probably a good deal higher than we find them now, since a considerable thickness of them must have been removed by erosion since they were deposited. We have, then, in the Arbuckle Mountains a truncated dome with the granite forming the core of the uplift and the steeply upturned older sedimentary rocks dipping in all directions away from it. Over the edges of the upturned rocks at some distance from the granite core we have the level-lying Franks conglomerate and the Redbeds.

Structure.—The structure has been spoken of as a dome, but it must be understood that the structure is not as simple as the term indicates. The rocks were under great pressure, as the uplift was formed by thrusts from the sides and not by pressure from beneath. As a result there were many minor folds produced and much faulting. Some of the folding is extremely complex and the faulting is so general as to make the structure very difficult to work out. The areas of the principal folds have been worked out with some degree of accuracy, but on account of the faulting and other conditions the folds are almost certainly without effect on oil and gas accumulation and there is no need of considering them in detail in this work.

WICHITA MOUNTAIN REGION.

The Wichita Mountains lie in the southwestern part of the State, in Comanche, Tillman, Jackson, Greer, and Kiowa counties. This region occupies approximately the area shown in figure 18. The long axis of the Wichita Mountains is in line with that of the Arbuckle Mountains and the two groups are almost certainly parts of the same general uplift with the connecting portion buried beneath the Redbeds between them. The Wichitas have had the same history and the same mode of formation as the Arbuckles, except that the Redbeds were deposited much higher relatively on the Wichitas and buried them so deeply that only the granite peaks and some of the higher limestone hills remained above the Redbeds or have been uncovered by erosion. Of the section of sedimentary rocks as exposed in the Arbuckles only the Reagan sandstone, Arbuckle limestone, and Viola limestone are shown in the Wichitas, and these only in comparatively small areas on the north side of the mountains. The Wichitas, then, may be regarded in the same way as the Arbuckles—as a truncated dome exposing considerable areas of the granite in the core of the uplift, and with the level-lying Redbeds lapping up over the upturned edges of the older sedimentary rocks. Presumably these older sedimentaries are folded and faulted similarly to those of the Arbuckles, but the covering of Redbeds completely hides the structure of the underlying rocks.

THE CRETACEOUS OR RED RIVER LIMESTONE REGION.

This area lies in the southern part of the State between Red River on the south and the Arbuckle and

Ouachita mountains on the north. Parts of Love, Carter, Atoka, Pushmataha, and McCurtain counties and all of Marshall, Bryan, and Choctaw counties are included in the area as shown in figure 19. The rocks are sandstones,

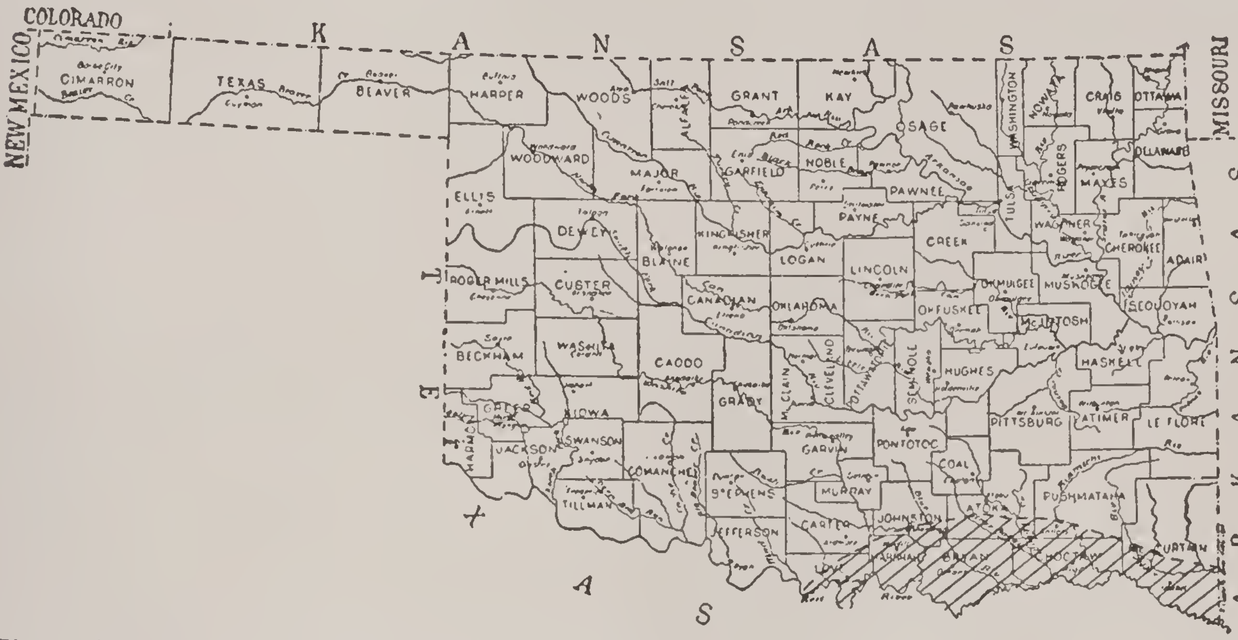


Fig. 19.—Map of Oklahoma showing the Red River limestone region.

shales and limestones, which dip very gently to the southeast. The section as exposed is as follows, beginning at the base:

(1). The Trinity sand, 300 to 400 feet thick. Fine yellow sand with conglomerate beds locally at the base.

(2). The Goodland limestone, 25 feet thick, massive white limestone.

(3). The Kiamichi formation, 150 feet thick, blue, soft shale with thin shell limestone beds in the lower portion.

(4). The Caddo limestone, 60 feet thick, yellow and white limestone interstratified with thin marly beds.

(5). The Bokchito formation, 140 feet thick, red and blue shale with thin irony limestone and lentils of soft sandstone.

(6). The Bennington limestone, 10 to 15 feet thick, blue shell limestone.

(7). The Silo sandstone, 200 feet thick with the top removed, brown, soft sandstone, locally hardened by iron cement, shale and shaly sandstone.

All these formations dip gently to the southeast. The Trinity sand laps over the upturned edges of the older rocks of the Arbuckle and Ouachita mountains to the north. The dip of the formations is very uniform and no structure beside the southeastward dipping monocline has been found. The limestones are more resistant than the sandstones or shales and usually stand up as northward facing bluffs which extend for long distances east and west. Both the limestones and the limy shales form a very rich soil when weathered down.

THE REDBEDS AND TERTIARY REGION.

Lying above and outcropping to the west of the Pennsylvanian rocks is a great thickness of red shales and sandstones which are mostly of Permian age. In Kansas most of the Permian rocks are non-red and only the upper portion has the red color, but on coming south into Oklahoma the rocks of the lower part of the system begin to take on a red color and a short distance south of the State line all the Permian rocks and the extreme upper portion of the Pennsylvanian rocks are red. The only non-red Permian rocks in Oklahoma, except for some thin beds occurring with the rocks, are in an area comprising most of Kay County and small portions of Osage and Pawnee counties adjoining Kay. These are discussed in connection with the Kay County oil and gas field. The area of non-red Permian rocks is indicated on the general geologic map. (Pl. I). The Redbeds area is shown on the accompanying map (fig. 21). It occupies practically all the western half

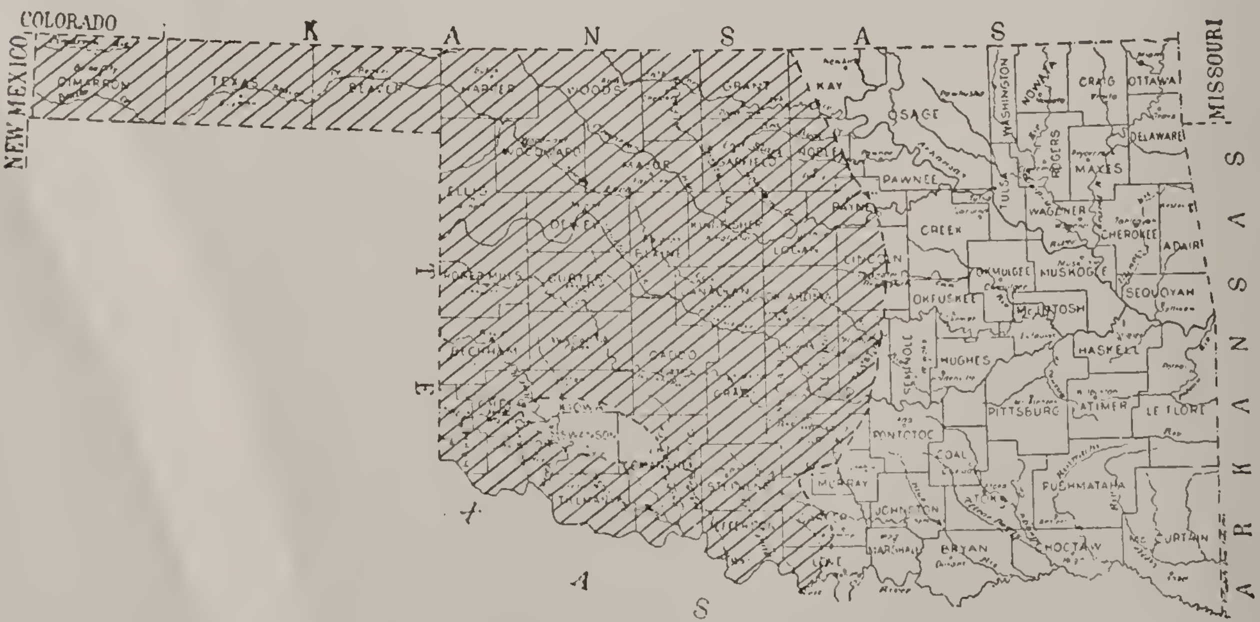


Fig. 21.—Map of Oklahoma showing the Redbeds and Tertiary region.

of the State, the eastern boundary being a line drawn from Blackwell southeast, passing east of Perry and Stillwater, past Chandler to Shawnee and thence southwest to the west end of the Arbuckle Mountains, around the mountains and south to Red River. Included in the territory west of this line are the Wichita Mountains and some large areas in Ellis, Woodward, Harper, Beaver, Texas, and Cimarron counties, which are covered by rocks of Tertiary age much younger than the Redbeds. These rocks, however, are underlaid at a depth of at most a few hundred feet by the Redbeds. As far as the prospects for oil and gas are concerned the area may be considered as part of the Redbeds area. They are, however, indicated by a different color on the geologic map.

The Redbeds consist of a great, but not definitely known, thickness of soft, red sandstones and shales with some ledges of gypsum and thin ledges of dolomite. The lower limit of the beds is not a plane since the rocks lower and lower in the series take on a red color to the south of the State line. The thickness is much greater therefore in the latitude of Shawnee than it is along the Kansas line and the beds thin again to the south in the vicinity of the Arbuckle and Wichita mountains. Near the middle of the State the beds probably reach a thickness of over 3,000 feet.

Stratigraphy.—The stratigraphy of the Redbeds is extremely erratic, that is, the ledges are short and lens shaped. Sandstones of 20 to 30 feet in thickness often pinch out in the distance of a few rods. Practically all the sandstones are strongly cross-bedded and short exposures give the appearance of strong dips which are extremely irregular in direction. If the ledge is exposed for some distance it is seen that the ledge as a whole lies practically level and that the appearance of dip is due to the cross-bedding. The only beds which can be followed for any great distances are some gypsums which lie pretty well up in the series. The details of the stratigraphy are of no importance in the consideration of the oil and gas prospects and need not be discussed.

Structure.—The erratic nature of the stratigraphy of the Redbeds, the softness of the rocks, and the cross-bedding of the sandstones, which, besides the gypsums, are the only ledges which can be traced for any considerable distance, make it very difficult to determine whether or not there are any minor structures in the Redbeds, but from all indications there are no structures in the greater part of the area which would be favorable for the accumulation of oil or gas. In the vicinity of the Arbuckle and Wichita mountains and in the belt between these mountains and Red River some folds have been found, at least some of which are connected with the accumulation of oil and gas. The extreme eastern portion of the region may also show favorable structures when it is worked carefully. The only indication of a fold so far found in the greater part of the area is at Okarche, where an anticline seems to extend northwest-southeast a couple of miles southwest of the town. Even here, however, the exposures are so short and the sandstones so cross-bedded that the presence of the structure is open to some question. Too much emphasis cannot be given the fact that little reliance can be placed on appearance of structure in short outcrops in this region. The cross-bedding of the sandstones is extreme and in short exposures gives all the appearance of strong dips, but when the ledge as a whole can be followed any distance it proves to be practically level in all cases which have come to the writer's notice. The shales associated with the sandstones are very soft, and when wet work out from under the sandstones permitting the latter to slip. Large pieces are often broken from the ledges and lie in positions which indicate strong dips. In most cases, however, this condition can be made out and the ledge in place is found to be level. These conditions of cross-bedding and slip occur so often where they can be definitely identified as such that it is only fair to presume that appearances of dip in very short exposures of single ledges are due to one of these causes unless they can be shown conclusively to be real dips.

V.

GEOLOGIC CONDITIONS IN OKLAHOMA WITH SPECIAL REFERENCE TO PROSPECTS FOR OIL AND GAS

In the following paragraphs the prospects for oil and gas in the different regions of the State are considered. The districts or geological provinces are considered in the order in which they were discussed in the previous sections.

Ozark Mountain region.—From the standpoint of the nature of the rocks and the structure there seems to be no reason why this region should not be productive of oil and gas. The Burgen sandstones is a loosely cemented, porous sand, which would form a good reservoir for oil and gas, and the shales of the Tyner and the Chattanooga shale should form a sufficiently thick impervious layer to make a good cap rock. The rocks are folded so that places where the structural conditions are favorable for accumulation can easily be located. However, up to the present no deposits of either oil or gas of commercial importance have been found in the Boone chert or the rocks below it. This fact is recognized by the drillers who almost invariably stop when they are sure that the "Mississippi Lime," (that is the Pitkin, Fayetteville and Boone) has been reached. Wherever these rocks have been penetrated a strong flow of salt water has resulted. So little detailed geologic work has been done in the region that it is impossible to say whether or not any of these wells have been located where the structural conditions were favorable for the accumulation of oil and gas, but it is highly improbable that all of them should have been located in synclines. The evidence, then, points to the fact that, although the nature of the rocks and the structural conditions are favorable for the accumulation of oil and gas if they were present, the Burgen sandstone and the underlying rocks must be barren of the organic matter to produce the oil and gas. So far as known there are no fossils in the Burgen sandstone and fossils are rare in the rocks in Arkansas of the same position and lower. In the absence of oil and gas, these rocks back from the outcrop are filled with salt water in the anticlines as well as in the synclines. The water falls on the outcrops of the older rocks to the east in Arkansas and works down the dip, being kept from escaping to the surface by the Tyner and Chattanooga shales. In the territory along Grand River the water is under sufficient head to rise to the surface whenever the shales are penetrated. The flowing wells at Vinita, Claremore, Adair, and other places in this region are of this type, and it appears that there is practically no hope of obtaining oil or gas in this part of the area. Very few wells have been drilled along the south side of the region and it may be that small pools may be encountered in this part of the area, although the chance for any development must be regarded as extremely small. The more favorable localities for prospecting so far as known are given under the counties in which they occur.

Pennsylvanian or Sandstone Hills region.—The geologic conditions in this area are extremely favorable for the formation and accumulation of oil and gas. The shales are black and bituminous. The limestones and sometimes the shales and sandstones are fossiliferous. There is thus an abundant supply of organic matter for the formation of oil and gas. The coarse-grained, porous sandstones form excellent reservoirs and the shales by which they are surrounded are impervious and prevent the escape of the oil to the surface. The structure is usually gentle, but is of the type best adapted to the accumulation of large bodies of oil and gas.

The occurrence of important producing areas in this region is to be expected, and it is here that the main fields are found. In the portion of the area north of the Arkansas are the Bartlesville, Delaware-Childers, Coody's Bluff-Alluwe, Osage and other fields; and in the portion south of the Arkansas are the Glenn Pool, the Cushing field, the development around Okmulgee, Muskogee, and Henryetta, and the gas fields at Poteau and Coalgate. Each of these fields or pools is considered in some detail in a subsequent section.

Ouachita Mountain region.—In the present state of our knowledge it must be regarded as doubtful whether the Ouachita Mountain region contains any oil and gas deposits. No deep drilling has been done in the area in Oklahoma and the writer knows of none in Arkansas. The rocks as a rule are practically barren of fossils and would consequently not be supposed to produce large quantities of oil or gas. However, the older rocks, *i. e.*, those older than the Standley shale, are somewhat metamorphosed by the forces which produced the uplift and it may be that the traces of animal life have been obliterated by the changes which the rocks have undergone. At any rate the fact that some of the rocks at some time contained considerable deposits of oil is proven by the presence of considerable quantities of asphalt along faults in the McGee and Impson valleys and in other localities.

The structure of the region is very sharp and faults are very common. Only a few of the faults are known to have asphalt deposits, so that several conditions seem possible. First, the oil deposits may have been small and widely separated so that the present asphalt deposits represent all of the ancient oil beds. Second, the oil in escaping to the surface along the fault plains shortly after they were formed may have left the deposits of asphalt very near the surface of that time, and the deposits may have been largely removed by erosion since. Third, some of the oil deposits may not have been affected by the faulting and are still below the surface in some of the more gentle folds. Fourth, some of the faults may have intersected the oil-bearing strata, but may have sealed the deposits instead of allowing the oil to escape to the surface. As stated in the section on accummulation, some of the principal pools in the California fields have this sort of structure. (See figure 6).

When everything is considered it seems as if this area must be considered as unfavorable territory for oil and gas, but there always remains the possibility that some of the more gentle folds or the territory along some of the fault lines may prove productive. The small amount of geologic work which has been done in the region and the fact that nothing has been published on the portion which has been worked make it impossible to point out any localities that are more favorable for prospecting than the others.

Arbuckle Mountain region.—The general conditions in the Arbuckle Mountains are very similar to those in the Ouachita Mountains, although the sections themselves are very different. The rocks are much folded and faulted. The presence of large asphalt deposits show that at one time there were extensive deposits of oil of which the lighter constituents have escaped. These oil deposits were contained in the Simpson formation and possibly in part in the Viola limestone. The question then arises as to whether or not all of the oil has escaped. The presence of some seeps of very heavy oil or viscous asphalt is an indication that the process of asphalt formation is not yet completed and there may be some bodies of oil totally sealed in from the surface.

The structure in the area of the mountains themselves is such that the presence of such bodies of any great size is extremely improbable. The folds are sharp and are frequently broken by faults which very often bring the Simpson formation, which is the petroliferous horizon, to the surface so that if oil ever was present it has probably escaped. The area has been worked over pretty thoroughly and no localities are known which seem at all favorable for prospecting.

The conditions in a belt around the mountains may be somewhat more favorable since the older folded rocks were covered by the Pennsylvanian and Permian rocks on the east, north, and west in a comparatively short time after the folding of the mountains and after a longer interval by the Cretaceous rocks on the south and the folds were probably not so deeply eroded as those in the exposed parts of the mountains are at present. There is also the possibility that the folding and faulting may be less pronounced farther away from the core of the mountains. In either of these conditions the oil may remain in the older rocks, or if it works up out of them there is a strong probability of its being trapped in sandstones or other porous rock before it reaches the surface. These conditions are believed to account for the accumulations in the Wheeler and Madill fields near the Arbuckle Mountains. The conditions are discussed more fully in connection with the discussion of the relation of the geology to the prospects for oil and gas in the Red River limestone area and part of the Redbeds area.

Wichita Mountain region.—It has been noted in the description of the Wichita Mountains that they have the same sort of structure and the same geological conditions in general as the Arbuckle Mountains except that they were more deeply buried in the Redbeds than the Arbuckles. It follows that the discussion of the prospects for oil and gas in the Arbuckle Mountains applies also to the Wichitas. If we restrict the area to the peaks of granite rocks and small areas of limestone to the north of the mountains, the chances may be said to be zero. The conditions around the mountains are the same as those around the Arbuckles and are considered in connection with the discussion of the Redbeds and with the description of the development at Lawton and Gotebo.

Cretaceous or Red River limestone region.—The general conditions in the Red River limestone area are shown in the accompanying diagram. The Cretaceous sandstones, shales, and limestones lie nearly level above the older rocks of the Arbuckle and Ouachita mountains, which were folded and faulted and worn down before the Cretaceous rocks were deposited over them. The Cretaceous rocks themselves are very fossiliferous and the character of the rocks of the upper part of the section is such that oil and gas should be formed in them. However, there is no folding or change in the general southeastward dip, so far as has been observed, and consequently there is no opportunity for the accumulation of large quantities of the oil or gas.

The Trinity sand, the lowest formation of the Cretaceous, contains practically no plant or vegetable remains, but on the other hand it does contain several deposits of asphalt which are supposed to be the residue of deposits of petroleum, the lighter oils of which have escaped. In addition to the asphalts one pool of oil of commercial importance, that at Madill, has been found in this sand in Oklahoma. The origin of this oil and of the asphalt deposits is somewhat uncertain, but it is usually believed to have been formed not in the Trinity itself, but in the underlying older rocks. By reference to figure 20 it is seen that the Trinity is deposited over the upturned edges of the Pennsylvanian and older rocks which were folded at

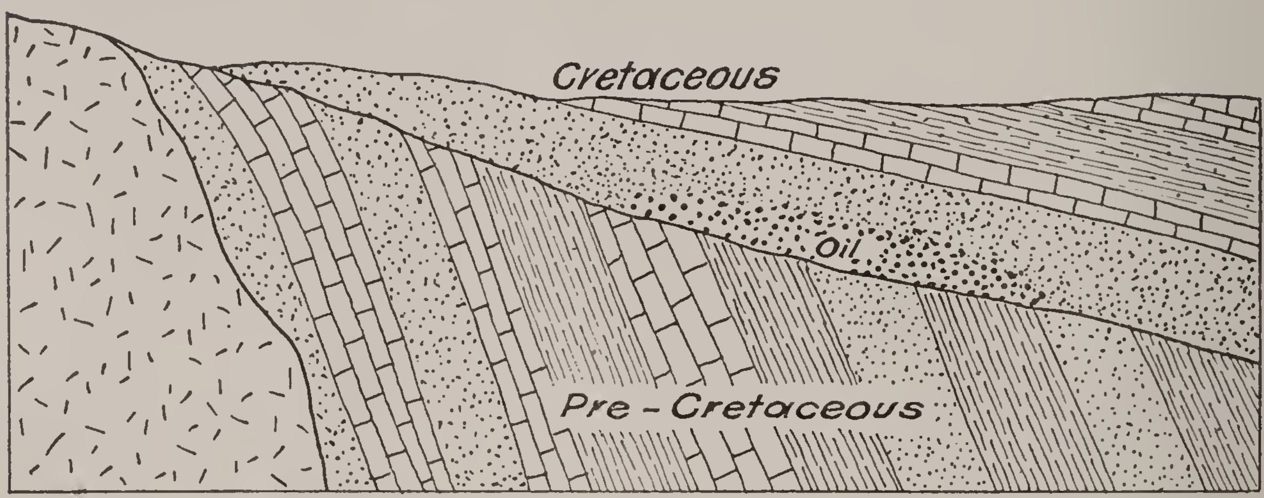


Fig. 20.—Diagram illustrating the geologic relations of the Cretaceous rocks and the occurrence of oil and gas in them.

the time of the formation of the Arbuckle Mountains. The Pennsylvanian rocks and the Simpson sandstone of the older formations are known to be oil-bearing as is shown by the asphalt deposits of the Arbuckle Mountains and of the Ardmore region. If the oil in these older tilted rocks had not escaped before the Trinity was deposited it would gradually work its way up out of these rocks into the Trinity. If the Trinity was very thin at that locality the oil would probably move on to the surface where the lighter constituents would escape and the heavier ones would be left in the form of asphalt. In this connection it may be said that the Trinity at the Madill pool is about 400 feet thick, while farther north where most of the asphalt deposits occur the sand is probably considerably thinner. The basal portion of the Trinity is usually coarser than the higher parts, and thus would afford a place for the accumulation of the oil and gas. If one of these coarser places should be overlaid by very fine or clayey sand the conditions would be very similar to those of sandstone lenses occurring in shale or to local thickening of sandstones which have been mentioned in the discussion of the conditions of accumulation. (See figure 9).

The presence of the pool at Madill is not indicated by any surface characteristics, and it is easily seen that accumulations of this kind would not be related to structure of the rocks at the surface or to any surface feature. There may be many such pools in the region, but the drill is the only method of prospecting for them. It seems reasonable to suppose that the chances for such accumulations would be greater back from the outcrop of the Trinity, provided that the rocks underlying the Trinity were equally petroliferous and that they were inclined in the same way that they are near the outcrop.

It is the writer's opinion, then, that other pools resembling the one found at Madill may be found in the southern parts of Marshall, Bryan, and Choctaw counties and possibly in southern Love and McCurtain counties, but the development is strictly a wild-catting proposition. There is no structure nor any surface indications to serve as guides in prospecting or in locating wells. In any case it is not probable that oil will be found in this region at a depth greater than 1,000 feet, since the Trinity should be passed through at that depth in any part of the area and at considerably less depths in a large part of it. The chances for encountering commercial bodies in the older rocks underlying the Trinity are almost zero, although such a thing is possible.

The Redbeds region.—The red color of the Redbeds is, in itself, almost conclusive proof that they do not contain any considerable quantity of oil or gas. It was noticed in the sections on origin and accumulation that oil and gas are almost certainly derived from organic matter and that they probably were formed in the rocks in which they now exist or at least have not moved through the rocks for great distances. The red color of the Redbeds is due to the presence of iron in the oxidized form, probably in a form identical with ordinary iron rust. In the presence of organic matter this red compound is changed chemically to dark-colored, usually black or green compounds. The prevailing red color of these rocks, then, is proof that there was not sufficient organic matter buried with them to effect this change. The quantity required to change the red iron compounds to dark colored compounds is very much less than would be required to give commercial deposits of oil or gas, so that it seems quite certain that there are no deposits of these substances which were formed in the red rocks themselves.

The Redbeds consist so largely of fine-grained clay-shale that it seems impossible for the oil and gas to have migrated for great distances through them, and any deposits which were formed in other rocks and which have moved into the Redbeds must be found very near the rocks from which they came. This reduces the portion of the Redbeds area which can be considered as at all promising for oil and gas to a narrow strip along the eastern margin where they are sufficiently thin for the underlying non-red rocks to be reached by the drill and a similar area around the Arbuckle and Wichita mountains and between these mountains and Red River. The probabilities are greater in this region than along the eastern margin, because in the southern area the older rocks below the Redbeds are steeply tilted and any oil or gas which was in these rocks has had an opportunity to work up and out into the basal layers of the Redbeds. The conditions in the Wichita Mountains are similar except that the Redbeds come up higher on the older rocks, so that the exposures of the latter are much less than in the Arbuckles. The thickness of the Redbeds increases very rapidly to the north from both groups of mountains, but between the mountains and south to Red River and beyond, the depth to the older rocks is nowhere over a few hundred feet. In this region there is also the possibility of determining the structure, while in the main portion of the area to the north of the mountains there seems to be no evidence of structure, so far as has yet been determined.

The development of the region in the vicinity of the mountains, while not extensive, is very promising. The

Wheeler field south of the Arbuckle Mountains, the Lawton and Gotebo fields near the Wichitas, and the Loco and Duncan (Arthur) fields between the two groups are described in the section on the oil and gas development outside the main fields. There has been no development worthy of note south of the mountains in Oklahoma, but the Petrolia, Electra, and Burkburnett fields in Texas, a short distance south of Red River, are strong indications that the region is at least worthy of investigation. The newspapers have just reported (July, 1913), the discovery of oil at Crete, Jackson County. If this report should be correct, the area in which oil may be expected is extended farther west than indicated by previous development. During the summer of 1912, the United States and Oklahoma Geological Surveys conducted co-operative work in southeastern Tillman and southern Cotton counties under the direction of M. J. Munn of the Federal Survey and the work is being continued the present year by C. H. Wegenmann, also of the United States Survey. Mr. Munn was successful in finding sufficient structure to indicate that the area is well worthy of prospecting. The full report on the work is still in press, but a preliminary press report was issued by the United States Survey shortly after the completion of the field work, the full text of which as far as it concerns the prospects in this particular region is given herewith.

The area covered by the reconnaissance embraces about 360 square miles in the southeastern corner of Tillman County and the southwestern part of Cotton County, Oklahoma. It includes the whole or parts of Tps. 3, 4 and 5 S., Rs. 12, 13, 14 and 15 W., and portions of Tps. 4 and 5 S., R. 11 W., and the east part of Tps. 4 and 5 S., R. 16 W.

Favorable Places for Test Wells.

In his preliminary statement to the Survey of the main results of the examination, Mr Munn reports that an anticline apears to cross Red River in or near the southwest quarter, Sec. 32, T. 5 S., R. 12 W. The dip within one and one-half miles along the western limb of this fold is probably between 50 and 75 feet (the character of the rocks exposed rendering an exact measurement impossible). The trend of this fold is uncertain but it may be stated that almost any portion of Sec. 32, T. 5 S., R. 12 W., appears favorable, structurally, for oil and gas. The northwest quarter of the section seems most favorable. If an oil and gas pool is present in this vicinity it very probably extends to adjacent portions of Sec. 33, 28, 29 and 31.

In T. 4 S., R. 12 W., some good exposures of Permian sandstone and clay-lime conglomerate suggest strongly that a structural "high" exists a short distance north of the town of Randlett. It is not possible at this time definitely to outline this anticline or structural dome, but it seems likely that the crest is situated somewhere in the SW. ¼ of sec. 21, the SE. ¼ of Sec. 20, the NE. ¼ of sec 29, or the NW. ¼ of sec. 28, T. 4 S.,, R. 12 W. The "high" may be a dome of small extent, or it may be a part of a fairly definite anticline trending eastward, leaving the township in either sec. 24 or 25. There may be a secondary structural dome in sec. 24, T. 4 S., R. 12 W., because the beds dip about 50 feet from the top of the large butte in the northeast quarter of this section; at a small butte about one mile north of it in sec. 13, and also at about the same rate towards the northeast. The structure of the rocks south of the large butte for almost two miles can not be determined. In the NW. ¼ sec. 26 the beds are several feet lower. The trend of this anticline is probably south 50° or 60° E. The position of this fold was not determined in T. 4 S., R. 11 W. It seems most likely to pass across some portion of sec. 32 and 33, but it is probably becoming lower and flatter toward the southeast. The shallow test well drilled in the southeast corner of sec. 30 probably lies half a mile south of the axis of this fold. This location seems on the whole a favorable one for testing, but a still better one would be about 1¼ miles northwest of it, as the rocks there are probably 30 feet higher structurally. If a test well is sunk near Randlett it should be located near the center of either sec. 21 or 27, T. 4 S., R. 12 W.

In T. 4 S., R. 13 W., the strata at the southwest corner of sec. 24 seem to be between 40 and 50 feet higher than they are in sec. 35 and 11. Other available data suggest that the high elongated hill in secs. 22, 23, 24, 25, 26 and 27, T. 4 S., R. 13 W., is in part structural and therefore somewhat more favorable for oil and gas than portions of the adjacent territory. There seems to be little preference in a location for a test here. Probably as good a place as any would be in the northeast quarter of sec. 26.

In a general way the northwestern part of T. 4 S., R. 13 W., would appear worth a trial for oil or gas if pools are found in other areas. Secs. 8, 9, 16, and 17 are probably somewhat more promising than the adjacent ones. A small round hill in the NW. ¼ sec. 16 is capped by a thick clay-lime conglomerate that is probably 40 feet higher at this place than at the northern edge of Devol, one mile to the southwest. It is also about 20 feet higher than at an exposure near the northeast corner of sec. 8, but its altitude at intervening points is not known. This clay-lime conglomerate bed dips about 15 feet in the first 1¼ miles to the north from the northwest corner of sec. 8, and from that point dips about 55 feet more in the next 1½ miles northward to the dry hole in the NW. ¼ sec. 28, T. 3 S., R. 13 W. It seems very probable that if this well had been located one mile farther to the southeast it would have been on the axis of the anticline which plunges steeply toward the north. So far as structure is concerned the location of this dry hole is very unfavorable, and it should not be considered a fair test for this vicinity. In fact, it is thought that test wells located in the SW. ¼ of sec. 33, or on, or near the high hill in the southwest corner of sec. 35, T. 3 S., R. 13 W.; in the NE. ¼ or the NW. ¼ of secs. 8 and 9 respectively, T. 4 S., R. 13 W., will perhaps, have as good chance of developing oil or gas as any part of this territory.

North of Deep Red Run rock exposures are meager. If a test well is contemplated in T. 3 S., R. 13 W., north of Deep Red Run it might as a venture be placed in the N. ½ of sec. 9 or adjacent territory to the northeast.

In Tps. 3 and 4, S., R. 14 W., the principal structural feature is a "high" vaguely outlined by exposures on Big Blue and Little Blue creeks and on streams flowing north into Deep Red Run. Spirit level lines to these outcrops show that from the divide between Red River and Deep Red Run the rocks dip fairly uniformly, but at a low angle to both of these streams. The exact position and character of this structural feature is not fully determined. It is probably a broad low irregular fold with a somewhat sinuous east-west trend and may be a continuation of the "high" already described in the northwest part of T. 4 S., R. 13. It seems to continue westward through portions of T. 4 S., R. 15 W. A test in the area east of Grandfield should be located either in the north tier of sections of T. 4 S., R. 14 W., or in the southern tier of T. 3 S., R. 14 W. Probably the central part of sec. 1, T. 4 S., R. 14 W. should receive slight preference.

When the field work was being done a derrick had been built in the southwest corner of sec. 9, T. 4 S., R. 14 W. about one mile southward from the station at Grandfield. This seems to be a fairly favorable location for a wildcat test, though the available data are too meager to admit of a more definite statement.

In T. 3 S., R. 14 northward from Deep Red Run the rocks rise very gently, but the exposures are so rare as to furnish no evidence of decided folds if they exist.

There is some good evidence that a small anticline crosses Big Blue Creek in the SE. ¼ of sec. 26, T. 4 S., R. 14 W., less than a mile above its mouth. The axis of this fold seems to trend almost east-west. A test in this vicinity should be located near the east-west line through the middle of secs. 26, 27, 28, and 29.

In T.. 4 S., R. 15 W., the beds appear to rise at a very small angle from the east, south, and north to a broad level area in secs. 7, 8, 9, 10, 11, 14, 15 and 16 in which very few exposures occur.

The structure of T. 3 S., R. 15 W. also is not definite. The most prominent feature is a gentle rise of the rocks toward the west and southwest, across the township.

A dry hole located in the NE. ¼ of sec. 9, less than a mile north of the station at Loveland, seems to be near the middle of a very broad flat syncline in which the rocks are practically level.

Work was done in the eastern parts only of Tps. 3, 4, and 5 S., 16 W. Few exposures are present in this territory and but little geologic information is available regarding the structure. The character of the topography suggests a general dip toward the west from east of the middle of T. 4, but this evidence taken alone is of very little value.

According to the present incomplete data it is suggested that the first wells in Tps. 3, 4, and 5 S., Rs. 15 and 16 W. should be located in some parts of the high, smooth prairie country south of the "Breaks" in T. 4 S., R. 15 W. Also it is suggested that any producer who may be inclined to wildcat in the Quanah district should locate on the old town site of Quanah or in the west half of sec. 31, T. 3 S., R. 15 W.

In offering these suggestions for the use of drillers in choosing locations for test wells ("wildcatting"), the geologists are assuming that the formations containing the oil-bearing sands in the Electra, Burkburnett and Petrolia fields of northern Texas underlie adjacent portions of Oklahoma. This assumption is warranted to some extent at least by the evident continuity of the outcropping beds from one district to the other. It has been assumed that the formations containing the oil sands in northern Texas also contain the same or similar oil-bearing beds in southern Oklahoma. It is quite certain that the general structural conditions are similar in the two areas, and on the whole there seems to be no reason, determinable in advance of drilling, why portions of southern Oklahoma do not contain pools of oil and gas of commercial size.

In considering the prospects for development in the Redbeds region one other factor should be taken into account. This is the expense of drilling. The returns when a strike of oil is made are so large that prospecting may be done when the chances are rather small if the cost of drilling is small. For instance, in the shallow field in northeastern Oklahoma the cost of sinking a well to the oil and gas-bearing horizon is usually less than $1,000. In the Redbeds away from the mountains the conditions are entirely different. The rocks are soft and cave so badly so that drilling is very difficult and expensive. The depth at which there is any hope at all of finding oil or gas is also great, 2,000 feet or more over most of the area, and the chances for finding anything at that depth very small on account of the absence of surface structure which would enable one to select the more probable localities for prospecting. The cost of sinking a well to a depth of 2,000 feet when most of the depth is through Redbeds will vary considerably, but $10,000 is a conservative estimate. The cost increases very rapidly with increasing depth and a well 3,000 feet deep probably cost $20,000 or more. Prospecting in this region is thus very expensive and in view of the small chance for any returns is scarcely to be considered a good business proposition.

Plate II.—Location of axes of folds in Southeastern Oklahoma.

VI.

HISTORY OF THE OIL AND GAS INDUSTRY IN OKLAHOMA

The Oklahoma oil fields are part of the Mid-Continent field which includes the eastern parts of Kansas and Oklahoma. Attempts to secure oil and gas were made in Kansas as early as 1860, but the methods used were not fitted to drill to sufficient depths and it was not until 1882 that commercial quantities of either oil or gas were found. In that year gas with a small supply of dark heavy oil was found at Paola and gas alone in Wyandotte County. The field at Paola is still furnishing some gas, but the wells in Wyandotte County failed after about 15 years. Active development began about 1890; the Neodesha field was opened in 1893, and in the same year a good gas well opened up the field at Iola. Drilling was commenced about the same time at Humboldt, Chanute, Cherryvale, Coffeyville and Independence; but it was not until about 1900 that the greatest development began in these localities.

For several years the portion of the Mid-Continent field in Kansas was much more important than that in Indian Territory, but after about 1904 the principal development was on the south side of the line and the Territory surpassed Kansas in output. Kansas reached its maximum output in 1907 when 41 millions of barrels were produced, and has declined rather rapidly since that time, decreasing about 1¼ million barrels for each of the last four years. Gas has been a more important product in Kansas than in Oklahoma and except in 1904 the value of the gas has been greater than that of the oil, reaching a maximum value of $8,293,846 in 1909, but declining to $4,854,534 in 1911.

The discovery of oil and gas in Kansas about 1882 excited the interest of the Five Civilized Tribes in Indian Territory, and in 1884 the Choctaw Council passed an act forming the Choctaw Oil and Refining Company. The Cherokees followed the example of the Choctaws almost immediately and passed a similar act. Both companies secured the co-operation of the Dr. H. W. Faucett of New York. A well was started in the Choctaw Nation on Clear Boggy Creek about 14 miles west of Atoka, and one in the Cherokee Nation, on Illinois River about 20 miles north of Tahlequah. The Cherokee Council of 1885 repealed the Charter of 1884 and operations on the well north of Tahlequah were stopped. The charter was re-instated in 1885, but financial support could not be obtained and the proposition was not carried further. Drilling continued at the Choctaw well until Dr. Faucett's death in 1888, when it had reached a depth of 1414 feet without encountering more than showings of oil and gas.

There was little further activity in Indian Territory until 1894, when the Cudahy Oil Company secured a blanket lease on the Creek Nation and had 2 wells drilled at Muskogee. Both showed good prospects, but there was no development until 1904, when title to the lands could be obtained.

The Cudahy Oil Company also secured leases on about 200,000 acres in the vicinity of Bartlesville and operations were started there. In 1896 the passage of the Curtis bill forced them to surrender all "unproved" lands, leaving them only the section on which Bartlesville now stands. Some development had been made at Chelsea prior to 1893 and the Cherokee Oil and Gas Company had a large acreage leased. The Curtis bill caused the surrender of these leases and little was done in the Cherokee Nation until 1904, when it became possible to get allottee's leases approved by the Department of the Interior.

Prior to 1904 tests had been made in the Osage Nation as early as 1896. At this time all the lands of the Nation were leased to Edwin B. Foster, who secured a 5-barrel well at a depth of 1,100 feet, 3 miles south of Chatauqua Springs, Kans. A well was drilled to a depth of 2,575 feet at Eufaula in the Choctaw Nation with good showings of oil and gas at three horizons. A well at Red Fork opened the Red Fork-Tulsa district in 1901.

The principal development in Oklahoma fields began in 1904 and in the following paragraphs brief accounts of the development in each year from that time to the present is given. The total production and value of the output is given in this connection, but the detailed statistics are reserved for another section.

During the first six months of 1904 practically all the activity in the Indian Territory was confined to the Osage Nation. The Indian Territory Oil and Illuminating Company had a blanket lease on all the Osage lands and sublet the lands to the actual operators. The first well in the Cleveland pool in Pawnee County, Okla. Terr., was in September and a great rush both to the Oklahoma lands and to the Osage lands across the river resulted. Some development was also carried on throughout the year in the vicinity of Muskogee, Chelsea, Red Fork, and Bartlesville. The townsite pool at Muskogee was developed during this year. Later in the year the Secretary of the Interior began to confirm leases in the Cherokee Nation. Drilling was immediately prosecuted with great activity, most of it being centered in the vicinity of Bartlesville, Chelsea and Alluwe, Lenapah, and Dewey. At the close of November Chelsea had about 96 producing wells; Red Fork, 50; Cleveland, 10; Muskogee, 35 or more; Bartlesville nearly 100; and other points in the Osage territory 75 or 80 more. The Prairie Oil and Gas Company was the principal purchaser of the product. The prices paid during the year varied from 31 cents for the heavy oils to 72 cents for the lighter oils. The production of Oklahoma and Indian Territories was 1,366,748 barrels, valued at approximately $1,325,750.

In 1905 there was no phenomenal new development, but the Shallow field was extended north to Coody's Bluff, making a proven length of from 15 to 18 miles; the Bartlesville-Dewey pool was actively developed, especially along the Cherokee-Osage line south from Pawhuska, to the northwest and west from Bartlesville, and to the northwest of Dewey, where a new pool was developed; the Cleveland field was actively developed and some wells were had in the vicinity of Pawhuska in the western part of the Osage Nation. The field near Wheeler in the southern part of the

State was discovered in 1905. Prices for oil were very low in 1905, the price paid for the lighter grades of oil being 50 to 53 cents.

In 1906 active development continued in the regions already opened, especially in the shallow Coody's Bluff field and in the Bartlesville area. The remarkable feature of the year was the opening of the Glenn pool, a few miles southeast of Red Fork, in the early part of the year. The first well was completed in December, 1905. By the end of 1906 a number of wells with an initial capacity of over 1,000 barrels had been drilled in and the limits of the pool had not been located. The total number of wells in the pool by the end of the year was about 110. Another remarkable pool was opened on sec. 27, east and a little south of Dewey and 4 miles east of Bartlesville. This area is only one mile across, but was developed very rapidly, and some wells of over 1,000 barrels capacity were brought in. The limits of the pool were soon defined, however, and the wells had settled down to about 300 barrels capacity by the end of the year. By the beginning of 1907 the field along the 96th meridian was pretty well outlined as extending from the Kansas line south almost to Tulsa with a width of up to 5 miles or more. Several 1,000 barrel wells were brought in during 1906, most of them on the Osage side of the line, but some on the Cherokee or eastern side. These wells held up better than most of those in other parts of the field. The Morris pool in southeastern Okmulgee County was opened by a well southeast of town in the summer of 1906. As at previous times, the Prairie Oil and Gas Company was the only important purchaser of the Oklahoma oils. The prices were very low. The average for the year was 47 cents for light oil and 31⅝ cents for heavy oil. Late in the year arrangements were made by two of the large interests of the Gulf coast, the Texas Company and the Gulf Pipe Line Company, to build pipe lines into the Oklahoma field and both lines were completed during the following year. As in 1905, the published statistics combine the production of Kansas and Oklahoma The production of both States was about 16,500,00 barrels and the value, $7,250,000. The total production in Oklahoma and Indian Territories for the year was in the neighborhood of 7,000,000 barrels and the value about $3,800,000. Neither the value nor the production can be stated accurately since the statistics for Kansas and Oklahoma were not kept separately.

In 1907 the Glenn pool continued its remarkable record of the previous year. At the beginning of 1907 this pool was showing a monthly production of 385,939 barrels. This increased rapidly until in the month of October it reached its maximum of 2,441,662 barrels. The production of the pool then began to decline and by the end of the year had declined to the rate of six months before. Considerable development was also made in the Morris pool. Several good wells were brought in, but the field proved to be rather spotted. In the Cherokee district the development in the shallow field continued and the production was maintained in spite of the fact that few new wells were brought in during the latter part of the year. The Dewey-Copan field was extended west by some wells of very large production. This extension was in the Osage lands. A good field was developed along Hogshooter Creek about 15 miles southeast of Bartlesville. The larger oil wells had a capacity of about 500 barrels per day and the gas wells from 5 to 15 million cubic feet per day. The Hogshooter field has since become more important on account of its gas than on account of its oil production. The prices for oil continued very low. There was very little variation through the year, the price for light oil ranging from 39 to 41 cents and for the heavy oils from 26 to 28 cents. The production for the year was 44,300,149 barrels with a value of $17,-824,342.

Development work in 1908 was steady and the production of Oklahoma showed some increase over that of 1907 although there were no remarkable new finds. The decrease in production of the Glenn pool was checked by the drilling of new wells, the cleaning out and shooting of old wells and the finding at widely separated points of a deeper productive sand. A new pool of exceptionally high grade oil was found at Muskogee. Very late in the year a 1,400 barrel well was completed in the Morris pool which led to considerable new drilling. Probably the principal development of the year was in the northern end of the shallow field (the Delaware-Childers pool). Production in the vicinity of Dewey and in the Osage generally declined. The price for light oil was uniformly 41 cents throughout the year and for heavy oil remained very nearly 32 cents. The production was 45,798,765 barrels, valued at $17,694,843.

In 1909 a strong effort was made by the Producers Association to curtail the production on account of the extremely low prices prevailing and there was only a slight increase over that of the previous year. The Glenn pool, and the Osage showed a slight decline. The only new pool of importance was the Preston pool 5 miles north of Okmulgee. A new pipe line, that of the Oklahoma Pipe Line Company to Baton Rouge, La., was assured. The price for light oil was 41 cents per barrel for the first half of the year and 35 cents the latter half. Heavy oil stood uniformly at 28 cents. The production was 47,859,218 barrels and valued at $17,428,990.

In 1910 there was a considerable increase in production over that of 1909. All the older fields were developed intensively and there was no marked decline in any of them. The principal new development was in Okmulgee County in the vicinity of Henryetta and in Osage County at Osage Junction, across the Arkansas from the Cleveland pool. Gas was discovered at Poteau in the extreme eastern part of the State and south of the developed territory. The prices paid for oil ranged from 35 to 42 cents per barrel for light oil and from 28 to 42 cents for heavy oil. During the last part of the year the price for all grades of oil was made uniform and this practice has since been continued. The new pipe line to Baton Rouge was completed, which assisted in bettering trade conditions. The production was 52,028,718 barrels, valued at $19,922,660.

Development in 1911 was considerably retarded by the prolonged drouth which hindered both drilling and manufacturing enterprises, but in spite of this there was an increase in the production over that of 1910. The principal factors of this increase in the production were the continued development of the pools near Osage Junction and in the Pawnee County pool and the increase in the Hogshooter field. The price of oil advanced from 44 to 50 cents per barrel and the rising prices had no small share in stimulating activity, so that the production was increased to 56,069,637 barrels, valued at $26,451,767.

For 1912 the most important feature of the industry was the increase in the price of oil, since this was mainly responsible for the increased activity throughout the field. During the year the price for oil increased from 50 to 83 cents per barrel. The operators responded actively to the increased prices for the product and drilling was prosecuted more rapidly than in any previous year. The old pools were extended and filled in and a great amount of wildcatting was done, much of which was successful in developing new territory. The most striking feature of the new development was the discovery of the Cushing pool in western Creek County. The first well was brought in during March and by the end of the year over 75 completions had been made with very few failures and over 100 rigs were centered in the field. The initial production of the wells was very high and the quality of the oil good. Other important developments were: the discovery of deeper sands in the Cleveland field, which had been producing from shallower sands for 8 years, the eastward extension of the Glenn pool with wells of 300 to 500 barrels initial capacity, the opening of the Adair pool west of Nowata, the continued development of the Ponca City field in Kay County to the west of the main field, and the pronounced activity in Okmulgee County, carrying the field to the southeast. More good gassers were brought in in the Poteau field which had been opened during the previous year and a new gas field opened in Coal County. The Wheeler field showed renewed activity as did the field at Gotebo. A good gas well was brought in near Duncan in Stephens County, and there was some development at Loco in the southeastern part of the same county. Some heavy oil was obtained in both localities. The State showed a decrease in production of about 4,000,000 barrels from that of 1911, the total production being 51,852,457 barrels. The average price was 67.4 cents, giving a total value of $34,957,612, an increase of $8,505,845 over 1911 in spite of the decrease in production.

In 1913, there has been no remarkable development, but all the older fields have shown steady activity and a healthy development. The fields near Duncan, Loco, and Lawton have attracted considerable attention and some of the larger companies have entered the fields. Oil as well as gas has been found in these fields. The price of oil has continued to rise until at the present time it stands at $1.03 per barrel. It is too early yet to make any predictions as to the production or value for the year, but the indications are that the loss in production of 1912 will be made up and that on account of the increased price of the product the value will be still greater than in 1912. So far (July) the pipe line runs for each month have shown an increase over the corresponding month in 1912.

The statistics of production for the different pools are given, so far as they are available, under the discussion of the pools. However, it seems best to give in this connection the three tables following, since they deal with the State as a whole and supplement the notes already made on the history of the field.

TABLE SHOWING PRODUCTION, VALUE, ETC., OF PETROLEUM IN OKLAHOMA, 1900-1912.

Year	Production barrels	Increase.	Percentage of increase	Value.	Rank.	
					Prod.	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

*Decrease. e Estimated.

TABLE SHOWING NUMBER OF WELLS COMPLETED IN OKLAHOMA, 1904-1912.

	1904	1905	1906	1907	1908	1909	1910	1911	1912
Completed	361	2510	2779	3956	2844	3279	3777	4087	5993
Oil	243	2059	2268	3490	2458	2742	3188	3294	4712
Gas	21	98	163	148	102	157	181	489	438
Dry	97	353	348	318	284	380	408	304	843

TABLE SHOWING TOTAL AND AVERAGE INITIAL PRODUCTION OF NEW WELLS IN OKLAHOMA, 1905-1912, IN BARRELS.

	Total initial production	Average initial production
1905	111,390	54.1
1906	161,286	71.1
1907	459,862	131.7
1908	214,152	87.1
1909	206,454	75.3
1910	226,638	71.1
1911	262,333	79.6
1912	228,886	48.6

VII.

DESCRIPTION OF THE MAIN OIL AND GAS FIELDS OF OKLAHOMA

The oil and gas fields of Oklahoma may be divided into the main field in the northeastern part of the State and the outlying areas in the other sections. The main oil and gas field may be subdivided into several districts as follows: Nowata district or shallow field, Bartlesville district, Sapulpa district, Tulsa district, Muskogee district, Okmulgee district, Osage district, Pawnee County or Cleveland district, Cushing district, and Kay County. Most of these districts are again subdivided into pools or fields. The location of the principal pools is shown on the development map (Pl. III). In the following sections each district is considered in turn and the pools contained in each are noted separately.

NOWATA DISTRICT.

The Nowata district includes Nowata County and the northern part of Rogers County. It is the portion of the Cherokee field known as the "Shallow Field" with the addition of the Adair pool west of Nowata. The district may be divided into the following pools: Coody's Bluff-Alluwe, Delaware-Childers, Nowata or Claggett, California Creek, and Adair.

Coody's Bluff-Alluwe pool.—The Coody's Bluff-Alluwe pool lies principally on the east side of the Verdigris River, extending from Spencer Creek west of Chelsea on the south, northward to the line between Tps. 26 and 27 North. The total length of the pool from north to south is about 18 miles. The greatest width is about the latitude of Alluwe Post Office, where it is about 5 miles, and the least width is about 2 miles in the vicinity of Coody's Bluff Postoffice.

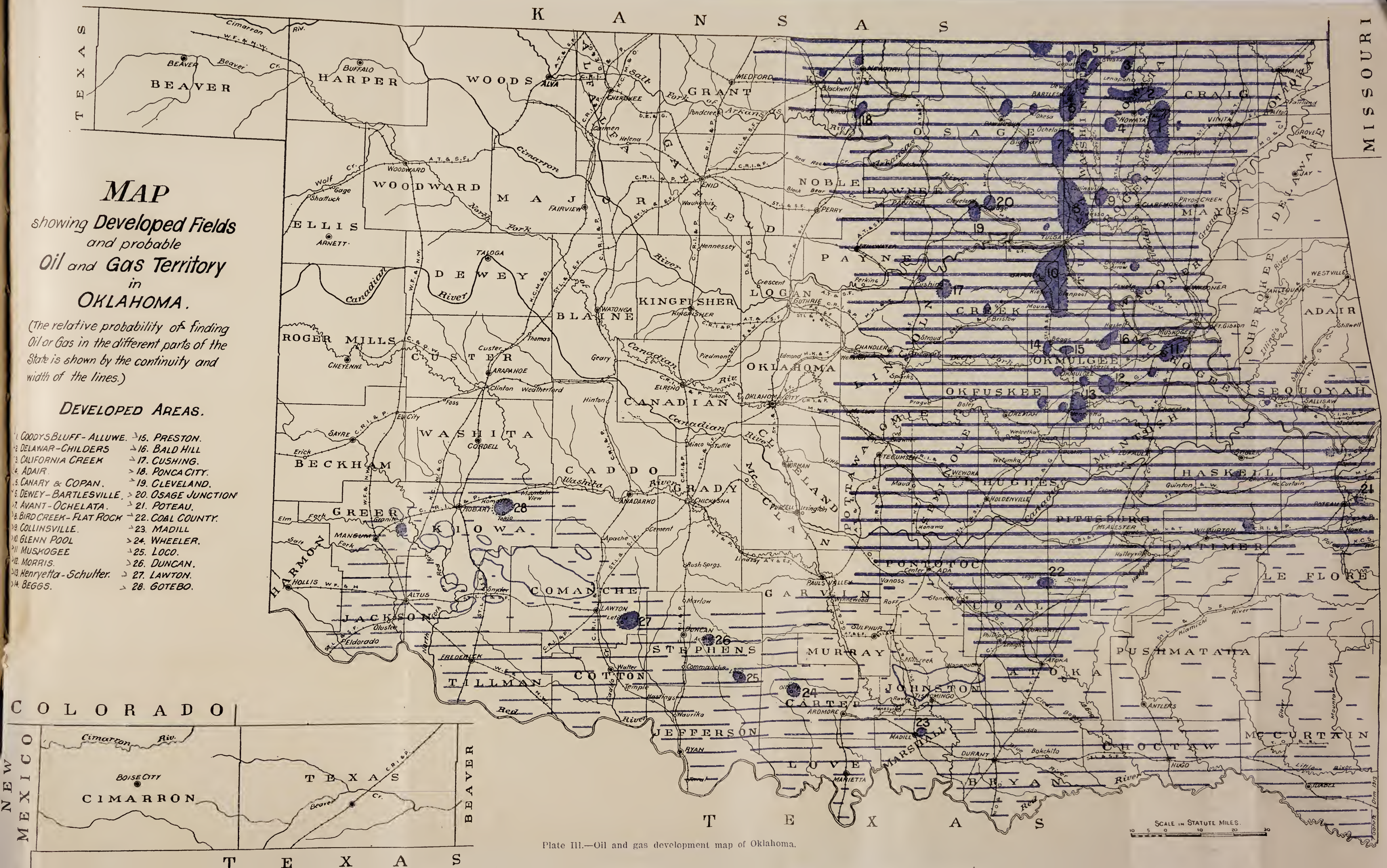


Plate III.—Oil and gas development map of Oklahoma.

The total area of the pool is about 75 square miles. The northern and southern portions of the pool are sometimes considered separately as the Coody's Bluff and Alluwe pools, the division line being drawn at Salt Creek, where there is a rather marked break in the development. The extreme southern part of the pool lies west of Chelsea and is sometimes known as the Chelsea pool. The northern line of the Coody's Bluff-Alluwe pool is merely one of convenience, as the development is practically continuous with that of the Delaware-Childers pool.

The development is fairly solid over the area as outlined, although there are occasional dry holes scattered through the field sometimes in close proximity to producing wells. There are also occasional gas wells throughout the field, but they are much more abundant along the east side, especially in the Coody's Bluff portion of the field where the gas development extends as much as 2 miles to the east of that of the oil. The state of development in the early part of 1913 is shown in figure 22.

The wells in the pool vary considerably in depth on account of the irregularities of the surface and on account of the fact that the axis of the pool is diagonal to the strike of the rocks, i. e., the wells in the northern part of the pool are started at a higher geological horizon than those at the southern end of the field and the depth to the producing sands is correspondingly greater. The depth of the wells in the Alluwe portion of the pool varies from about 350 to about 575 feet and in the Coody's Bluff portion from about 500 to about 750 feet. In general the shallower wells are to the south and east and the deeper ones to the north and west. The wells in the southern part of the pool are started near the upper surface of the Fort Scott (Oswego) formation and those in the northern part of the field, with few exceptions, start below the base of the Altamont.

Two producing sands are known in each portion of the pool. The upper is probably the Bartlesville sand and is found about 400 feet below the top of the Fort Scott or Oswego limestone. It furnishes by far the greater portion of the production. The lower sand in the southern portion of the pool is about 65 feet lower than the Bartlesville. The lower sand in the northern part is 200 feet below the Bartlesville. It is known as the Burgess sand. The Bartlesville sand varies from 20 to about 25 feet and the lower sand in the Alluwe portion of the field from 15 to 20 feet in thickness.

The oil from this field is usually a dark green or greenish black in color and its specific gravity is in the neighborhood of 35 degrees Baume. The base is of mixed paraffin and asphalt. The proportions of the two vary greatly but the paraffin usually predominates.

The following tables give the well record and the total and average initial production for this pool in 1905, 1906, and 1909, 1910, and 1911. For 1907 and 1908 the statistics for the whole shallow sand district are combined and those for the separate pools cannot be given. The southern part of the field is divided by the U. S. Geological Survey into the Chelsea and Alluwe pools.

TABLE SHOWING AVERAGE INITIAL CAPACITIES OF WELLS IN THE COODY'S BLUFF-ALLUWE-CHELSEA POOL.

Year	Coody's Bluff		Alluwe		Chelsea	
	Total	Average	Total	Average	Total	Average
1905	7,160	27.3	5,116	31.9	3,960	18.1
1906	22,845	44.8	13,749	33.6	6,828	19.6
1909	1,565	22.7	7,196	32.4	7,405	33.1
1910	1,625	24.3	4,465	25.5	7,920	24.6
1911	928	17.2	1,674	18.0	1,935	15.6

WELL RECORD OF THE COODY'S BLUFF-ALLUWE-CHELSEA POOL.

Year	Coody's Bluff				Alluwe				Chelsea—			
	Tot.	Oil	Dry	Gas	Tot.	Oil	Dry	Gas	Tot.	Oil	Dry	Gas
1905	280	262	8	10	165	160	4	1	244	218	20	6
1906	549	510	28	11	441	409	25	7	400	348	44	8
1909	72	69	3	.....	246	222	24	.....	262	224	38	.....
1910	73	67	6	.....	190	172	7	1	351	322	25	4
1911	56	54	2	.....	98	93	4	1	138	124	11	3

The following logs are typical of the Coody's Bluff-Alluwe pool:

For the Alluwe portion of the pool.

LOG OF WELL, MAJORA E. CAREY NO. 4, IN SEC. 19, T. 25 N., R. 17 E.

	Thickness, Feet.	Depth, Feet.
Soil	15	15
Gravel	5	20
Shale	15	35
Lime	30	65
Shale	5	70
Lime	8	78
Shale	20	98
Lime	5	103
Shale	17	120
Sand	12	132
Shale	246	378
Sand	11	389
Shale	20	409
Sand	6	415
Shale	37	452
Oil sand	12	464
Shale	5	469

For the Coody's Bluff portion of the pool.

LOG OF WELL, NO. 2, IN SEC. 13, T. 26 N., R. 16 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Soil	15	15	Dark shale	4	190
Gravel and sand	21	36	Lime	8	198
Light shale	84	120	Light shale	30	228
Lime	18	138	Lime	10	238
Dark shale	8	146	Light shale	262	500
Lime	40	186	Oil sand	31	531
			Dark shale	15	546

LOG OF WELL, HILL N. E. OF ALLISON PUMP HOUSE, SEC. 24, T. 26 N., R. 16 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Lime	35	35	Shale	30	318
Shale	175	210	Lime	10	328
Lime	20	230	Shale	242	570
Shale	8	238	Gas sand	20	590
Lime	50	288	Oil sand	20	610

Nowata pool.—The Nowata or Claggett pool is the western extension of the Coody's Bluff pool. It embraces about 5 square miles in Nowata County, in secs. 8, 9, 16, 17, 18, T. 26 N., R. 16 W. The depth of the wells varies from about 550 feet near Verdigris River on the eastern side of the field to about 725 to 750 feet on the western edge of the pool. The productive sand is the Bartlesville, which lies from 390 to 410 feet below the top of the Fort Scott or Oswego lime. The sand varies in thickness from 15 to 20 feet and is separated by 5 to 10 feet of sandy shale from a lower sand of about the same thickness. The wells in the eastern part of the pool are started about the top of the Big Lime (Altamont) and those in the western part about the horizon of the Lenapah limestone.

The Nowata pool is pretty well surrounded by dry holes which define the area of the pool. There are also dry holes scattered through the pool, but it is probable that many of these are not truly dry, but gave a smaller production when they were brought in than was expected, or than could be profitably handled at that time. The number of gas wells in the pool is small. Several occur on secs. 16 and 21 about 2½ miles northwest of Nowata and another group is about 5 miles southwest of the town. The town is supplied from this group of wells. Four or five more wells are scattered through the field. The supply is sufficient for local demands only.

The following logs are typical of the Nowata pool:

LOG OF WELL. CHAS. CLAGGETT NO. 1. IN SEC. 17, T. 26 N., R. 16 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Shale	40	40	Black shale	10	390
Lime	30	70	Lime	12	402
Black slate	15	85	Black shale	25	427
White slate	10	95	Lime	8	435
Lime, Pawnee	40	135	Black shale	30	465
Black shale	5	140	White shale	35	500
White shale	10	150	Sand	25	525
Sand	35	185	Black shale	30	555
Black shale	115	300	Shale, banded	161	716
Lime	30	330	Oil sand	20	736
Black shale	10	340	Slate	5	741
Lime	40	380	Sand	12	753
			Shale	5	758

LOG OF WELL, MARY METRER NO. 1, SEC. 19, T. 26 N., R. 11 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet,	Depth, Feet,
Surface and shale	85	85	Limestone	10	450
Limestone	25	110	Shale	30	480
Shale	25	135	Limestone	6	486
Limestone	40	175	Shale	19	505
Shale	200	375	Sand	35	540
Limestone	20	395	Shale	95	635
Shale	5	400	Sand	20	655
Limestone	35	435	Shale	96	751
Shale	5	440	Oil sand	21	772

The development of this pool is shown with that of the Alluwe-Coody's Bluff pool in figure 22. The following table gives the well record of the pool and the total and average initial production of the wells of the pool since 1909.

WELL RECORD OF NOWATA OR CLAGGETT POOL.

Year	Wells Completed				Initial Production	
	Total	Oil	Dry	Gas	Total	Average
1909	232	213	15	4	5620	26.4
1910	109	103	4	2	2150	20.9
1911	149	88	25	36	1202	13.7

Delaware-Childers pool.—This pool extends westward from the Childers Post Office to the northeastern corner of T. 27 N., R. 14 E. It is the westward extension of the northern end of Coody's Bluff pool and the general conditions are approximately the same. Along Verdigris River the width of the pool is a little over 2 miles, but north and west of Delaware it is less than one-half mile. The development is shown on the map (fig. 23). The logs of the dry wells show that the sand is present on both sides of the productive area, but it seems to be tight. The sand is apparently continuous with that of the Coody's Bluff-Alluwe field and is therefore thought to be the Bartlesville sand. The depth of the oil varies from 670 to about 900 feet. The initial production of the wells in this pool was high, many

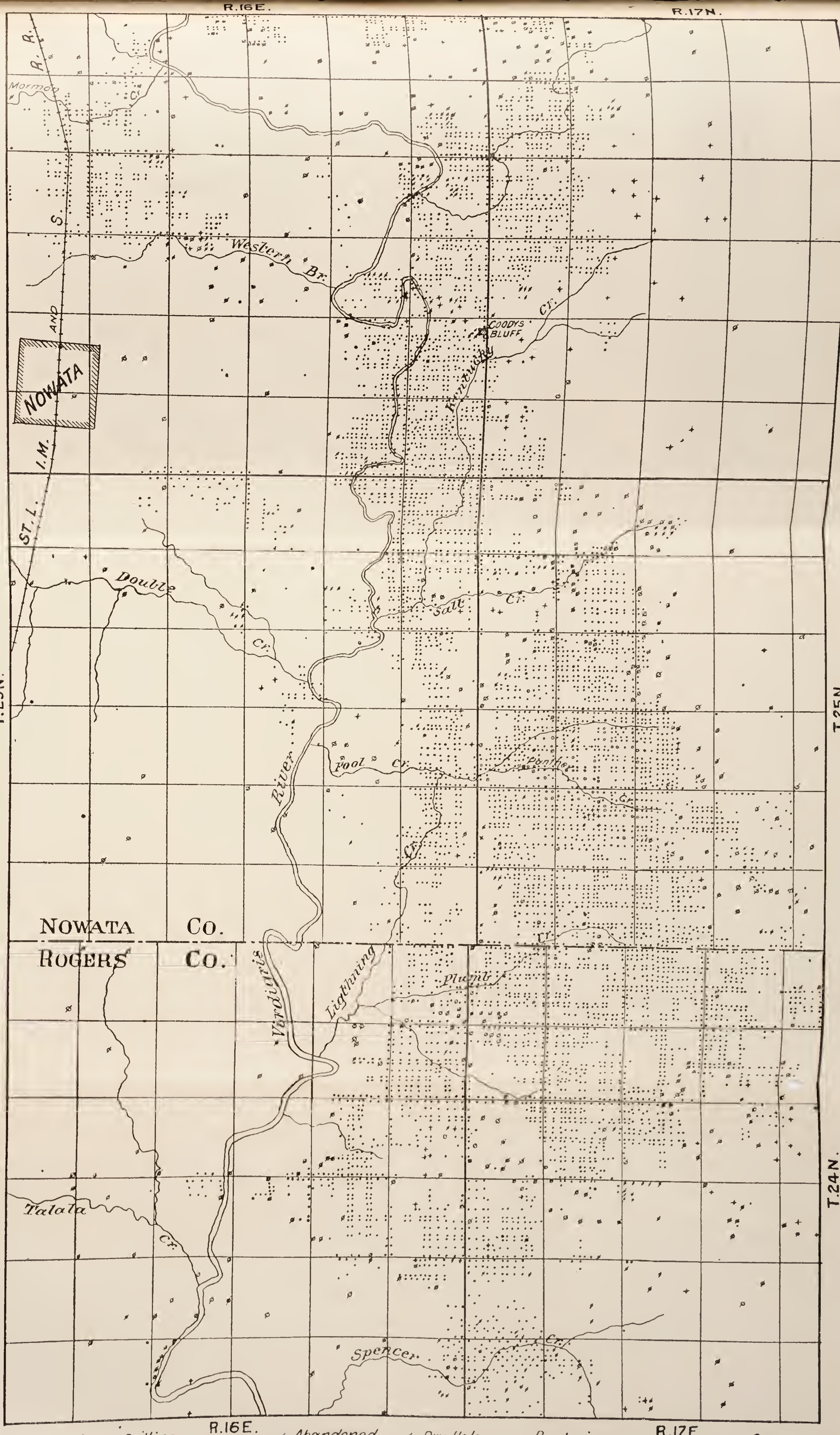


Fig. 22.—Development of the Coody's Bluff-Alluwe and Nowata pools.

of the wells starting off at better than 150 barrels. The pool was developed very rapidly and the decline in production was also rapid; most or all of the wells now producing are being pumped and some have been abandoned. The production now is small compared to the initial production. The oil is very similar in character to that of the Coody's Bluff pool.

The following log is typical of this pool:

LOG OF WELL, HENRY ROBBINS NO. 1, IN N. E. ¼ S. E. ½ SEC. 28, T. 27 N., R. 16 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Lime	25	25	Shale	12	368
Shale	55	80	Lime	12	380
Lime	50	130	Shale	30	410
Shale and sand	150	280	Lime	8	418
Lime	30	310	Shale	252	670
Shale	6	316	Gas sand	10	680
Lime	40	356	Oil sand	40	720

The well record of this pool and the initial production of the wells are shown in the following table:

WELL RECORD OF DELAWARE-CHILDERS POOL.

Year	Wells Completed				Initial Production	
	Total	Oil	Dry	Gas	Total	Average
1909	546	475	65	6	57,320	120.7
1910	757	673	80	4	59,185	88.0
1911	650	597	43	10	54,266	90.9

California Creek pool.—The California Creek field is located principally along the creek of that name in Tps. 28 and 29 N., R. 15 E., about 6 miles south of Coffeyville, Kans. The development has been comparatively recent, most of it having taken place in 1911 and 1912. The majority of the wells are gassers and the pool is much more important on account of its gas than on account of its oil production. In December, 1912, a total of 25 gas wells had been brought in which had an average capacity estimated at from about 3,500,000 to about 4,250,000 cubic feet per day, and an average initial pressure of 373 pounds to the square inch. A large part of the supply goes to Coffeyville, Kans., and some to other towns in Kansas through the lines of the Kansas Natural Gas Company. The general geologic conditions of this pool are the same

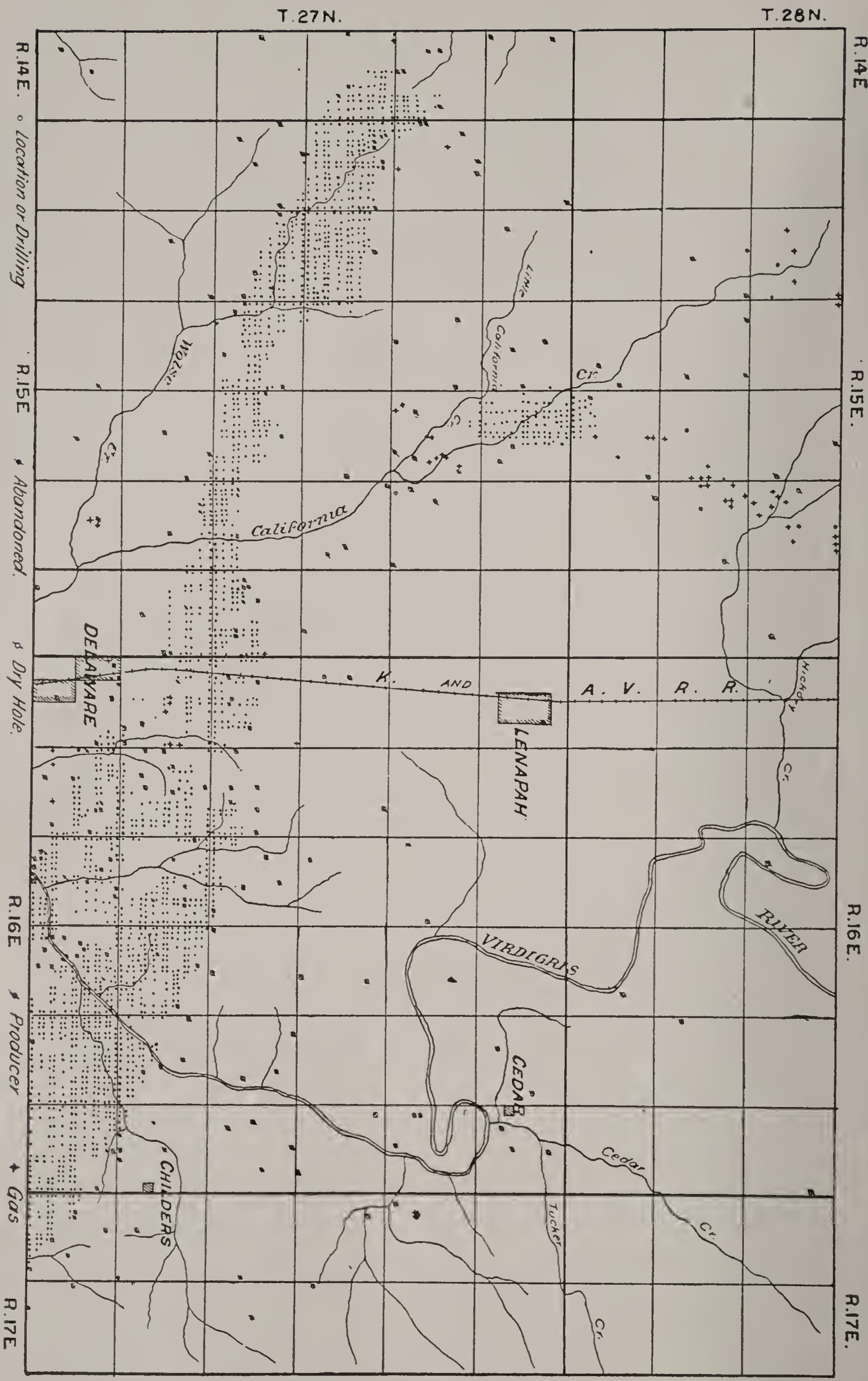


Fig. 23.—Development of the Delaware-Childers and California Creek pools.

as those of the Delaware-Childers pool. The following log is typical for the California Creek pool:

LOG OF WELL, DANIEL LOWERY, SEC. 26, T. 28 N., R. 15 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Soil	4	4	Shale	6	526
Clay	11	15	Lime	35	561
Shale	20	35	Shale	5	566
Sand	5	40	Lime	8	574
Light shale	40	80	Shale	25	599
Dark shale	100	180	Lime	8	607
Brown shale	50	230	Shale	100	707
Shale	70	300	Lime	5	712
Limestone	65	365	Light shale	40	752
Shale	20	385	Dark shale	100	852
Sand	30	415	Light shale	200	1052
Sand	5	420	Dark shale	59	1111
Shale	65	485	Miss. lime	9	1120
Lime	35	520			

The development of all except the extreme northern part of this pool is shown with that of the Delaware-Childers pool in figure 22.

Adair pool.—The Adair pool is located about 6 miles west of Nowata, principally in T. 26 N., R. 15 E. While it lies in the Nowata district as defined in this book, it is more closely related geologically to the Hogshooter and other pools of the Bartlesville district than to the shallow pools east and north of Nowata. The wells start about the top of the Coffeyville formation and encounter the Fort Scott (Oswego) lime at about 625 feet and the top of the Bartlesville sand about 400 feet lower. The thickness of the Bartlesville sand is reported as being 34 feet. The Adair pool is one of the recent developments of the Oklahoma field. It was discovered in October, 1911, and its development has been very rapid. Recent work shows a trend to the south into the valley of Purgatory Creek. The development of the pool is shown with that of the Hogshooter pool in figure 27.

BARTLESVILLE DISTRICT.

The Bartlesville district lies to the west of the Nowata district and includes all of Washington County and a narrow strip along the east side of Osage County. For consideration here the district is divided into the following pools: Canary, Copan, Wann, Dewey-Bartlesville, and Hogshooter. In general, the oil and gas are found in the same sands as in the Nowata district, but on account of the prevailing westerly dip, they occur at considerably greater depths, usually over 1,000 feet. On this account this district has usually been known as the Cherokee deep-sand field in distinction from the shallow-sand field to the east.

Canary pool.—The Canary pool lies in the extreme northeastern part of Washington County in T. 29 N., Rs. 13 and 14 E. The pool embraces an area of about 10 square miles and has its long axis in a northeast-southwest direction.

The productive oil horizon in the Canary pool is reached at depths of from 1,175 to 1,200 feet, with the greatest depth in the southwestern part of the field. The wells start in the shales of the Wilson formation of Kansas. The productive oil sand is the Bartlesville, which also furnishes some gas. Gas is also found in the Mississippi gas sand. The Bartlesville is unusually thick in this pool. The majority of the logs show thicknesses of from 40 to 60 feet and some of them as much as 110 feet. It is probable that when only 40 feet or less is shown in the log that the sand was not drilled through. A large number of wells produce both oil and gas, in which case the gas comes from the upper portion of the sand and the oil from the lower portion. There are also several gas wells scattered through the northeastern part of the pool, while the southwestern part is almost strictly a gas field. The whole pool is remarkably free from dry holes.

The Canary is probably considered as a part of the Copan pool in the published statistics of the United States Geological Survey. For the Copan pool the average initial production is given at 54.4 barrels in 1909 and 33.7 barrels in 1910. These figures are probably fairly accurate for the Canary pool.

The gas field of this pool is continuous with the pool of Caney, Kans. The gas is obtained in part from the Bartlesville sand and in part from the Mississippi gas sand. The average initial capacity of the wells was determined as 31,570,000 cubic feet per day and the average pressure was 440 pounds per square inch. The demands made on the field were very heavy and the wells deteriorated rapidly. In September, 1911, the capacity was determined as 916,000 cubic feet and the pressure as 18 pounds. Measures are being taken to revivify the wells by pumping off the water and also by drilling deeper into the sand in the wells in which it was not drilled through when they were brought in.

The development of the Canary pool is shown in figure 24.

The following log is typical of the Canary oil and gas field.

LOG OF WELL, EMMA WELCH NO. 2, SEC. 18, T. 29 N., R. 14 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Big lime	65	670	Gas sand	20	1241
Oswego lime	90	870	Oil sand	41	1309

The well record and statistics of initial production of the oil wells for this pool are included in the Copan pool.

Copan pool.—The Copan pool extends from northeast to southwest across T. 28 N., R. 13 E. It occupies an area of about 8 square miles and is practically continuous with the Canary pool on the north and with the Bartlesville-Dewey pool on the south. Some development in the southeast part of T. 28 N., R. 12 E. extends the development into Osage County and may be considered a part of the Copan pool. The pool is primarily an oil producer, although there are a few scattered gas wells.

The sands found are the same as in the Canary pool, the Bartlesville and the Mississippi gas sand, and in addition a shallow sand which was overlooked in the early development. The Bartlesville is found at from 1,300 to 1,450 feet below the surface and about 350 feet below the top of the Fort Scott (Oswego) lime. It is about 29 feet thick. The Mississippi sand lies about 200 feet below the Bartlesville and is about 25 feet thick. The shallow sand lies about 700 or 800 feet below the surface and is probably the sandstone in the upper part of the Labette shale.

The average initial production of the oil wells drilled in the Copan (probably including the Canary and Wann pools) in 1909 was 54.4 barrels and in 1910 was 33.7 barrels.

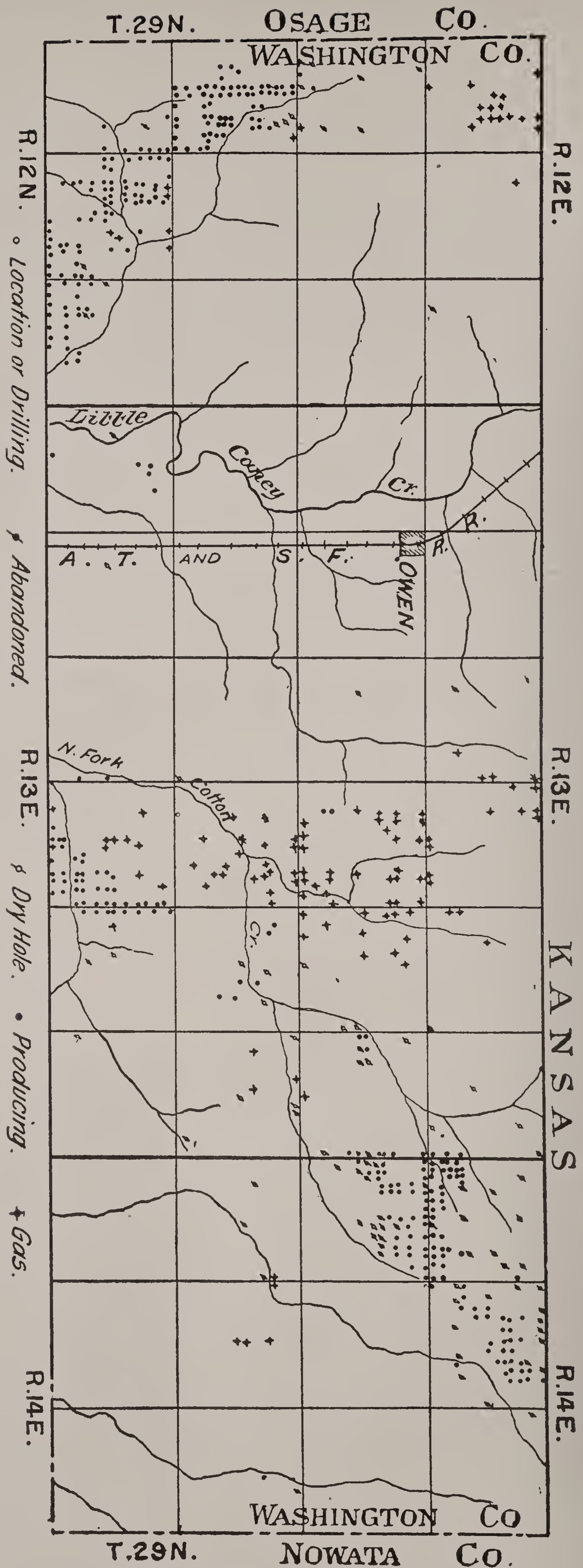


Fig. 24.—Development of the Canary pool.

The development of the pool is shown in figure 25.

The following logs are typical of the Copan pool:

LOG OF WELL, JANE HILL NO. 2, SEC. 35, T. 29 N., R. 13 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Little lime (Lenepah)	20	565	Oswego lime	80	990
Big lime	90	780	Gas sand	20	1265
			Oil sand	33	1309

LOG OF WELL, WILLIAM MILLER NO. 6, NE. ¼, SEC. 1, T. 28 N., R. 13 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Soil and clay	20	20	Sand and shale	50	420
Limestone	5	25	Big lime	315	735
Sand, soft	40	65	Shale	65	800
Shale	95	160	Limestone	35	835
Sand, soft	40	200	Limestone	5	840
Shale	50	250	Shale	110	950
Limestone	20	270	Oswego lime	80	1030
Shale	100	370	First show of oil.....		1331

Wann pool.—This pool is located to the east of the Copan pool in the west part of T. 28 N., R. 14 E. The development consists of a group of wells from 1 to 2 miles west of Wann and another group about 4 miles southwest of Wann. The general conditions of the pool are similar to those of the Copan pool. The development is shown together with that of the Copan and the northern part of the Bartlesville-Dewey pools in figure 25.

The well record of the Copan (including Canary and Wann) pool is given in the following table:

WELL RECORD OF THE COPAN POOL.

Year	Wells Completed				Initial Production	
	Total	Oil	Dry	Gas	Total	Average
1909	95	43	17	35	2340	54.4
1910	208	121	22	65	4082	33.7
1911	282	216	45	21	5890	27.3

Dewey-Bartlesville pool.—The Dewey-Bartlesville pool occupies a large area extending from the north line of T. 27 N., on the north to the south line of T. 26 N., on the south and from the eastern line of Washington County west across the country and from 1 to 3 miles into Osage County. There are many undeveloped spots in this area, but except along the eastern line of Washington County there are very few sections that do not have some producing wells. The portion of the pool north from Bartlesville is divided into two fairly distinct divisions by a belt along the Missouri, Kansas & Texas

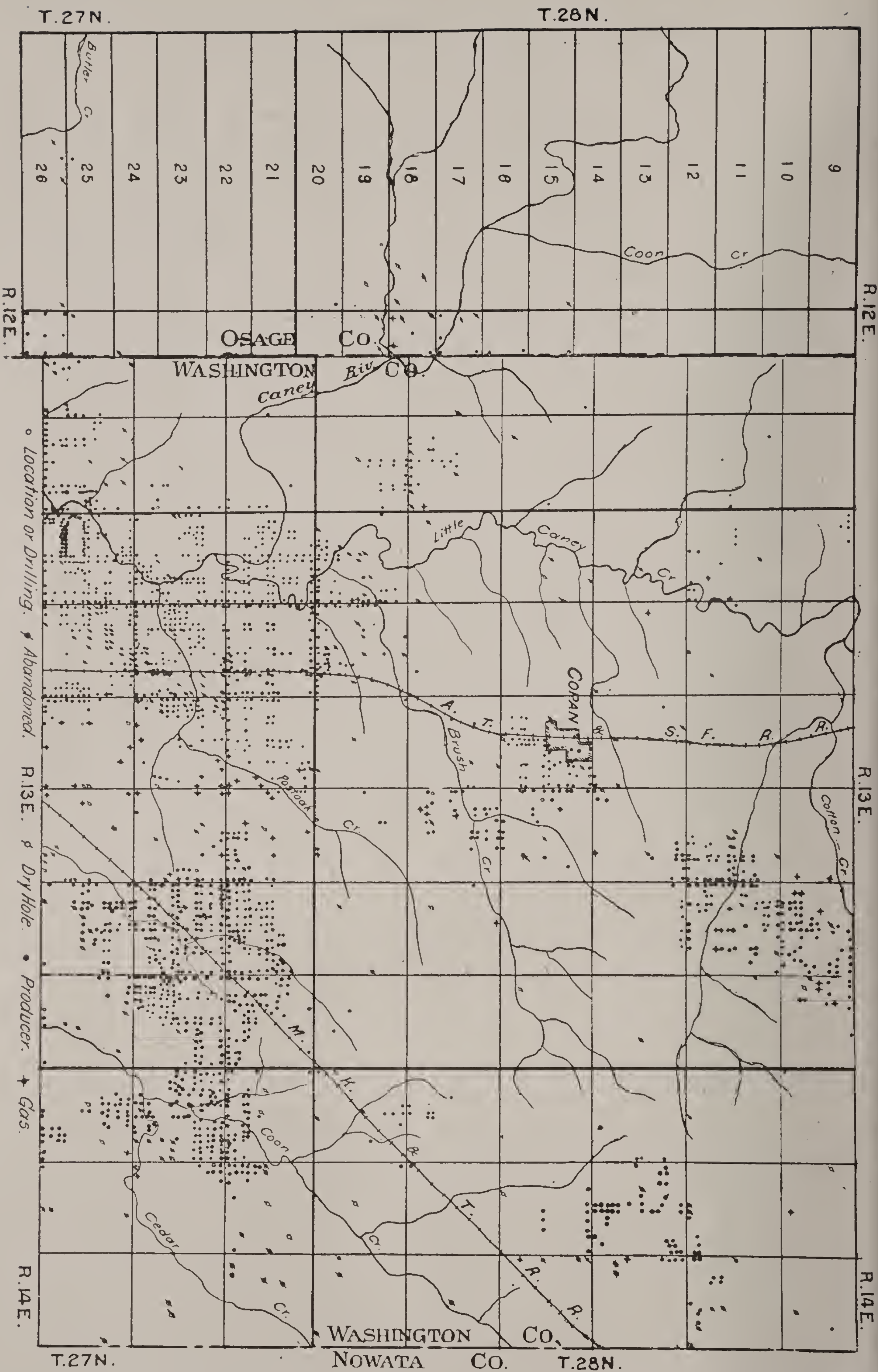


Fig. 25.—Development of the Copan, Wann, and north part of the Dewey-Bartlesville pools.

Railway, which has several dry wells. To the north the pool is practically continuous with the Copan pool, to the southeast with the Hogshooter pool and to the southwest with the Ochelata-Avant development. The division into separate pools is thus largely one of convenience, but the lines of separation are drawn at more or less pronounced breaks in the development.

Four sands have proven productive of oil or gas or both in the Dewey-Bartlesville pool. The shallowest is found about 525 feet below the surface and about 125 feet above the top of the Big Lime. It is known as the McEwin sand and is about 30 feet thick, medium-grained and generally light in color. It is probably a lens in the Nowata shale. In some of the wells of the northern part of the pool a sand known as the Peru sand has proven productive of oil. This sand is about 20 feet thick and lies just below the Big Lime. Neither of these shallow sands has proven of great importance and in the early development were usually ignored in the effort to reach the deeper and more productive sands. Some fairly good wells have been brought in from both sands, however, and it is probable that as the deep sands are exhausted these shallow sands will prove worthy of development in view of the high price paid for oil in comparison to the price in the early days of the pool.

The Bartlesville is by far the most important oil-producing sand of the pool. It lies between 1,200 and 1,350 feet below the surface and its top is about 350 feet below that of the Fort Scott (Oswego) limestone. The sand varies in thickness from 25 to 40 feet with some logs showing up to 60 feet. In character the sand is coarse, and light to brownish in color. The gas is usually present in the upper part of the sand.

The Burgess sand is the most important gas sand of the pool. It lies a short distance above the Mississippi lime and about 150 feet below the Bartlesville sand. The sand seems to be persistent throughout most of the pool.

The Dewey-Bartlesville pool was one of the first developed in Oklahoma and has been a great producer ever since. It is now undoubtedly past its prime, but the intensive development of the pool and the working of the shallow sands will undoubtedly prolong the life of the pool for years to come.

The gas wells of this pool occur principally in the vicinity of Bartlesville and in a belt extending to the east and connecting with the Hogshooter pool. There are also several gassers in a belt extending north and south through Dewey. The initial capacity of several wells in this and the Hogshooter pool was determined as 15,850,000 cubic feet per day and the average pressure as 464 pounds. In September, 1911, the average pressure was 219 pounds and the average capacity was 9,283,000 cubic feet. The wells have been drawn on for practically their full capacity and in view of this fact are holding up remarkably well. Many of them, however, are beginning to take water.

The development of the greater portion of the Dewey-Bartlesville pool is shown in figure 26 and that of the northern part of the pool in figure 25 with that of the Copan and Wann pools.

The following logs are typical of the pool:

LOG OF WELL, ALBERT WHITETURKEY NO. 1, SEC. 18, T. 26 N., R. 13 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet	Depth, Feet.
Shale	84	84	Oswego lime	73	873
Lime (Dewey)	30	114	Black slate	21	893
Sand and shale with limestone	346	460	Oil sand	19	913
Lime (Lenapah)	30	490	Sand and shale	245	1158
Sand and shale	104	594	Gas sand	7	1165
Big lime	70	664	Shale	30	1195
Sand and shale	136	800	Gas sand	85	1280
			Oil sand	30	1310

LOG OF WELL, MINNIE OSAGE NO. 1, SEC. 9, T. 26 N., R. 13 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Clay	30	30	Slate	15	875
Lime (Dewey)	30	60	Oswego lime	90	965
Slate	180	240	Slate	50	1015
Sand	25	265	Sand	25	1040
Slate	235	500	Slate	252	1292
Lime (Lenapah)	40	540	Bartlesville sand	3	1295
Slate	130	670	Slate	80	1375
Big lime	60	730	Lime	5	1380
Slate	95	825	Slate	92	1472
Sand	35	860	Sand	3	1475
			Mississippi lime	at	1475

The well record and the initial production of the wells in the years for which statistics are available are shown in the following table:

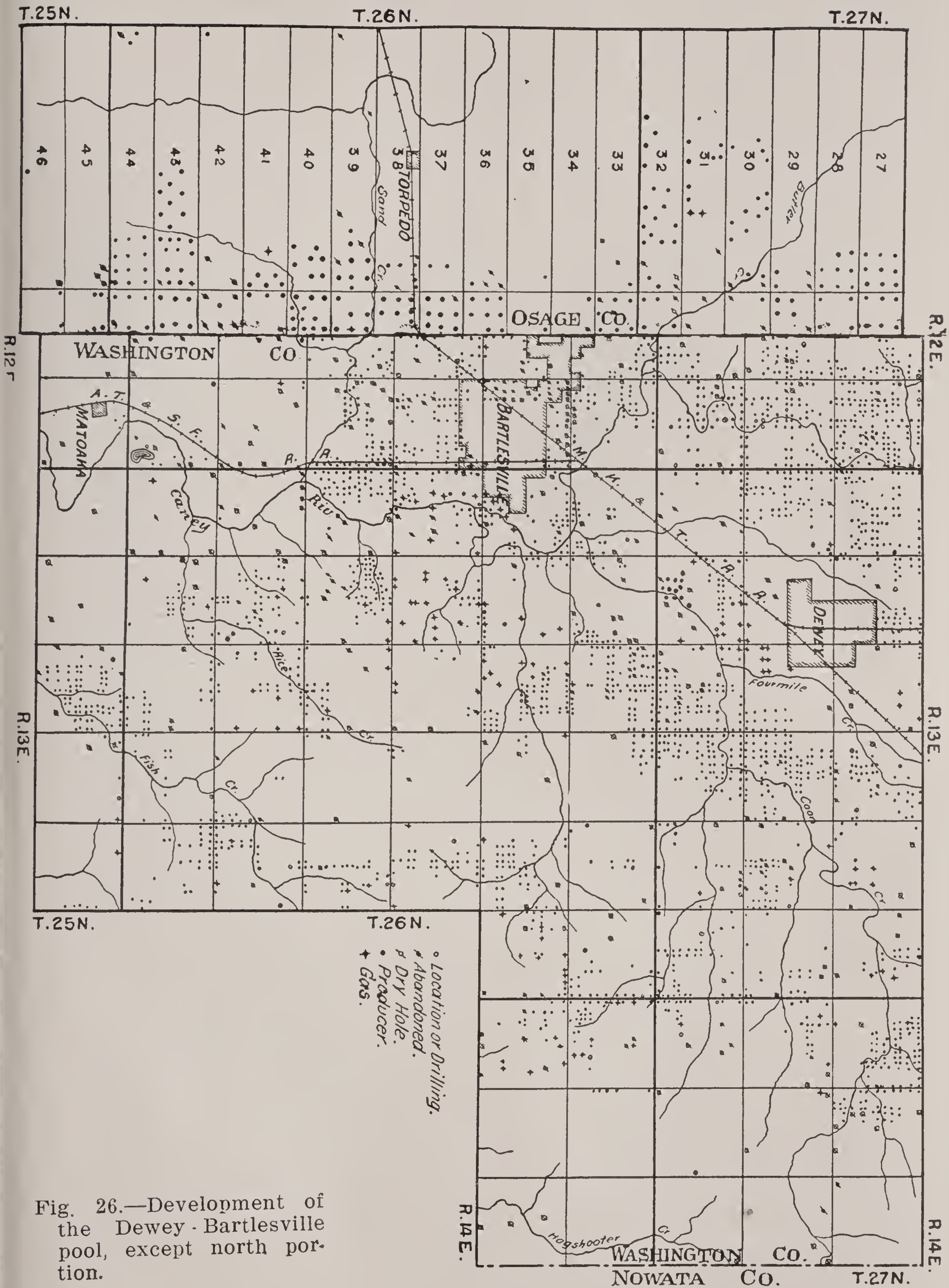


Fig. 26.—Development of the Dewey - Bartlesville pool, except north portion.

WELL RECORD OF THE DEWEY-BARTLESVILLE POOL.

Year	Wells Completed				Initial Production	
	Total	Oil	Dry	Gas	Total	Average
1906	790	606	123	61	....	....
1909	254	238	11	5	11,475	42.2
1910	251	232	11	8	10,196	43.9
1911	188	165	15	8	4,955	30.2

Hogshooter pool.—The Hogshooter pool includes a strip on both sides of Hogshooter Creek in the southeastern part of Washington County. The pool is about 12 miles long from north to south and from a fraction of a mile to about 4 miles in width. Only the northwestern part of the pool is oil producing, the larger portion of the pool constituting one of the greatest gas fields in the State. The pool is practically continuous with the Dewey-Bartlesville pool on the north and the general conditions are the same as for that pool and the Copan pool.

There are several productive sands. The highest is about 40 feet below the Big lime and is about 40 feet thick. The Bixler sand is just below the Oswego lime and varies from 5 to 50 feet in thickness. Neither of these sands has proven of much importance, although some oil has been obtained from both. The Peru (?) sand is about 200 feet below the top of the Fort Scott (Oswego) lime. The thickness shown in the logs is usually 30 to 40 feet, although as little as 10 feet is shown in some logs. The Bartlesville sand lies about 200 feet below the Peru sand or about 400 feet below the Oswego lime. As in the other pools of the district this is the most important sand. The thickness is usually shown as 30 feet, but there is much variation in the logs. The Mississippi sand is reached by only a few of the wells. It produces principally gas.

The condition of the gas field has already been considered in connection with the Bartlesville field. Practically all the large gas companies have lines into the field and the wells are failing rather rapidly under the demands made upon them. The gas is piped to Bartlesville, Dewey, and Miami, Okla., for use in the smelters, cement plant, and mining camp, and to the principal cities in southeastern Kansas and to Joplin, St. Joseph, and Kansas City, Mo.

The development of the Hogshooter pool is shown with that of the Adair pool of the Nowata district in figure 27.

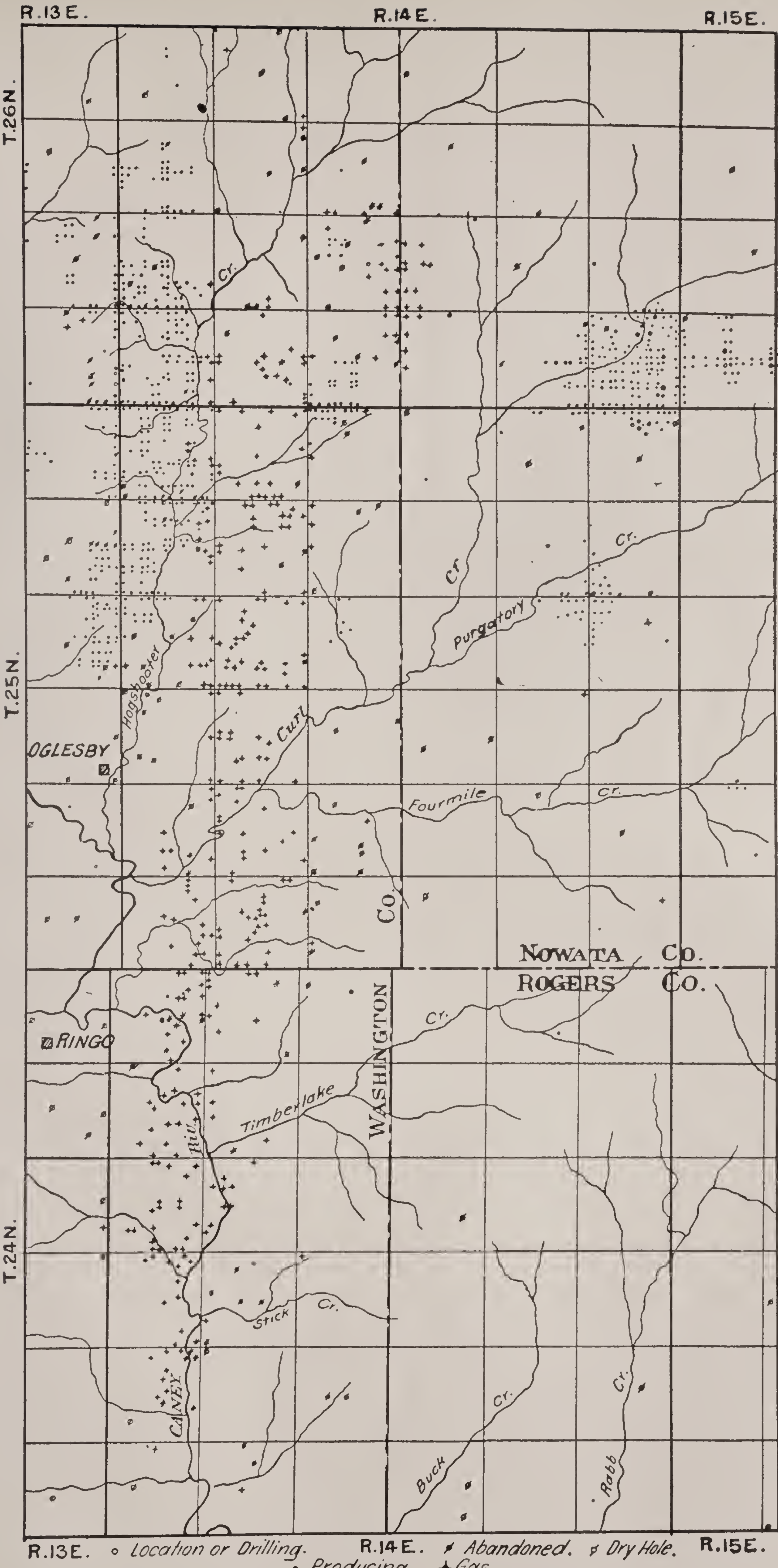


Fig. 27.—Development of the Hogshooter and Adair pools.

The following log is typical of the Hogshooter pool:

LOG OF WELL, JOHN LOWREY, JR., NO. 2, SEC. 6, T. 25 N., R. 14 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth. Feet.
Clay	40	40	Lime	35	495
Gravel	4	44	Shale	153	648
Shale	46	90	Lime	26	674
Sand	10	100	Shale	5	679
Shale	108	208	Lime	32	711
Sand	12	220	Shale	4	715
Shale	80	300	Lime	8	723
Lime	8	308	Sand	40	763
Shale	112	420	Shale	278	1041
Lime	28	448	Oil sand	21	1062
Shale	12	460	Shale	17	1079

The well record and the initial production of the oil wells of the pool are shown in the following table:

WELL RECORD OF THE HOGSHOOTER POOL.

Year	Wells Completed				Initial Production	
	Total	Oil	Dry	Gas	Total	Average
1909	107	71	12	24	3750	50.0
1910	155	109	8	38	5115	46.9
1911	339	192	31	116	8795	45.8

THE TULSA DISTRICT.

The Tulsa district includes the portion of Tulsa County north and east of Arkansas River and a small area in western Rogers County southeast of Collinsville. By far the greater part of the development is included in a district about 5 miles wide extending from Skiatook on the north to Tulsa on the south, a distance of about 13 miles. This district is usually divided into separate pools, the Skiatook, Bird Creek, Turley and Flat Rock, but, since the conditions are so similar in all of them, these pools are considered together as the Bird Creek-Flat Rock pool in this book. Besides the Bird Creek-Flat Rock pool the other important pool of the district is the Collinsville-Owasso gas pool which lies in Tulsa and Rogers counties southwest of Collinsville and northeast of Owasso. There are also a considerable number of gas wells in a belt extending southwest from Dawson to the east of Tulsa and in another belt extending west from Tulsa to Sand Springs.

Bird Creek-Flat Rock pool.—The Bird Creek-Flat Rock pool lies between Tulsa and Skiatook. Bird Creek flows from north to south through the pool and gives it its name. The north end of the pool is often known as the Skiatook pool and the south part is known as the Flat Rock pool from the development along the creek of that name. The development in a northeast-southwest belt passing through the village of Turley is sometimes distinguished as the Turley pool. The geologic conditions are practically the same as for the pools of the Nowata and Bartlesville districts. The wells are started very near the horizon of the limestone which has usually been called the Lenapah, but which has been found to be about 100 feet higher in the section than that limestone. The wells are thus started at the same horizon as those of the Red Fork and Glenn pools in the Sapulpa district to the south and a little lower than those of the Dewey-Bartlesville pools in the Bartlesville district to the north. The productive sands are encountered at a depth of about 1,000 to 1,200 feet. The number of logs available for study is too small to give any generalization as to number and thickness of productive sands, but from the geology of the region they should be about the same as in the Dewey-Bartlesville pool. The Bartlesville sand is the principal producer and is found at a depth of very nearly 1,200 feet.

The followings logs are believed to give a fairly accurate idea of the rocks encountered in drilling:

LOG OF WELL, VIOLA B. THOMAS NO. 1, SEC. 7, T. 20 N., R. 13 E.

	Thickness, Feet.	Depth, Feet.
Soil	20	20
Slate, white	25	45
Shells	5	50
Slate, white	50	100
Slate, blue	60	160
Coal	6	169
Mud	31	200
Slate	50	250
Slate, brown	45	295
Shells	5	300
Lime, white	25	325
Lime	110	435
Sand	15	450
Shale	10	460
Sand and shells	15	475
Shale	75	650
Lime	35	685
Shale	80	765
Lime, gas	10	775
Sand and shells	50	825
Sand, water	75	900
Sand and shells	90	990
Shells	5	995
Slate, black	50	1045
Lime	10	1055
Slate, black	30	1085
Shells	5	1090
Shale	35	1125
Lime	25	1150
Slate, black	40	1190
Sand, water	70	1260
Lime	40	1300
Sand, water	30	1330
Slate	15	1345
Slate, black	20	1365
Lime, gray	10	1375
Sand (Burgess)	10	1385
Sand, water	10	1395
Sand, black, water	10	1405
Slate	110	1515
Sand and lime	5	1520

LOG OF WELL, SEC. 28, T. 21 N., R. 13 E.

	Thickness, Feet.	Depth, Feet.
Soil	14	14
Lime, gritty	25	39
Shale	231	270
Lime (big)	130	400
Shale	167	567
Lime (Oswego)	48	615
Shale	55	670
Lime	15	685
Shale	211	896
Lime	10	906
Shale	152	1058
Sand, gas	78	1136
Sand, oil	23	1159

The Bird Creek-Flat Rock pool was one of the earlier developments in the Cherokee Nation and has been productive of many large wells. The limits of the separate pools comprising the large pool have been well defined for some time and the development has been intensive rather than extensive. The present condition of the development is shown in figure 28.

The well record and initial production of the wells of this pool in the years for which statistics are available are as follows:

WELL RECORD OF THE BIRD CREEK-FLAT ROCK POOL.

	Bird Creek						Flat Rock					
	Wells Completed				In. Prod.		Wells Completed				In. Prod.	
Year	Total	Oil	Dry	Gas	Total	Av.	Tot	Oil	Dry	Gas	Total	Av.
1909	101	78	17	6	3,595	46.1	95	89	5	1	12,970	145.7
1910	188	165	20	3	9,510	57.6	....	....	.....	.....	....	.....
1911	265	233	23	9	10,495	45.0	....	....	.....	.....	....	.....

Collinsville pool.—The Collinsville pool lies to the east of Bird Creek pool, along the line between Tulsa and Rogers counties. The general conditions are the same as for the former pool except that the wells start in the section a short distance above the Big Lime or Oolagah formation. Some oil is found, but the pool is far more important as a gas than as an oil producer.

The gas wells are of large capacity, but usually not so large as those of the Hogshooter pool. A good share of the product is utilized by the large zinc smelters recently erected at Collinsville and by the brick plant there. The development is shown in figure 29.

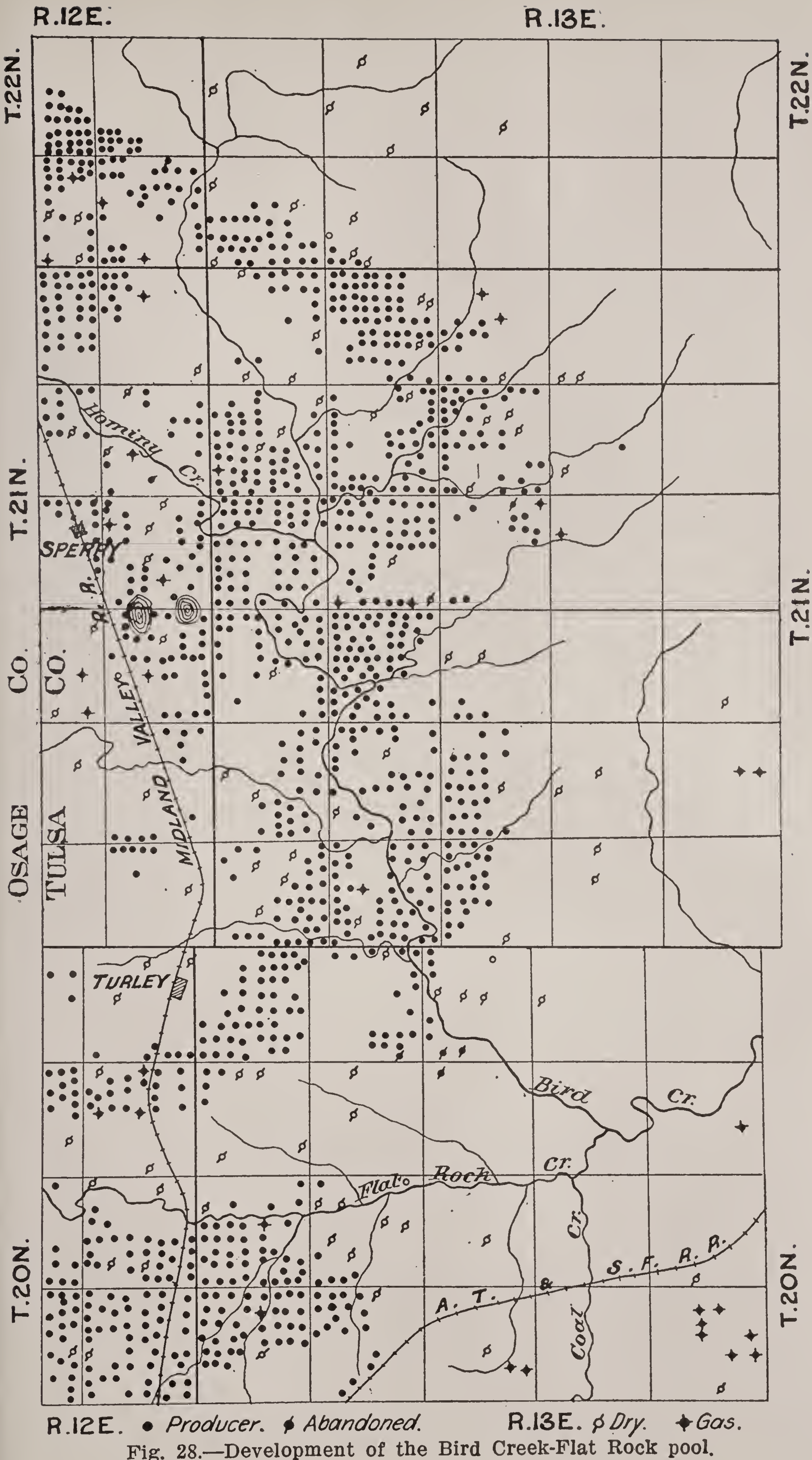
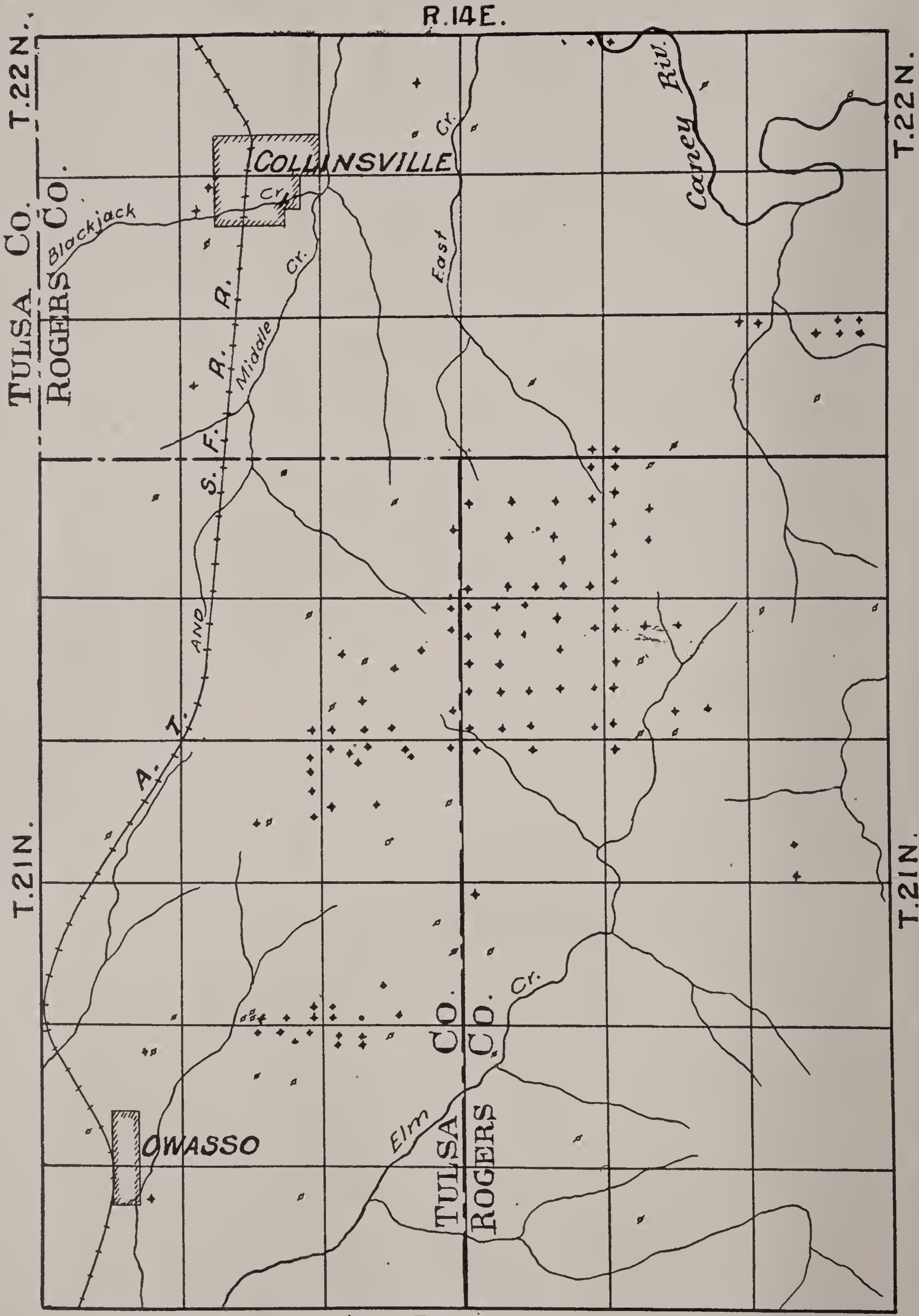


Fig. 28.—Development of the Bird Creek-Flat Rock pool.



∘ Location or Drilling. ⌀ Dry Hole. • Producer.
⌀ Abandoned. + Gas.

Fig. 29.—Development of the Collinsville pool.

The following log of a well in the Owasso pool gives an idea of the rocks encountered in drilling:

LOG OF WELL, ANDREAS LEERSKOW NO. 3, N. ½ NE. ¼, SEC 30, T. 21 N., R. 14 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Soil	14	14	Lime (?)	30	530
Slate	21	35	Slate	80	610
Lime (Big)	100	135	Lime	10	620
Slate	225	360	Shale	242	862
Lime (Oswego)	30	390	Sand and gas	14	876
Slate	110	500	Slate, black	15	891

THE SAPULPA DISTRICT.

The Sapulpa district includes the Glenn pool and some smaller outlying pools near Jenks, Red Fork, Taneha, Kellevville, and Mounds. The conditions throughout the pool are very similar and a discussion of the Glenn pool applies to the smaller pools so far as the number, thickness and character of sands is concerned.

The Glenn pool.—The Glenn pool is one of the greatest oil producing areas in the world. It was opened by a well drilled by Galbreath and Colcord in the summer of 1906. Development was very rapid and the pool soon became a phenomenal producer. The older wells of the pool have decreased greatly in production, but the pool has been extended and the total production is still very great, although it has receded considerably from its maximum and the pool is undoubtedly past its prime.

The pool lies to the east of Sapulpa. It has a width of about 4 miles and a length of about 8 miles. The greater part of the pool lies in the eastern parts of Tps. 17 and 18 N., R. 12 E.

The wells of the pool are started at or near the horizon of a limestone which has usually been correlated with the Lenapah of the region to the north of the Arkansas, but which is probably 100 feet higher in the section than the Lenapah. This limestone, known to the drillers as the Checkerboard limestone, outcrops through the pool so that the wells in the eastern portion are started below the limestone and those in the western portion as much as 100 feet above the limestone.

Several sands are encountered in the wells of the Glenn pool and different ones of these are productive in different parts of the pool and in the outlying pools. The number of logs studied is not sufficiently large to make very definite statements, but those studied agree fairly well and indicate the following conclusions:

(1). Two shallow sands lie above the main producing sands. One of these is found at a depth of about 800 to 850 feet below the surface and the other about 100 feet lower. Both of these sands show some oil and gas locally, but are not important producers.

(2). The Red Fork sand is recorded at depths of from 1,275 feet to 1,400 feet. The thickness varies from 10 to 30 feet. This sand is an important producer, although it falls far short of the Glenn sand in this respect.

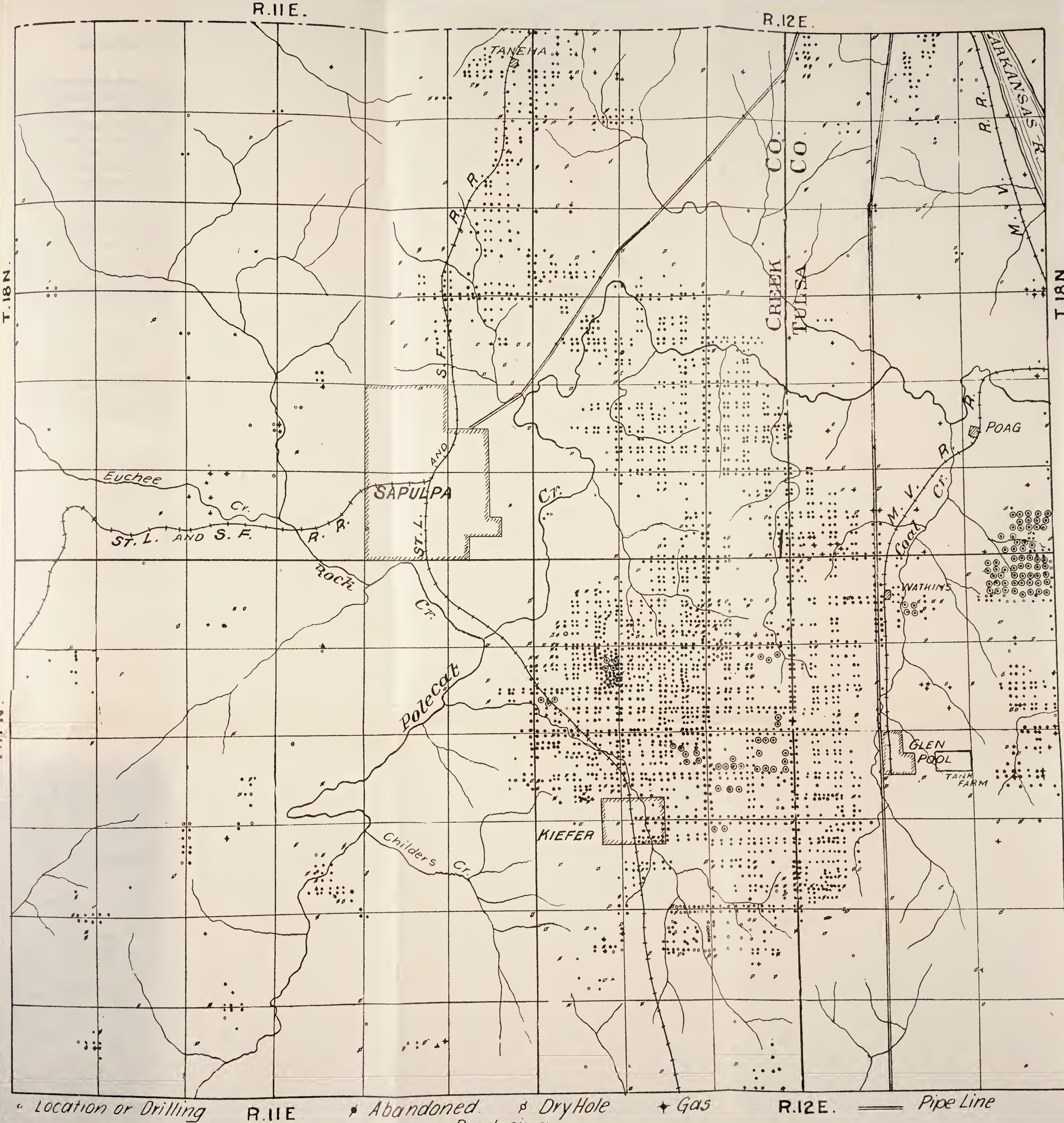
(3). The Glenn sand is the great producer of both oil and gas. It is reported at depths of from 1,400 to 1,550 feet with majority of the logs showing its upper surface between 1,450 and 1,500 feet. The thickness as shown in the logs varies greatly in short distances, the extremes noted being 10 to 124 feet. Much of this apparent variation is due to the fact that many of the wells stopped before reaching the bottom of the sands, although there is almost certainly considerable variation in the thickness. The gas is usually found in the upper portion of the sand and the oil lower down. A strong flow of salt water is often encountered at the bottom of the sand. This sand is correlated with the Bartlesville sand of the pools farther north by many of the drillers.

(4). A few logs show a sand which is called only the stray sand at a depth of about 1,650 feet. The thickness is recorded as 35 to 40 feet.

(5). The Taneha (Squaw) sand is encountered at about 1,750 feet. The thickness varies from 10 to 50 feet.

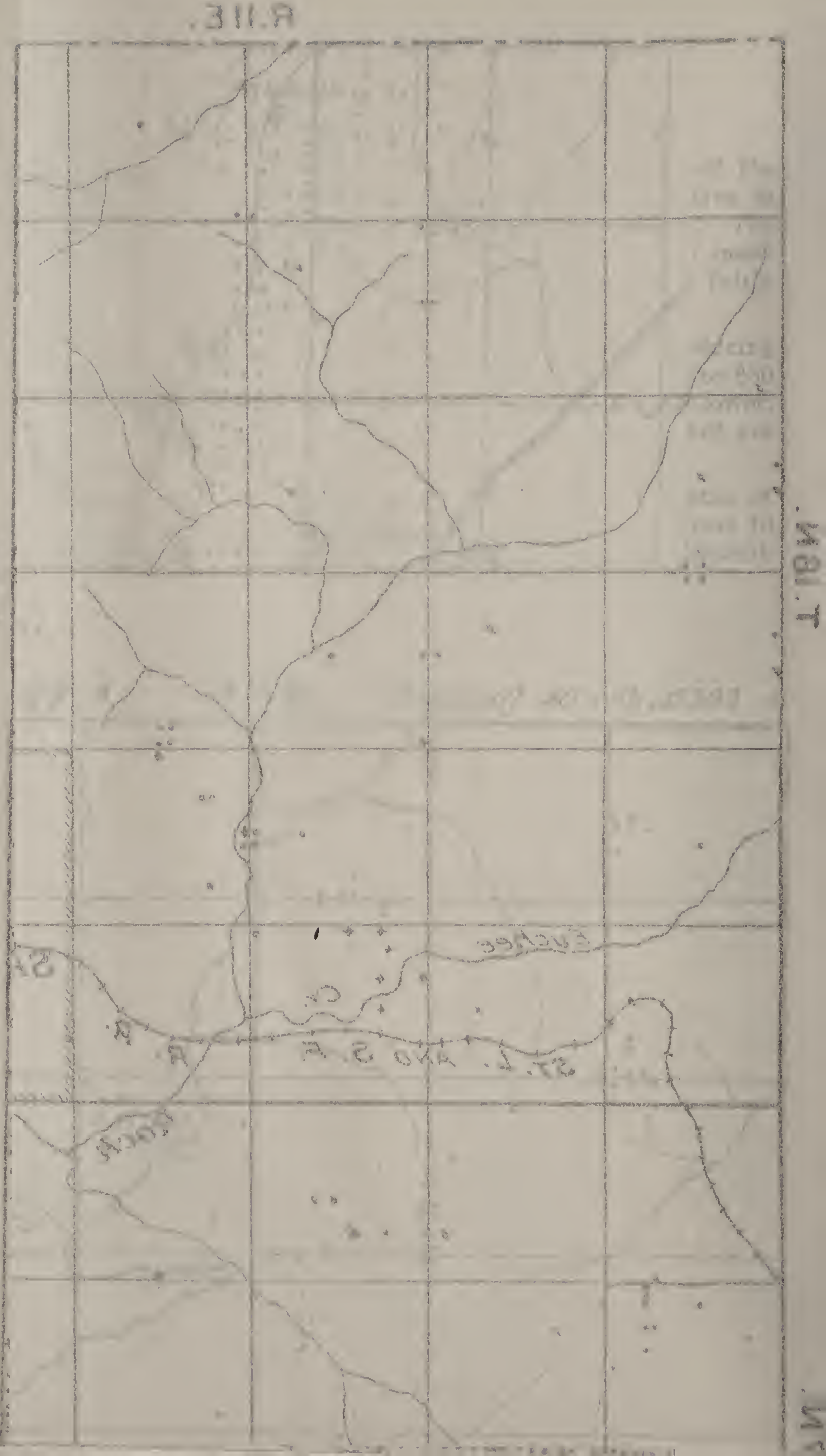
(6). The Sapulpa sand is shown in the logs of some of the deeper wells. The depth is about 2,350 feet and the thickness 10 to 40 feet.

The structure of the Glenn pool has not been worked out. The area has been examined several times in a hasty way and no sharp structure can be seen. It is thought that



◦ Location or Drilling R.11E ✦ Abandoned ⌀ Dry Hole ✦ Gas R.12E. ═ Pipe Line
• Producing

Fig. 30.—Development of Glenn Pool and northern extension.


R.11E.
T.18N.
T.18N.
St. L. and S.F.
Cr.

the accumulation may be due to the great thickness of the sands at this locality and not to folding. The variation of the thickness of the Glenn sand in particular is extreme, and Hutchinson (Bull. Okla. Geol. Survey No. 2) states that a series of carefully kept logs extending across the pool shows that the sand thins rather rapidly in both directions from the middle of the pool. This sort of a body of sand would give the arched effect of an anticline without revealing itself at the surface. (See figure 9).

The average initial production of the Glenn pool cannot be given accurately for the years previous to 1909, since the statistics are combined for the whole Creek Nation. The average of the Glenn pool was undoubtedly higher than that of the whole Creek Nation, which was 383.2 barrels in 1906, 277.9 barrels in 1907, and 146.1 barrels in 1908. The average initial production of the pool proper in 1909 was 78 barrels, and in 1910 was 62.6 barrels.

The development of the pool and its northern extension is shown in figure 30.

The following logs show the conditions in the Glenn pool as recorded by the drillers. The first log is of a well to the east of the main part of the pool and the second of a well in the Taneha pool to the north and west of the main pool:

LOG OF WELL, LIZZIE COSER NO. 13, SEC. 13, T. 17 N., R. 12 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Soil	12	12	Lime (Oswego?)	25	845
Slate	88	100	Shells	30	875
Sand	30	130	Shale	96	971
Slate	40	170	Sand	44	1015
Sand	30	200	Shale	215	1230
Slate	390	590	Sand (Red Fork)	25	1255
Lime	25	615	Brown shale	92	1347
Slate	55	670	White shale	28	1375
Lime	35	705	Stray sand	55	1430
Shale	115	820	Gas sand (Glenn)	30	1460
			Oil sand (Glenn)	32	1492

LOG OF WELL, ALVIN G. LAND, SEC. 1, T. 18 N., R. 11 E.

	Thickness, Feet.	Depth, Feet.
Soil	10	10
Shale	230	240
Lime	5	245
Shale	15	260
Sand	40	300
Shale	90	390
Sand	10	400
Shale	300	700
Lime	50	750
Shale	110	860
Lime	40	900
Lime shells	25	925
Sand	50	975
Shale	25	1000
Lime	10	1010
Shale	65	1075
Sand	20	1095
Shale	75	1170
Sand	30	1200
Shale	125	1325
Sand	25	1350
Sand and shells	40	1390
Shale	70	1460
Sand (oil)	10	1470
Shale	190	1660
Sand	44	1704

1,000,000 cubic feet of gas at 1360.

The well record for the Sapulpa district, including the Glenn, Mounds, Red Fork, Sapulpa, and Taneha pools, since 1909, is given in the following table. During these years the Taneha pool, the northern extension of the Glenn, has been the most active and has furnished over three-fourths of the development. The Mounds and Sapulpa pools are credited with no development in 1910.

WELL RECORD OF SAPULPA DISTRICT.

Year	Wells Completed				Initial Production	
	Total	Oil	Dry	Gas	Total	Average
1909	472	422	39	11	49,555	117.4
1910	391	357	21	13	36,575	102.5
1911	223	184	37	2	16,566	90.3

The total production of the Glenn pool by months since its opening is shown in the following table:

TABLE SHOWING THE PRODUCTION OF THE GLENN POOL BY MONTHS.

Month	1907	1908	1909	1910	1911
January	385,939	1,796,461	1,362,602	1,745,206	1,099,192
February	572,414	1,897,054	1,410,878	1,543,660	967,924
March	1,084,636	2,098,411	1,543,463	1,974,514	2,584,464
April	1,716,079	1,968,761	1,467,179	1,674,709	1,570,947
May	1,923,926	1,630,111	1,590,730	1,676,366	1,069,863
June	1,971,387	1,051,045	1,809,989	1,573,578	958,519
July	1,922,387	1.914,134	1,856.524	1,557,869	965,122
August	2,003,607	1,770,819	1,699,486	1,609,702	981,946
September	2,309,205	1,639,252	1,670,167	1,593,986	937,886
October	2,441,662	1,832,033	1,602,988	1,521,794	969,247
November	1,971,595	1,404,234	1,539,342	1,400,118	864,519
December	1,625,127	1,491,998	1,393,392	365,412	910,489
Total	19,926,995	20,494,313	18,946,740	19,236,914	13,880,118

OKMULGEE DISTRICT.

The Okmulgee district includes Okmulgee County. There are several pools as follows: Morris, Bald Hill, Hamilton Switch or Preston, Beggs, Henryetta-Schulter, and small pools in the vicinity of Okmulgee, one to the southeast and others to the west in the southwest part of the county. The geology of the county has never been worked in detail and the rocks cannot be discussed under formation names. It is, however, almost certain that the wells in practically all of the pools begin at a horizon somewhat below that of the Fort Scott (Oswego) lime to the north. The rocks of the region consist of sandstones and shales, probably the equivalents of the upper part of the Cherokee shale. Some heavy limestones are reported in the logs of some of the wells, but since none are known to outcrop to the eastward there seems to be some mistake in the records or else the limestones are lenses which do not outcrop.

Bald Hill pool.—The Bald Hill pool lies in the southern part of T. 15 N., R. 14 E. The general conditions are very similar to those of the Morris pool to the south except that the wells are believed to be started at a somewhat higher horizon. The oil is a dark green color and tests 33 to 34 degrees Baume. The base is a mixed paraffin and asphalt with the paraffin predominating. None of the statistics for this pool are given separately.

Morris pool.—The Morris pool is situated southeast of the town of Morris in the extreme southeastern part of Okmulgee County. The wells are started about the horizon of the Fort Scott (Oswego) limestone of the area to the north of the Arkansas and are 1,500 feet or more in depth. This probably brings the production from near the base of the Pennsylvanian rocks of this vicinity. Development in this field has been fairly constant since 1906 when the first well to the southeast of the town was brought in. The pool is spotted and both oil and gas wells occur irregularly distributed. The percentage of dry holes is somewhat higher than the average. The oil tests from 35 to 37 degrees Baume and is high in paraffin with little or no asphalt. The development of the pool is shown in figure 31.

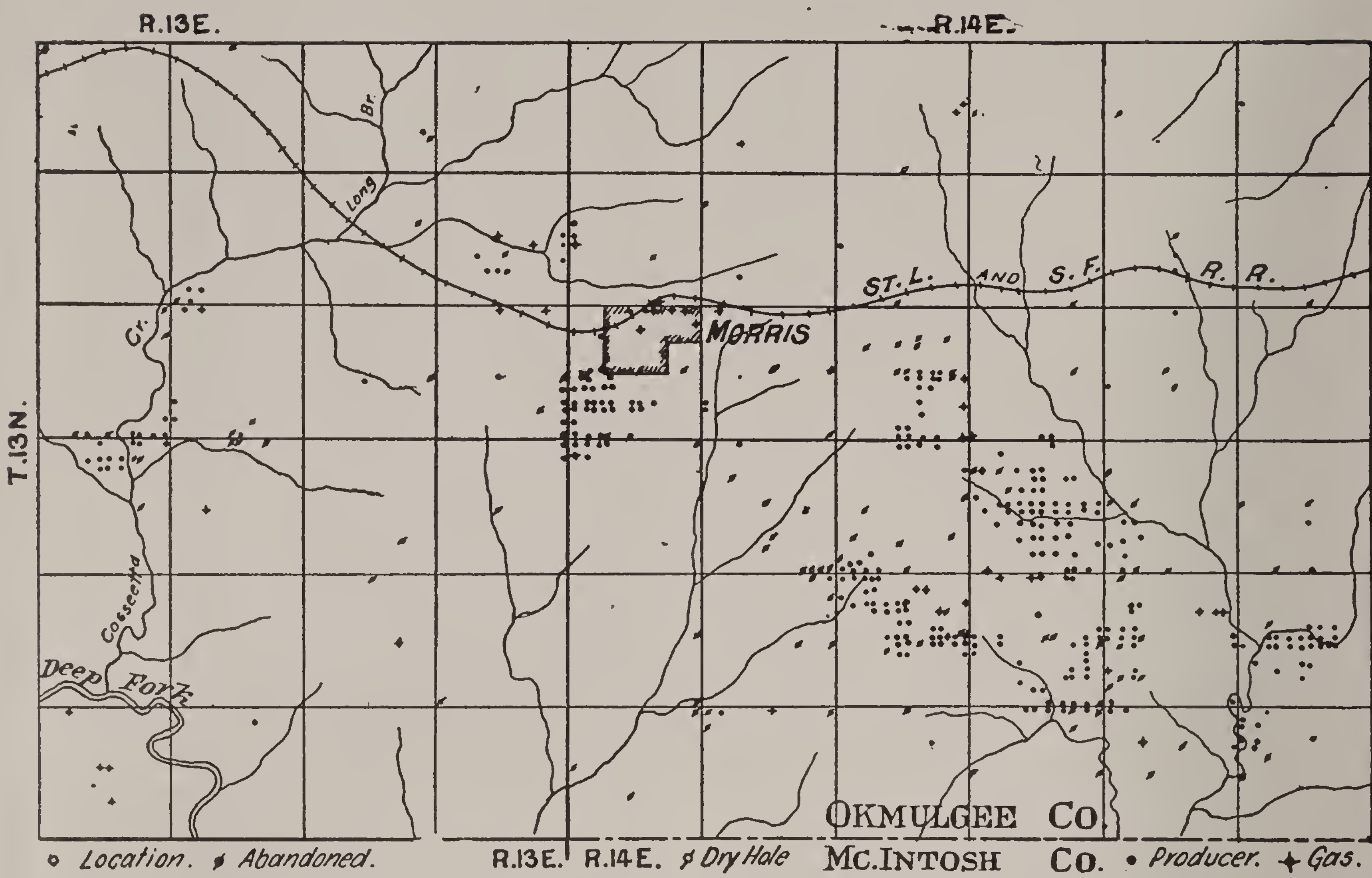


Fig. 31.—Development of the Morris pool.

The well record of the Morris-Okmulgee pool since 1909 as given by the United States Geological Survey is shown in the following table. This record probably includes the pool between Morris and Okmulgee and possibly the small pools to the west of Okmulgee:

WELL RECORD OF THE MORRIS-OKMULGEE POOL.

Year	Wells Completed				Initial Production	
	Total	Oil	Dry	Gas	Total	Average
1909	39	14	22	3	2010	143.6
1910	84	54	25	7	5865	108.6
1911	114	78	23	13	6970	89.4

The following log is given by Hutchison as typical of the Morris pool:

WELL IN MORRIS FIELD, SW. ¼ SEC. 5, T. 13 N., R. 14 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Conductor	18	18	Shale	85	782
Shale	4	22	Lime	80	862
Coal	3	25	Sand	100	962
Shale	100	125	Lime	29	991
Sand	12	137	Shale	257	1248
Shale	45	182	Sand	20	1268
Sand and shale	30	212	Shale	307	1575
Shale	215	427	Oil sand (show of oil)	20	1595
Lime	10	437	Shale	110	1705
Shale	250	687	Sand and lime with show of oil	73	1778
Sand	10	697			

Gas appeared at 1757 feet and increased to bottom of hole. Later the well was sunk to a depth of 1800 feet and the sand was still present.

Preston pool.—The Preston pool lies in the bend of the Frisco Railroad just west of Preston (Hamilton Switch), principally in sec. 2, T. 14 N., R. 12 E. The pool was opened in 1909 and for a time attracted great attention as oil wells of 1,000 barrels initial production and gas wells of 36,000,000 to 40,000,000 cubic feet capacity were brought in. Development was very active and the limits of the pool were soon defined. The area is only about 1 square mile and later drilling has not succeeded in extending it. Several wells to the southeast of the main development are considered as part of the same pool in the above statement.

The general conditions in this pool are the same as in the Morris pool. The structure of the vicinity has not been worked out. The following log gives the conditions as recorded by the drillers:

LOG OF WELL, ALEX. PRESTON NO. 1, SEC. 11, T. 14 N., R. 12 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Soil	15	15	Black slate	35	960
Shelly	110	125	White slate	10	970
White slate	190	315	Brown sand	540	1020
Black slate	38	353	White slate	170	1190
White slate	172	525	Black slate	20	1215
Black slate	10	535	White slate	105	1320
White slate	115	650	Black slate	65	1385
Lime	12	662	Sand (oil and gas)	165	1550
White slate	8	670	Black slate	30	1580
Lime	20	690	White slate	120	1700
Black slate	65	755	Black slate	43	1743
White slate	85	840	Oil sand	9	1752
Brown sand	75	915	Slate	268	2020
White slate	10	925	Gas sand	15	2035
			Oil sand	3	2038

The well record of the Preston pool since 1909 is given in the following table:

WELL RECORD OF THE PRESTON POOL.

Year	Wells Completed				Initial Production	
	Total	Oil	Dry	Gas	Total	Average
1909	9	8	....	1	2,300	287.5
1910	97	68	22	7	13,540	199.1
1911	....	....	....	....	....	....

Beggs pool.—The pool at Beggs is located about 2 miles south of the town and 2 miles west of the Preston pool. The conditions are almost precisely similar to those of the Preston pool.

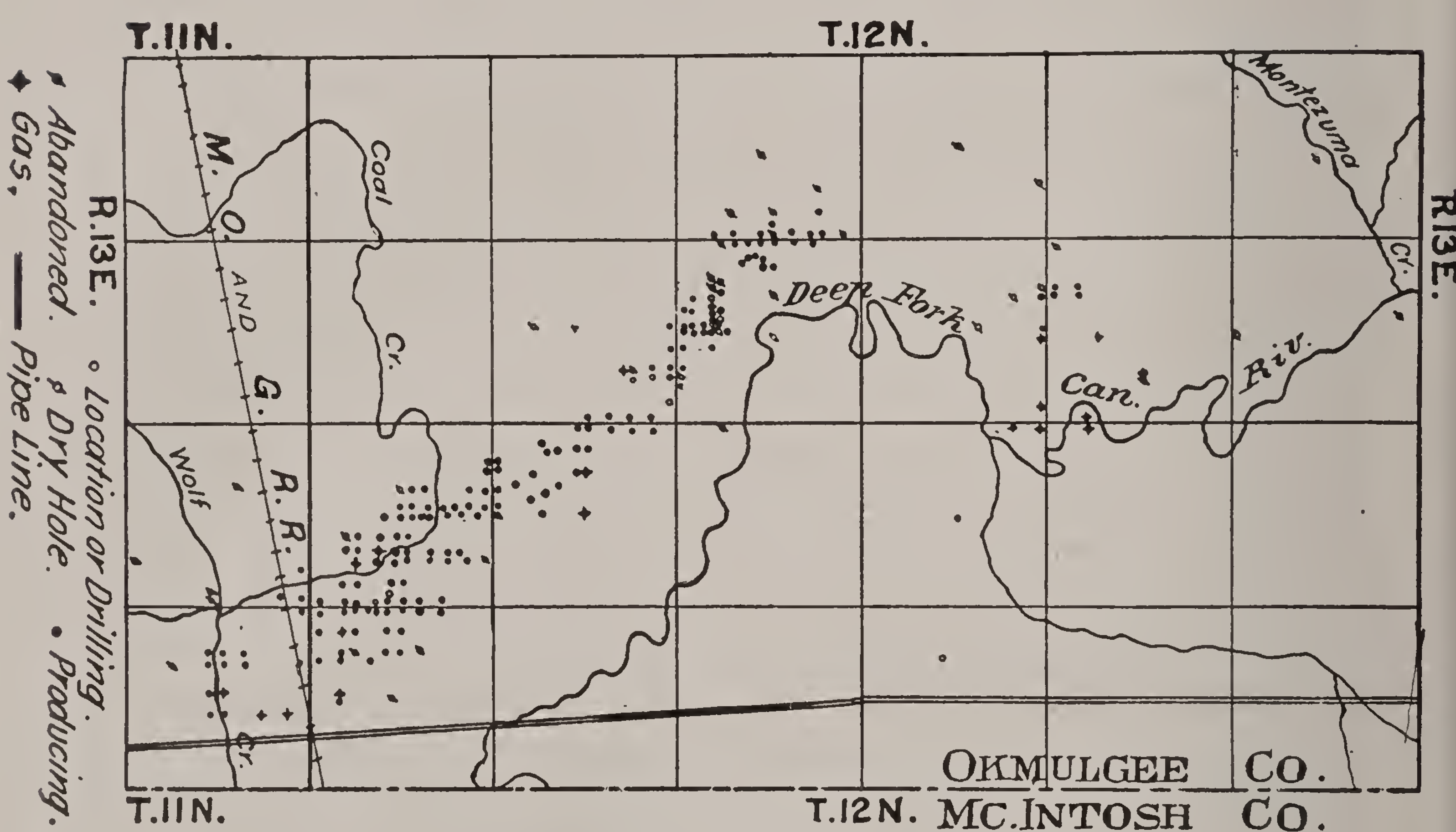


Fig. 32.—Development of the Henryetta-Schulter pool.

Henryetta-Schulter pool.—The Henryetta-Schulter pool lies in T. 12 N., R. 13 E., beginning about 1 mile southeast of Schulter and extending southeast for about 6 miles with an average width of about one-half mile. The wells are from 1,200 to 1,500 feet or more in depth. The production is reported at from 200 to 500 barrels. The conditions are in general the same as for the other pools in the Okmulgee district and need not be described in detail. The development is shown in figure 32.

MUSKOGEE DISTRICT.

The Muskogee district includes only the Muskogee pool and a small gas pool southwest of Wainwright. The latter pool consists of only a few gas wells and is of little importance.

Muskogee pool.—The Muskogee pool extends southwest from the city, between the M., O. & G. and M., K. & T. railways, for a distance of about 6 miles. The wells of the pool start about the top of the Ft. Scott (Oswego) lime of the Nowata and Bartlesville districts. The wells in the northeastern part of the pool, near the townsite, reach the productive sand at a depth of between 1,000 and 1,100 feet. The occurrences in the southwestern part of the pool are very erratic, some wells being over 1,000 feet deep and others striking good pay at considerably less depth. In any case, however, the wells extend beyond the depth which should carry them through the Pennsylvanian rocks according to the thickness given by Taff in the Muskogee folio and should penetrate the Mississippi lime. The logs do not indicate that this is true, as all the rocks encountered in the lower parts of the wells are sandstones and shales. It is probable that the actual thickness of the Winslow is greater in this region than the thickness obtained by Taff by measuring across the outcrop.

The development of the pool began on the townsite in 1904 and a small pool was outlined. This pool, known as the townsite pool, was soon exhausted and the wells abandoned. The development to the southwest began in 1906 and has been fairly constant ever since. The field is very spotted and the percentage of dry wells is rather high. There are also many gas wells irregularly distributed through the field. The well record of the pool since 1909 is as follows:

WELL RECORD OF MUSKOGEE POOL.

Year	Wells Completed				Initial Production	
	Total	Oil	Dry	Gas	Total	Average
1909	129	79	41	9	3,245	104.4
1910	171	123	43	5	16,640	135.3
1911	117	81	34	2	6,965	86.0

The development of the field is shown in figure 33.

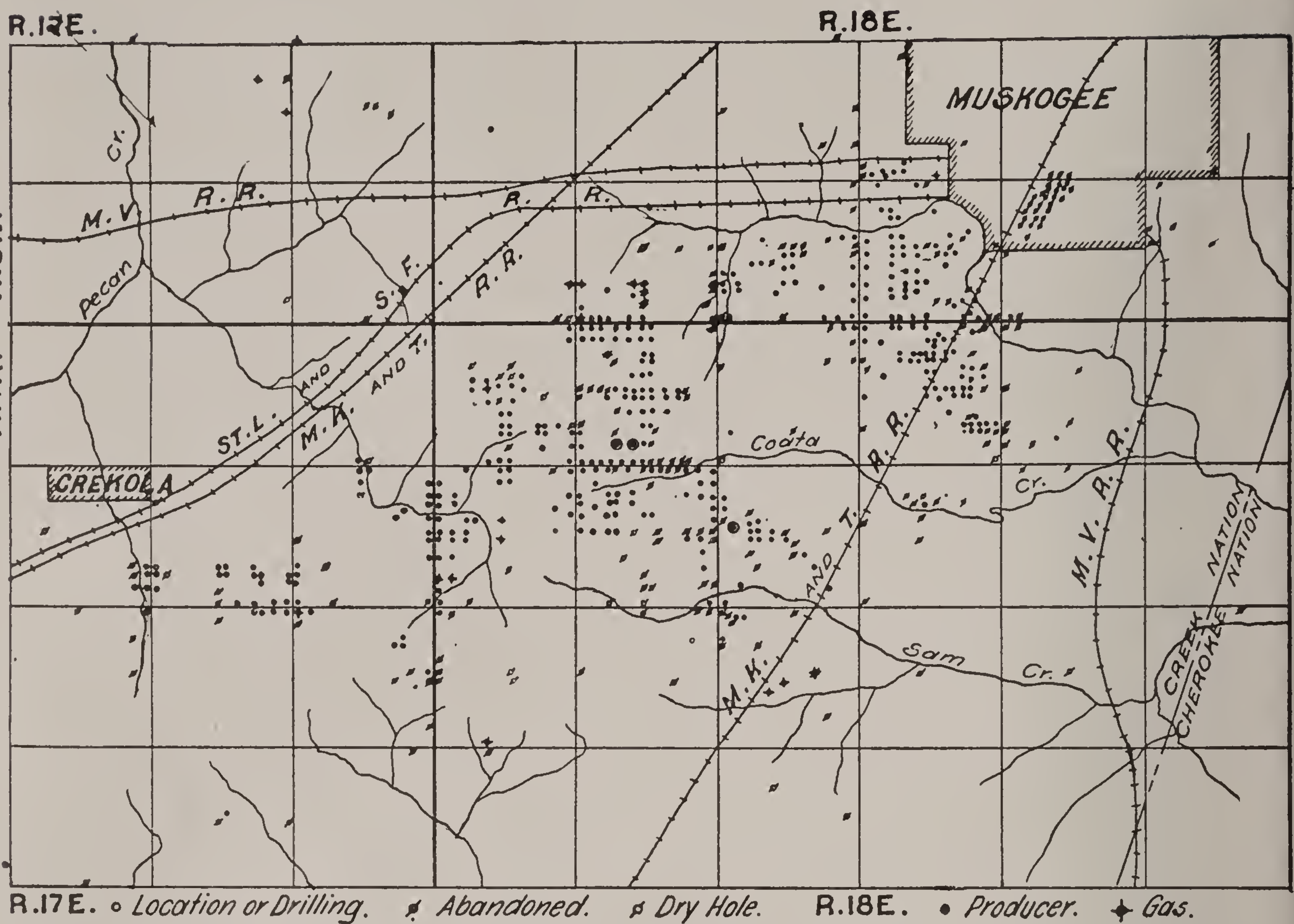


Fig. 33.—Development of the Muskogee pool.

The following logs are representative of conditions encountered in drilling. The first log is that of the first well drilled in the old or townsite pool and the second is a well in the newer development to the southwest:

LOG OF WELL IN OLD TOWNSITE FIELD, MUSKOGEE POOL.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth. Feet.
Soil	15	15	Shale	20	760
Brown sand	10	25	Salt water sand	15	775
Clay and gravel	35	60	Shale	15	790
Shale	40	100	Shale	75	865
Sand and salt water	20	120	Sand (smelled of oil)	10	875
Shale	100	220	Dark shale	100	975
Soapstone	230	450	Black shale and limestone	15	990
Shale and shells	10	460	Shale	35	1025
Sand	40	500	Limestone	25	1050
Gray shale	100	600	Sand	5	1055
Salt water sand	90	690	Blue slate	20	1075
Shale	40	730	Sand shale	25	1100
Sand and lime	10	740			

Drilled to 1100 feet and quit with a full flow of salt water.

LOG OF WELL, SARAH PERRYMAN NO. 2, SEC. 8, T. 14 N., R. 18 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Slate	320	320	Sand	5	1395
Lime?	20	340	Slate	40	1435
Slate	130	470	Lime	50	1485
Lime	15	485	Sand	25	1515
Slate	240	725	Slate	65	1580
Lime	15	740	Lime	20	1600
Slate	85	825	Shale	5	1605
Broken sand	25	850	Lime, sandy	13	1618
Slate	320	1170	Slate	10	1628
Lime, hard	45	1215	Sand	24	1652
Slate	15	1230	Slate	5	1657
Lime, hard	15	1245	Sand	4	1661
Slate	30	1275	Slate	13	1684
Sand, water	30	1305	Sand	16	1700
Slate	85	1390			

OSAGE DISTRICT.

The Osage district includes all of Osage County except a narrow strip along the eastern border, which forms part of the Bartlesville-Dewey oil and gas pool and has been discussed in connection with the Bartlesville district. The rocks of the district are shales and sandstone of the upper part of the Pennsylvanian system. The structure is monoclinal with a dip of about 30 feet to the mile to the westward. This dip is known to be interrupted locally by small folds, but it cannot be said as to whether or not the folding controls the accumulation of the oil and gas. The greater part of the county was surveyed by the United States Geological Survey in 1909, but the results of the survey have not been published and the results are not accessible to the public. Very little can be said as to the details of the stratigraphy or structure.

The greater part of the development is in the eastern one-third of the county and is continuous with that of the Bartlesville district to the east. Besides the strip along the Osage-Washington County line which has already been mentioned as belonging to the Dewey-Bartlesville pool, the largest pool is the Avant-Ochelata pool lying between the towns from which it is named. The second largest pool is at Osage Junction immediately across Arkansas River from the Cleveland pool in Pawnee County. Small pools have been discovered northwest of Tulsa, between Big Heart and Pawhuska, and in the northeastern part of the county just south of Chautauqua Springs, Kans.

From its beginning the development in Osage County has been seriously retarded by leasing restrictions and regulations imposed by the Department of the Interior.

In 1896 a blanket lease was granted covering the entire Osage Nation. This was renewed in 1906 to extend for another ten years. The company controlling this lease has done little or no drilling as a company, although many of the individual members own production in Osage County. The development has been accomplished by sub-leasing to oil operators. In order to facilitate the letting of leases the company divided that portion of the county adjacent to the Bartlesville-Tulsa development into lots, one-half mile wide by three miles long, extending east and west, except those lots which occur south of Township 29 north, and east of range 11 east, which are three and one-half miles in length. The lots are numbered, beginning at the northeast corner of the county, in consecutive order from that point southward to the southern boundary, thence northward on the second tier to the State line and again southward on the third tier. Hence a detailed discussion of the region usually refers to Osage County by lots.

The Department of the Interior has from time to time imposed regulations on these lessees and sublessees that have materially retarded the development of the district and the regulations now in force are such as to prohibit development in territory which has not previously been shown to be promising. Only a comparatively small part of the Osage territory has been well prospected and when the restrictions are removed there will undoubtedly be a large amount of prospecting and considerable development in the region.

The statistics of production and the well record for the Osage have been kept separately and are given at the end of this section. The production of the strip along the eastern border, which forms a part of the Dewey-Bartlesville field, is included in these tables as well as that of the Avant-Ochelata pool, the Osage Junction pool and the various small pools.

Avant-Ochelata pool.—The Avant-Ochelata pool extends north and east from Avant to Ochelata. The southern part of the pool is very narrow not exceeding one-half mile in width. The main portion is an irregularly shaped area lying from 3 to 8 miles west of Ramona, from which place the pool is sometimes known as the Ramona pool.

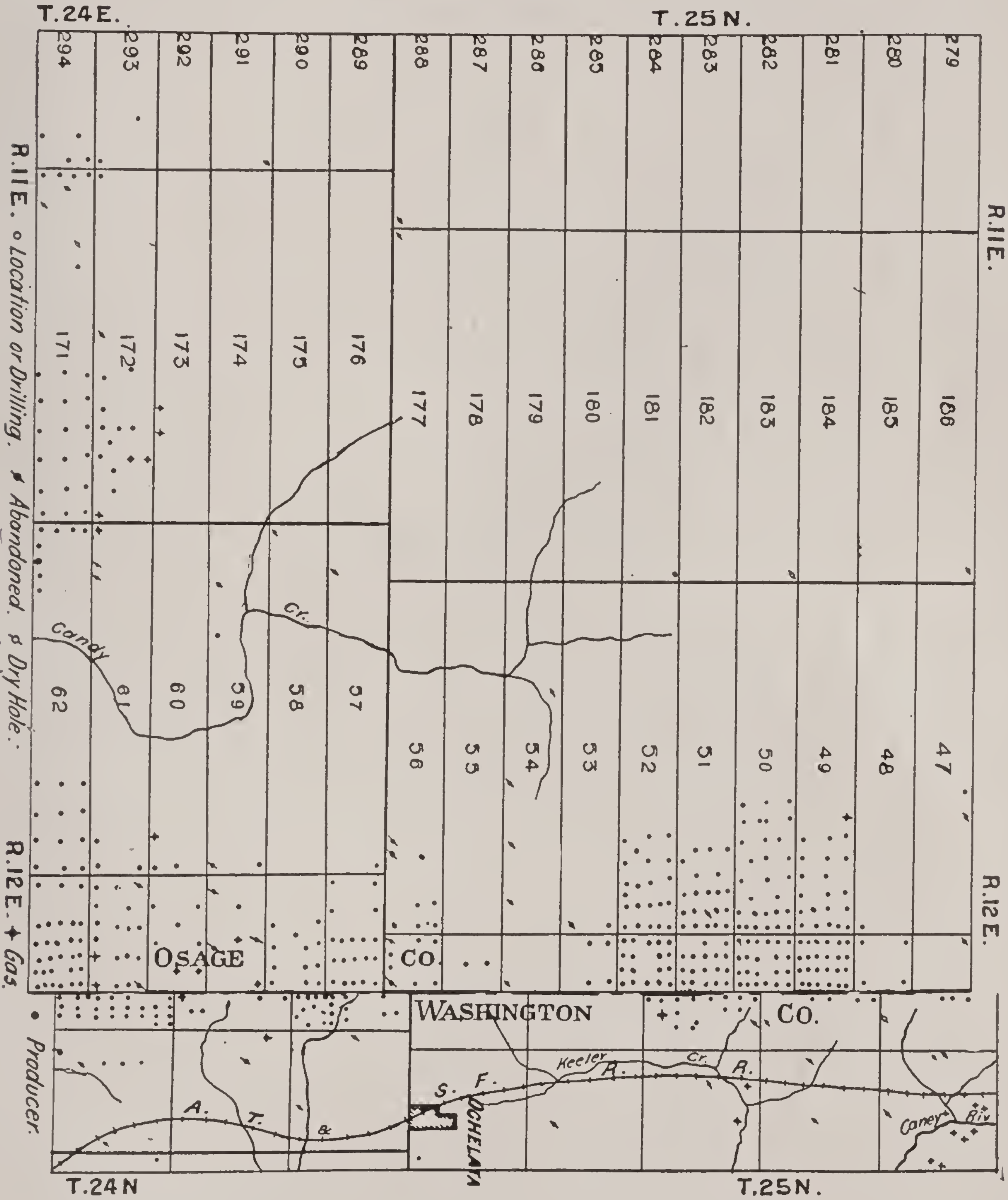


Fig. 34.—Development of north part of the Avant-Ochelata pool.

The area of this portion is about 15 square miles. The development is shown in figures 34 and 35.

The conditions in this pool are very similar to those of the Bartlesville pool except that they are started some-

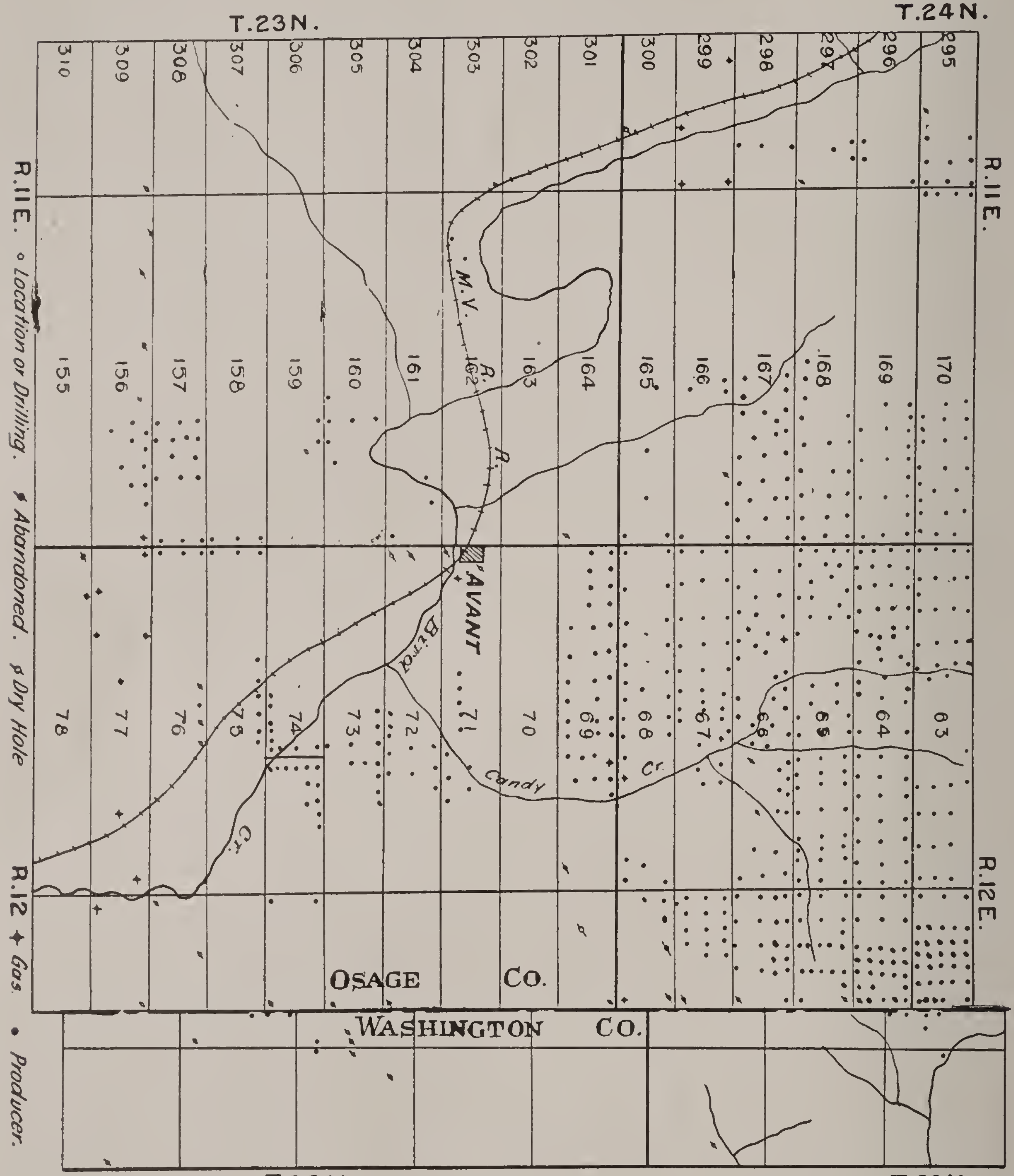


Fig. 35.—Development of south part of the Avant-Ochelata pool.

what higher in the section. The majority of the wells are started very near the horizon of the Avant limestone, a lens in the Wilson formation. The following log is believed to be typical of the conditions in the pool:

LOG OF WELL, BARNSDALL OIL CO. NO. 8, OSAGE LOT NO. 71, ABOUT TWO MILES NORTHEAST OF AVANT.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth. Feet.
Soil	20	20	Slate	120	980
Slate	40	60	Oswego lime	60	1040
Lime	40	100	Shale	100	1140
Shale	240	340	Slate	40	1180
Sand	50	390	Shale	222	1402
Shale	170	560	Sand	20	1422
Lime	8	568	Sand, gas	48	1470
Shale	192	760	Shale	9	1479
Lime	20	780	Sand, pay oil	21	1500
Shale	20	800	Sand	36	1536
Big lime	60	860	(Water at 1515)		

Osage Junction pool.—This pool lies directly across Arkansas River from the Cleveland pool in Pawnee County and all the conditions so far as known are precisely the same as in that pool. The development is shown in figure 36 with that of the Cleveland pool.

Other pools.—The first well in the Osage was drilled south of Chautauqua Springs, Kans., and a small pool was later developed in this locality in the extreme northeastern part of the county. The development is directly west of the Canary pool and except for the wells starting higher in the section, the conditions are the same.

A small pool to the northwest of Tulsa is practically the westward extension of the Turley and Flat Rock pools of the Tulsa district and the description of these pools applies to the pool in Osage County.

Other small pools have been opened at Big Heart, Nelagony, Pawhuska, Wynona, east of Hominy, and about 5 miles northeast of the Osage Junction pool, but so far these have proved to be of little importance. The Pawhuska pool is principally a gas producer.

Very little prospecting has been done in the western part of Osage County, although the occurrence of oil and gas in commercial quantities at Ponca City in Kay County to the west shows that the territory is at least worthy of investigation.

The well record for Osage County since 1904 is given in the following table:

WELL RECORD FOR OSAGE COUNTY, 1904 TO 1911.

Year	Wells Completed				Initial Production	
	Total	Oil	Dry	Gas	Total	Average
1904	361	243	97	21	....	....
1905	482	359	107	16	36,423	101.5
1906	262	215	30	17	20,047	93.2
1907	184	154	15	15	16,355	106.2
1908	153	129	16	8	19,377	150.2
1909	108	75	15	18	10,205	136.1
1910	239	206	25	8	35,060	170.2
1911	494	438	40	16	89,660	204.7

The production of Osage County is given by years in the following table:

PRODUCTION OF OSAGE COUNTY, 1903-1911.

Year	Barrels	Year	Barrels
1903	56,905	1908	4,961,147
1904	652,479	1909	4,516,524
1905	3,421,478	1910	5,892,970
1906	5,219,106	1911	11,707,676
1907	5,143,971		

PAWNEE COUNTY DISTRICT.

The development in Pawnee County is in the extreme northeast part near Cleveland, and is known as the Cleveland field or pool. The development of this pool began rather early in the history of the oil industry of the State and, with some halts, has continued until the present. The early development was in the town of Cleveland and the immediate vicinity and the more recent has been to the south and southeast of the town.

The rocks of the region consist of sandstones and shales of the upper part of the Pennsylvanian system and the wells are started near the horizon of the Elgin sandstone. The production is from sands at about the same level as the sands of the pools farther north and east and also from sands higher in the section.

The following description of the pool about the end of 1909 is given by Hutchinson in Bulletin No. 2 of the Oklahoma Geological Survey:

The first well drilled was on the Bill Lowery farm, just south of the townsite and was known as "Uncle Bill No. 1." The enterprise was promoted by local capital and resulted in a paying well at 1615 feet. Development followed rapidly and almost every town lot was soon drilled. The city council had to pass an ordinance forbidding the drilling of wells on the rear ends of business lots on Main Street. The principal part of the field was found south of the town in sections 16 and 17, although sections 18, 20 and 29 have also proved profitable territory.

Two sands were discovered, known as the Cleveland sand and Kelso sand. The Kelso sand, found on the Kelso farm southwest of Cleveland, is above the Cleveland sand and in the early development of the Kelso pool drilling ceased on reaching that horizon. Owing to the fact that at the time operations began in the Cleveland pool there was no law fixing the minimum distance at which oil wells should be drilled, development in this field resulted in great waste to operators. Wells were often drilled on adjacent town lots, so near each other that there was hardly room to build the rigs. In such cases many wells were soon exhausted and casings pulled without having repaid the initial cost. Perhaps nearly one-half the wells on the townsite have already been abandoned.

The limits of the pool have been pretty well defined, for several years by a series of dry holes drilled around its margin. The rock pressure has decreased to considerable extent, but the field is still a good steady paying one.

During the year 1909 there were 21 wells drilled in the Cleveland field only one of which was dry and but two produced gas. The other eighteen were oil wells with an initial production of 1095 barrels daily.

Since 1909 the development has carried the field farther to the southwest. The finding of deeper productive sands has, however, been the principal factor in prolonging the life of the field. The productive sands of the pool and their depths from the surface are given by Robt. H. Wood in Bulletin 531 B. of the U. S. Geol. Survey as follows:

PRODUCING OIL SANDS IN THE CLEVELAND FIELD.

Sand	500
Sand	1000
Layton	1300
Sand	1400-1500
Cleveland	1570-1700
Skinner	2200
Bartlesville	2400
Tucker or Meadows	2600-2800

The sands mentioned above, however, are not found in all the wells and where encountered are not always productive.

The well record of the field is given in the following table:

WELL RECORD OF THE CLEVELAND OIL AND GAS FIELD, 1908-1912.

Year	Wells Completed				Initial Production	
	Total	Oil	Dry	Gas	Total	Average
1908	22	14	7	1	455	32.5
1909	28	23	3	2	1,865	81.1
1910	13	10	2	1	713	71.3
1911	165	129	31	5	22,100	171.3

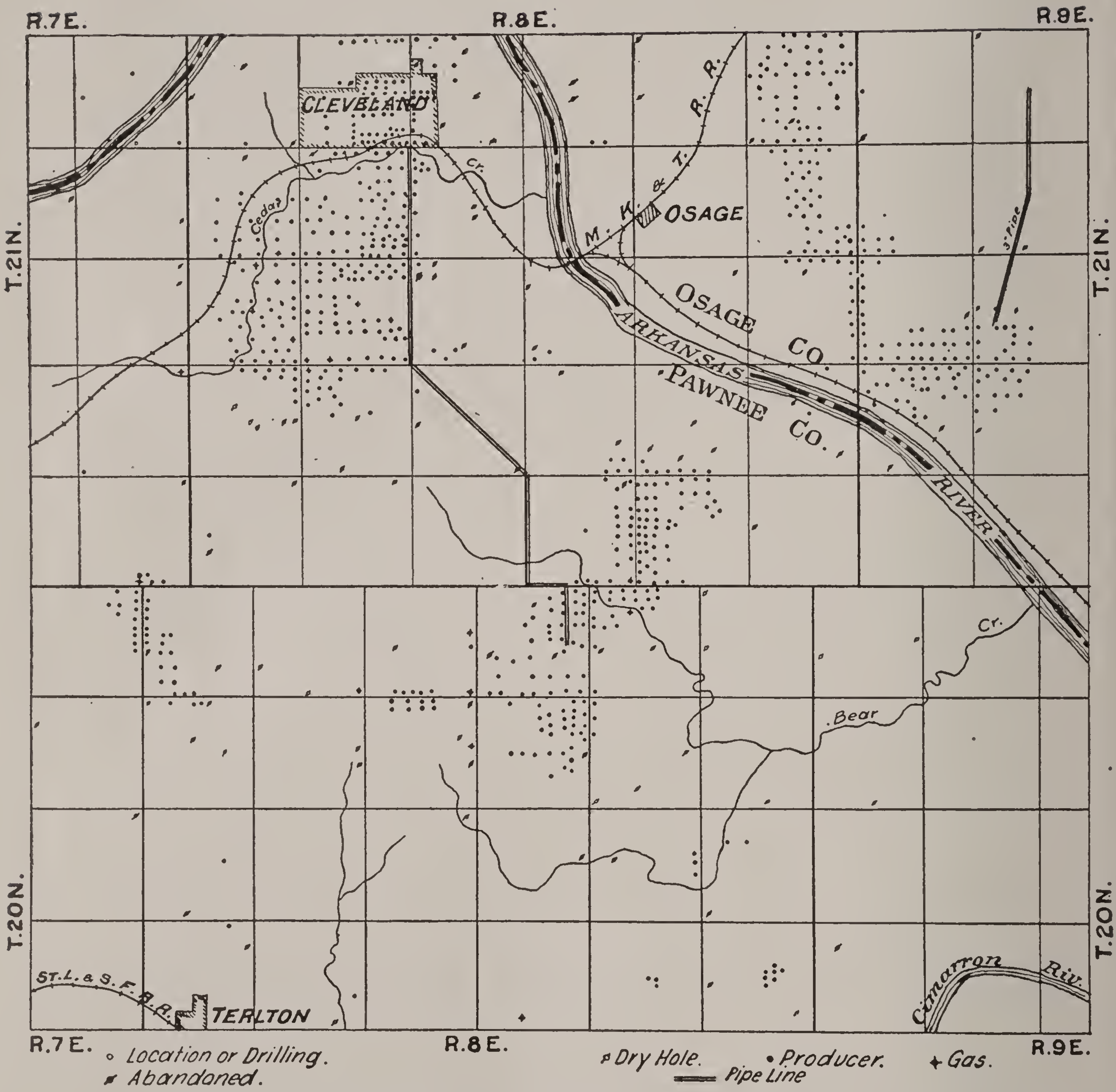


Fig. 36.—Development of the Cleveland and Osage Junction pools.

The following log illustrates the conditions encountered in drilling to the shallower sands. No logs of the deeper wells are available:

LOG OF WELL ON CLEVELAND TOWNSITE.

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

Some drilling has been done in Pawnee County outside of the Cleveland pool, but so far has met with little success. Several wells were drilled near Hallett and Jennings to the west of Cleveland and some oil and gas were found, but not in sufficient quantity to be of importance. Two wells were drilled near Pawnee and were dry, but neither was carried deep enough to reach any but the shallowest sands of the Cleveland field, so that the country cannot be regarded as being condemned. Wells have also been drilled at Maramec, Blackburn (2) and Ralston. The wells at Ralston and one at Blackburn were carried to considerable depths, probably to the Mississippi lime and had good showings of oil and gas. Good sands were encountered in these wells and the indications were good, although the wells themselves were abandoned and plugged. The log of the well at Blackburn is given by Wood, in the publication referred to above, as follows:

LOG OF WELL AT BLACKBURN.

	Thickness, Feet.	Depth, Feet.
Clay, yellow, soft	10	10
Mud, red, soft	10	20
Lime, black, hard	12	32
Shale, blue, soft	15	47
Sand, white, soft (water)	15	62
Mud, red, soft	10	72
Lime, white, hard	5	77
Red rock, soft	35	112
Sand, white, soft (water)	28	140
Shale, white, soft	6	146
Lime, white, hard	36	182
Red rock, soft	30	212
Shale, blue, soft	40	252
Lime, white, hard	4	256
Red rock, soft	10	266
Sand, white, soft (water at 285 feet)	36	302
Shale, white, soft	40	342
Sand, white, soft	15	357
Shale, blue, soft	85	442
Sand, white, hard (little salt water)	15	457
Shale, white, soft	70	527
Sand, white, soft (hole full of water at 530 feet)	85	612
Shale, white, soft	60	672
Red rock, soft	5	677
Sand, white, soft	8	685
Red rock, soft	24	709
Sand, white, soft	6	715
Shale, white, soft	16	731
Sand, white, soft (water)	40	771
Shale, white, soft	51	822
Red rock, soft	25	847
Lime, white, hard	6	853
Sand, white, hard (little water)	10	863
Shale, white, soft	54	917
Sand, white, hard	35	952
Red rock, soft	10	962
Sand, white, hard (little water)	30	992
Shale, white, soft	28	1020
Red rock, soft	10	1030
Sand, white, soft (little water)	15	1045
Red rock, soft	10	1055
Sand, white, hard (hole full of water at 1085 feet)	215	1270
Shale, blue, soft	75	1345
Lime, white, hard	35	1380
Shale, white, soft	20	1400
Lime, white, hard	15	1415
Shale, white, hard	35	1450
Sand, white, hard	30	1480
Shale, white, soft	35	1515
Red rock, soft	8	1523
Shale, blue, soft	23	1546
Lime, white, hard	8	1554
Shale, brown, soft	131	1685
Sand, white, hard (water at 1730 feet)	55	1740
Shale, black, soft	170	1910
Sand, white, hard	15	1925
Shale, black, soft	10	1935
Lime, white, hard	6	1941
Shale, black, soft	10	1951
Sand, white, hard	12	1963
Shale, black, soft	22	1985
Sand, white, hard	25	2010
Shale, black, soft	140	2150
Lime, white, hard	5	2155
Shale, black, soft	10	2165
Lime, white hard	45	2210
Shale, black, soft	6	2216
Lime, white, hard	10	2226
Shale, black, soft	8	2234
Lime, white, hard	9	2243
Shale, blue, soft	19	2262
Lime, white, hard	36	2298
Shale, black, soft	14	2312
Lime, white, hard	8	2320
Shale, white, soft	45	2365
Sand, white, soft (gas at 2370 feet; hole full of water at 2385 feet)	30	2395
Lime, white, hard	10	2405
Shale, black, soft	25	2430
Shells, black, hard	20	2450
Shale, black, soft	30	2480
Sand, white, hard	6	2486
Shale, black, soft	8	2494
Lime, pink, hard	14	2508
Shale, white, soft	82	2590
Lime, white, hard	6	2596
Shale, black, soft	54	2650
Mud, red, soft	40	2690
Shale, white, soft	22	2712
Lime, hard, gray	124	2836

THE CUSHING DISTRICT.

The Cushing district consists of a single pool which lies in the western part of Creek County near the Payne County line about 9 miles east of the town of Cushing. The producing area extends about 9 miles north and south and 3 miles east and west. The principal production is from secs. 5-6-7 and 8, T. 17 N., R. 7 E. The most recent development is in the northern end of the field.

The producing sands are five in number. These, with their average depths below the surface, are as follows:

Name.	Depth
Sand	980
Layton	1,430
Jones	1,900
Cleveland	2,000-2,100
Wheeler	2,200-2,400

Of these sands the Layton and Wheeler are by far the most important, the other three sands producing only small amounts. The Layton sand is irregular in production and the greatest dependence is placed in the Wheeler sand. While this formation is usually classed as a sandstone it is reported to be a rather coarse-grained limestone.

The structure of the field is anticlinal and the production follows the structure closely. In the eastern part of the field the Layton or upper sand is productive, while in the western part of the field the principal production is from the Wheeler or lower sand. This condition indicates an unsymmetric anticline with the steeper side to the east. The surface rocks are principally sandstones and shales with one prominent limestone. This limestone occurs on mounds southeast of Drumwright at elevations considerably greater than those of the escarpments to the east and west.

The production of the Cushing pool cannot be stated accurately, but the daily production is estimated at 24,000 barrels. The largest well so far reported produced 2,500 barrels per day and the largest gas well had a capacity of 27,000,000 cubic feet per day.

The following logs are believed to be representative of the Cushing district:

LOG OF WELL, MAGNOLIA MIKEY NO. 1, NW. ¼ Sec. 33, T. 18 N., R. 7 E.

	Thickness, Feet.	Depth, Feet.		Thcikness, Feet.	Depth, Feet.
Soil	4	4	Sand and water	5	740
Sandstone	66	70	Lime	5	745
White slate	28	98	Sand and water	40	785
Lime	12	110	Black shell	130	915
White slate	35	145	Lime shell	5	920
Red rock	5	150	Black shale	80	1000
White slate	30	180	Sand	20	1020
White sand	3	183	Black slate	20	1040
Whtie slate	35	218	Lime	5	1045
Red rock	17	235	White slate	45	1090
White slate	35	270	Black slate	230	1320
Sand	8	278	Lime	8	1328
Red rock	9	287	Sand (Layton)	18	1346
White slate	10	297	Slate	5	1351
Red rock	13	310	Sand and gas	60	1411
White slate	40	350	Slate	10	1421
Red rock	10	360	Sand (show oil)	49	1470
White slate	35	395	Slate	80	1550
White sand	15	410	Lime	3	1553
White slate	20	430	Slate	9	1562
Red rock	14	444	? ? ?	70	1632
White sand	26	470	Sand (Jones)	18	1650
Blue mud	39	509	Blue slate	25	1675
Lime	21	530	Lime	3	1678
Sand	15	545	Blue slate	60	1738
Blue slate	30	575	Sand and Gas	22	1760
Sand	15	590	Slate	30	1790
Blue slate	14	604	Sand and gas	10	1800
White slate	31	635	Slate	255	2055
Red rock	15	650	Lime	5	2060
Sand	30	680	Slate	20	2080
Sand and water	25	705	Sand	12	2092

Gas well, capacity 32,000,000 cubic feet per day. Largest gas at 2092 feet.

LOG OF WELL, A. DRUMRIGHT NO. 1, SW. ½ SEC. 32, T. 18 N., R. 7 E.

	Thickness, Feet.	Depth, Feet.		Thickness, Feet.	Depth, Feet.
Lime shell	25	1472			
Layton sand	27	1479	Sand	10	2060
Shale	8	1505	Slate	168	2228
Cleveland sand	40	1950	Wheeler sand (show)	10	2238
Slate	70	2020	Wheeler sand (pay)	42	2280

LOG OF WELL, J. WISHWELL NO. 1, SEC. 16, T. 17 N., R. 6 E.

	Depth, feet.
No Layton sand.	
Jones sand	from 1864 to 1871
Wheeler sand	from 2697 to 2788
Bartlesville sand	from 2845 to 2863
Mississippi lime	at 3038

KAY COUNTY DISTRICT.

Kay County is in the extreme north-central part of the State. The rocks are those of the upper Pennsylvanian and lower Permian. The formations as exposed are, beginning with the lowest, Wreford limestone, Matfield shale, Fort Riley limestone, Doyle shale, Winfield limestone, Uncas shale, Herington limestone, and some higher unnamed formations. The county has three pools that produce oil or gas or both—the Ponca City, Newkirk, and Blackwell pools.

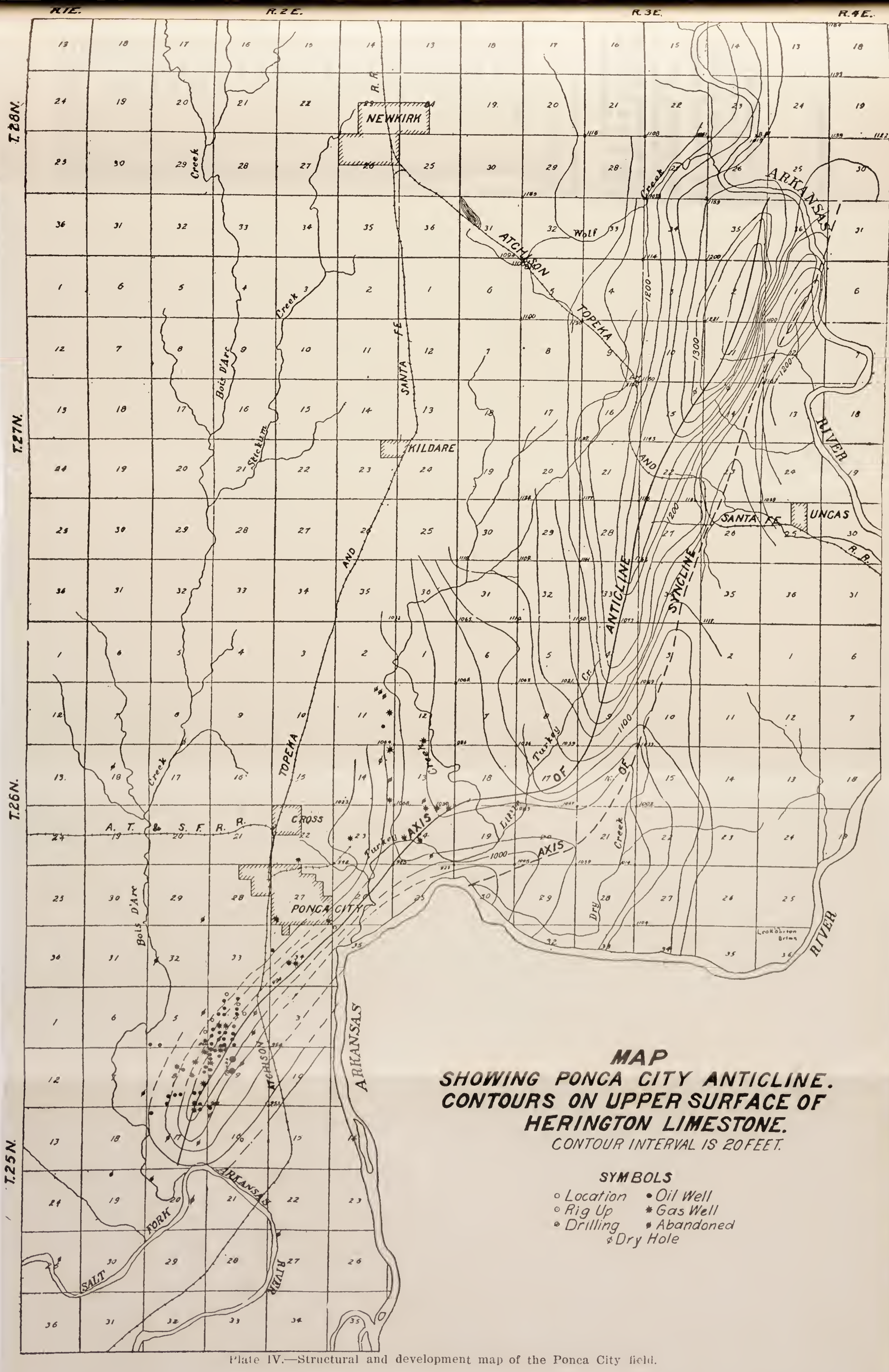


Plate IV.—Structural and development map of the Ponca City field.

Ponca City Pool.

This field has been described recently by D. W. Ohern and Robt. E. Garrett in Bulletin No. 16 of the Oklahoma Geological Survey and the following paragraphs are summarized from that report:

The principal part of the field so far developed is in the north-central part of T. 25 N., R. 2 E. This portion of the field produces both oil and gas. The first development was about 2 to 3 miles northeast of Ponca City in the east-central part of T. 26 N., R. 2 E. The wells in this portion

LOG OF WELL, MOLLIE A. MILLER NO. 2, IN NW. ¼ SEC. 9, T. 25 N., R. 2 E.

	Thickness, Feet.	Depth, Feet.
Soil	4	4
Sand and gravel	50	54
Lime	10	64
Red rock	36	100
Lime	5	105
Red rock	30	135
Sand (gas)	5	140
Red rock	60	200
Lime	10	210
Red rock	50	260
Sand (gas)	15	275
Red rock	75	350
Lime	20	370
Slate, white	30	400
Red rock	50	450
Lime	10	460
Red rock	35	495
Sand (gas)	45	540
Red rock	15	555
Lime	13	568
Red rock	5	573
Lime	7	580
Red rock	13	593
Slate	13	606
Lime	8	614
Red rock	6	620
Lime	20	640
Red rock	5	645
Sand	8	653
Red rock	7	560
Lime	80	740
Black slate	15	755
Lime	8	763
Shale, white	20	783
Sand, broken	12	795
Red rock	5	800
Black slate	15	815
Lime	6	821
Slate, white	25	846
Lime	12	858
Shale, black	12	870
Slate, white	15	885
Lime	5	890
Shale	8	898
Lime	12	910
Shale	20	930
Sand (water)	35	965
Slate	25	990
Lime	5	995
Slate	15	1010
Lime	6	1016
Slate	22	1038
Lime	12	1050
Slate	20	1070
Lime	12	1082
Slate	6	1088
Lime	12	1100
Slate	10	1110
Lime	15	1125
Slate and shells	25	1150
Lime	4	1154
Sand	16	1170
Slate	12	1182
Sand, broken	6	1188
Slate	24	1212
Lime	8	1220
Slate	30	1250
Lime	5	1255
Red rock	5	1260
Lime	3	1263
Slate	27	1290
Lime	9	1299
Slate	12	1311
Sand (water)	30	1341
Slate	5	1346
Lime	2	1348
Slate	15	1363
Lime	5	1368
Slate	32	1400
Red rock	5	1405
Lime, sandy (water)	20	1425
Slate	8	1433
Lime	18	1451
Red rocks	6	1457
Lime	8	1465
Slate	9	1474
Lime	24	1498
Slate	5	1503
Lime	3	1506
Black slate	10	1516
Red rock	7	1523
Sand (oil)	14	1537
Slate, black	22	1559

of the pool are gas wells with the gas coming from a sand about 500 feet deep. The development up to the end of 1912 is shown in the accompanying figure (Pl. V), which also shows the structure of the field. The wells start about the level of the Herington limestone and encounter oil and gas at different depths.

Structure.—The structure in the Ponca City field is a well developed anticline which extends from Arkansas River in sec. 35, T. 25 N., R. 3 E., southwest past Ponca City to Salt Fork of Arkansas River. The northern part of the fold is well defined, but the portion southwest from Ponca City is not so sharply shown. The anticline attains its maximum development in sec. 35, T. 28 N., R. 3 E., and dips very steeply to the north, but gently to the south. The eastern limb of the anticline dips much more steeply than the western. The syncline to the east of the anticline is well developed and its axis is parallel to and about 1 mile to the east of that of the anticline. The structure of the field is shown on Plate V by means of contours drawn on the upper surface of the Herington limestone. This plate also shows the development up to the end of 1912.

Development.—The development of the Ponca City field began in 1905 when a local company put down a well in the south part of the town and found gas at a depth of 500 feet. Other wells were drilled in this neighborhood and sufficient gas was found to supply the local demand. The supply began to fail in 1909 and some drilling was done to the northeast of the town and was rewarded by wells of up to 5,000,000 cubic feet daily capacity in the 500 feet sand. Not until 1911 was oil found in paying quantities. By the end of 1912 there were about 30 producing oil wells. The maximum initial capacity of the individual wells was 1,200 barrels and the average settled capacity about 35 barrels. The oil is of rather deep olive green color. The base is paraffin and the gravity ranges from 44 to 47 degrees Baume. There are 24 gas wells with an average initial production of 6,250,000 cubic feet daily. Of the total number of wells drilled about one-fourth are dry holes. This percentage is abnormally high, but it includes several holes which penetrated only the shallow sand and hence cannot be considered as true test wells.

Productive sands.—The field is underlaid by at least six sands, all of which are more or less productive of oil or gas or both. These sands are as follows in descending order:

(1). A sand about 275 feet below the Herington limestone, or from the surface since most of the wells start about the Herington limestone. This sand is not an important producer of either oil or gas.

(2). A sand about 375 feet below the Herington limestone. This sand produces gas in commercial quantities, but so far has not produced oil. It does not show in the log given.

(3). A sand about 550 feet below the Herington limestone. This is one of the most important gas producing sands of the pool and most of the older wells of the region of Ponca City stopped in this sand. It is probably the sand associated with the Emporia limestone of Kansas from which gas is obtained at Dexter, Arkansas City, Elmdale, and Council Grove, Kans., and which outcrops along Buck Creek in northern Osage County and also southeast of Fairfax in southern Osage County. The well logs show a maximum thickness of 49 feet for this sand with an average of about 25 feet. Several of the wells in this sand have capacities of as much as 7,000,000 cubic feet of gas per day.

(4). A sand about 975 feet below the Herington limestone. This sand is about 35 feet thick and produces both oil and gas. It is possibly the Elgin sandstone, which outcrops at Pawhuska and near Cleveland.

(5). A sand about 1,330 feet below the Herington limestone. It yields quantities of gas up to 6,000,000 cubic feet per day from certain wells, but its importance lies in the fact that it is also productive of oil. A considerable proportion of the oil from this pool is yielded by this sand. The sand varies from 15 to 40 feet in thickness. In general, the thicker sand seems to be productive of oil, while the gas comes from the sand where it is thinner. This sand cannot be correlated with any in the territory to the eastward unless the sand encountered at 112 feet in the Blackburn well be the same.

(6). A sand about 1,550 feet below the Herington limestone. This is the deepest sand which has so far proven productive in the pool. It produces both oil and gas and is the most important sand in the pool. Several wells recorded as gas wells produced 10 barrels of oil natural on being brought in. The sand ranges from 15 to 20 feet in thickness with an average of 17 feet.

Deeper sands.—One sand of considerable importance is known to be present beneath the sands so far found to be productive in the region. In the well of the 101 Ranch Oil Company in the northeast quarter sec. 25, T. 25 N., R. 1 E., a sand 56 feet in thickness was encountered at a depth of 2,520 feet which yielded a "showing" of oil. This sand then lies 970 feet beneath the 1,550 foot sand and is therefore provisionally correlated with that encountered in the Ralston well at 2,140 feet, where a thickness of 70 feet was found. This sand has been correlated with the Cleveland sand of the fields to the east and may reasonably be presumed to underlie the whole Ponca City field.

If the correlations above indicated be correct then the horizon of the Bartlesville sand, which is one of the most productive at Cleveland, Tulsa, Bartlesville, and elsewhere in the Mid-Continent area, should be encountered in the Ponca City field at about 3,200 or 3,250 feet, and the horizon of the Tucker sand which is very productive, especially in the Cleveland field, should show up at about 3,450 or 3,500 feet. No drill has gone to this depth in the present area, and no well in the region should be regarded as a test which has not gone deep enough to reach the horizons of these sands.

The structural sheet shows that the Ponca City anticline is best developed near the north end and there is no doubt but that conditions are here very favorable for the accumulation of oil and gas. The success attending the sinking of test wells will depend largely on the depth to which the drill is sent. As shown elsewhere in this report few holes extend below 1,550-foot sand. Indeed several wells have been labeled "dry" although they reached only the 1,330-foot sand. The dry holes northwest of Uncas did not go down a thousand feet, and therefore mean absolutely nothing as to whether oil and gas may or may not be found in that locality. The discovery of productive sands at 500 feet at Cleveland, 400 to 700 feet in the Cherokee shallow pool, 600 to 700 feet at Dewey, and 550 feet in the present area, while bringing quick returns on certain investments, has in the long run had a disastrous effect on the Mid-Continent field in general. In fact, in none of the pools in north-central Oklahoma does the productive sand lie deeper than 2,700 feet and in most cases at a much shallower depth, as in the Hogshooter, Dewey, Delaware, Coody's Bluff, Nowata, and Alluwe fields, where the chief sand—the Bartlesville—lies at a depth of 1,100, 1,300, 900, 700, and 600, respectively. It is true that at Cleveland the three richest sands lie at 1,400, 1,600, and 2,400 feet, respectively, and those at Cushing occur at 1,400 and 2,100 feet. But even these figures appear diminutive compared with depths reached by wells in West Virginia, where deeper sands—the Gordon for instance—are reached at 3,000 feet or more. In the Santa Maria field of California many of the wells reach a depth of 4,000 feet and more. In Oklahoma many test wells are abandoned before 2,000 feet in depth is reached and these abortive attempts have served only to frighten prospectors away from those localities. In the Ponca City region every part of the anticline should be tested down to a depth of not less than 3,400 feet, the approximate position of the Tucker sand. This deep drilling should be done whether oil and gas are encountered at higher horizons or not.

The most recent development in the field is a 100-barrel well on the northern end of the anticline. This well was brought in about September 1 by the Ponkirk Oil Company (Armstrong and associates). It is located at the center of sec. 2, T. 27 N., R. 3 E., about one-fourth mile from the axis of the anticline. This well indicates very strongly that the whole territory along the axis of the anticline as shown in the structural map of Ohern (Plate V) will prove productive.

*Newkirk.**

About the time development started at Ponca a local

*The descriptions of the Newkirk and Blackwell pools are taken entirely from the paper by Robt. H. Wood which has been cited.

company was organized at Newkirk and drilled a number of wells in and about the town site, in the southwestern part of T. 28 N., R. 2 E. The holes range from 600 to 1,688 feet in depth and it is reported that all produced gas from a sand at a depth of about 600 feet. None of the wells produced very heavily, each averaging from 100,000 to 200,000 cubic feet daily. Some of them are still supplying the inhabitants near by with fuel, but the most of them were drowned out by the inroads of salt water within a year or two after being drilled. The wells at Newkirk are about in strike with those of Ponca, but their heads are probably about 50 or 75 feet higher geologically. With that correction allowed, the different sands should occur at about the same depths as at Ponca. This conclusion is strengthened by a detailed log of the well drilled to a depth of 1,688 feet south of the townsite, in the NE. ¼ SE. ¼ sec. 28, T. 28 N., R. 2 E. This log shows 10 feet of gas at 610 feet, 20 feet of barren sand at 1,360 feet, 10 feet of barren sand at 1,445 feet, and a series of barren sands interstratified with shale from 1,662 to 1,688 feet, the bottom of the hole. The presence of this gas, though not in great quantity, may be significant of a greater accumulation near by. It is regretted that some of the wells were not sunk about 5 miles farther east, where an anticline has been observed crossing Arkansas River.

Blackwell.

In 1904 or 1905 local capitalists began prospecting for oil and gas on the townsite of Blackwell. Much trouble was experienced in drilling through the red beds and the first two or three wells were lost or abandoned without result. Indications of gas were found, however, and prospecting continued to the north. About this time another local company entered the field. Some gas wells were soon "brought in," with a daily production of 200,000 to 5,000,000 cubic feet, and drilling has continued intermittently ever since, until, when the writer visited the pool in February, 1912, 21 gas wells had been "brought in" out of a total of about 37 holes drilled. The pool, as developed, is nearly a mile wide and extends from the town site N. 5 deg.-10 deg. E. for 10 miles through the eastern part of Tps. 27, 28, and 29 N., R. 1 W. In February, 1912, two wells were being drilled in the northern part of the field, beyond any development. The wells range from 650 to 1,500 feet in depth, the main producing sand being found at an average depth of 750 feet below the surface. Gas is also found in other sands in this pool, from 125 to 985 feet in depth, though usually not in paying quantities. A number of logs were procured for study, and although the records differ materially from those at Ponca, it is believed that the principal gas sand at 750 feet is equivalent to the 250-foot sand at Ponca, or possibly a sand found in some places about 100 feet higher. This pool is geologically the highest pool in the State and the lower sands which produce at Cleveland and other parts of the Mid-Continent field, if persistent, should be found from 200 to 300 feet deeper than at Ponca—that is, the Cleveland sand should be reached at 2,800 to 3,000 feet, the Bartlesville sand at 3,600 to 3,800 feet, and the Tucker or Meadows sand, in the "Mississippi lime" (?) of the drillers. at 3.900 to 3,100 feet. A "showing" of high-grade oil was reported from one of the wells just outside the town site to the northwest, in the NW¼ sec. 23, T. 27 N., R. 1 W., but the depth of the sand was not recorded. This well also produced gas. It was capped and the gas has been turned into the mains of the town and the oil ignored.

There are at present two distributing companies, the Union Oil & Gas Co. and the Blackwell Oil & Gas Co., supplying the town of Blackwell, and another company, the Junction Oil Co., is supplying Braman, a town 9 miles northwest of Blackwell. The Wichita Gas Co. is entering the field and hopes to supply the Chilocco Indian School and Arkansas City, Kans., with gas from this pool.

VIII.

OIL AND GAS DEVELOPMENT OUTSIDE THE MAIN FIELD

Besides the occurrence of oil and gas in the northeastern part of the State in what may be called the main oil and gas field, there are several localities in which oil or gas or both have been found in sufficient quantities to be of commercial value or to be important as indicating the limits to which the main field may be extended and the wisdom of further prospecting in certain localities. These occurrences may be divided into three classes, as follows:

(1). Occurrences a considerable distance in advance of the development of the main field to the east and southeast. This group includes the wells or small pools at Wewoka, Coalgate, Poteau, Spiro, Vian, Red Oak, and Kinta. With the exception of the well at Wewoka, all this development has proven productive of gas rather than oil, but the number of wells drilled is yet too small to warrant the conclusion that this will be the case with further development.

(2). Occurrences in the Cretaceous or Red River limestone area along Red River south of the Arbuckle and Ouachita mountains. The only pool in this area is the Madill pool, although there are reported strikes of oil in shallow wells in other localities.

(3). Occurrences around the margins of the Arbuckle or Wichita mountains or between the two mountain groups. This region includes the development at Wheeler, Loco, Duncan (Arthur), Lawton, Granite, and Gotebo.

In the following paragraphs these occurrences are described as fully as the knowledge of them will permit. In some cases the descriptions may seem more detailed than is warranted by the present importance of the field, but since these outlying pools are the indications of the ultimate extension of the producing field it seems best to give all the detail possible concerning them.

OCCURRENCES OF OIL AND GAS TO THE SOUTH AND SOUTHEAST OF THE MAIN FIELD.

All the gas and oil found in the region to the south and southeast of the main field occur in rocks of the same general age as those in which the oil and gas of the main field occur, that is in rocks of Pennsylvanian age. The easternmost occurrences are probably in rocks of slightly greater age than the productive rocks of the main field. The separate occurrences of this region have been mentioned in a preceding paragraph.

Wewoka and Seminole County.—The development in the vicinity of Wewoka up to 1909 was described rather fully by Hutchison in Bulletin No. 2 of the Oklahoma Geological Survey and his description is given here in full.

"As at present developed, the only occurrence of petroleum or natural gas in Seminole County is in two sections lying just east of Wewoka, the county seat. Oil was first discovered here in 1908 when it created considerable excitement. Development, however, has been very slow and the possibilities of the field are not yet determined. This pool is the farthest southwest of any development in the main field. The latest available data show that three companies, namely, the Wewoka Trading and Realty Company, the Southwestern Mining Company, and the Chipco Company, have drilled wells in this region.

"The operations of the Wewoka Trading and Realty Company resulted in one good well and three failures. A pumping test of sixty days showed the producing well to have a capacity of 144 barrels. It is not known whether this company has done any drilling during the past year or not. The Southwestern Mining Company so far as now known, drilled but one well, and it is dry. The Chipco Company, at the time of the last report, had also put in a dry well and had started their No. 2. Operations have been quiescent during the past year, owing in part to the low prices of oil. There seems no reason why the region should not be found a prolific one, for it is well within the geologic province in which oil and gas occur most abundantly in Oklahoma. The following log of well No. 4 of the Wewoka Trading and Realty Company is representative of conditions as reported by the drillers.

WEWOKA TRADING AND REALTY CO. NO. 4, ON SEC. 19, T. 8 N., R. 8 E.

	Thickness, Feet.	Depth, Feet.
Light clay	25	25
Blue shale (sticky)	32	57
Hard light limestone	4	61
Dark blue shale	49	110
Light sand (water 115 feet)	17	127
Shale	7	134
Sandstone (broken formation)	28	162
Blue shale, sand shells about 170 feet	108	270
Red shale	5	275
Soft, light sand full of water	10	285
Hard dark sand	10	295
Shale	35	330
Dark limestone	30	360
Dark shale	30	395
Hard limestone	10	405
Light shale	81	486
Black shale	24	510
Red shale	105	615
Dark and light shale	150	765
Limestone	3	768
White shale	21	789
White sand, much salt water, big oil show	42	831
Light shale	4	835
Very hard white limestone shale	93	938
Sandstone, good show of green oil 931 feet	10	948
Light shale	132	1080
Black shale	25	1105
White shale (soft, caves badly)	10	1115
Hard limestone	5	1120
Sandstone (medium hard)	22	1142
Brown shale	16	1158
Hard white sandstone	12	1170
Dark shale	140	1310
Black shale	13	1323
Hard limestone	2	1325
White shale (caving)	20	1345
Soft, white sand	44	1389
White shale	61	1450
Dark shale, show of oil at 1460 feet	25	1475
White shale, sand and lime shells	58	1533
Hard white sandstone	8	1541
White shale, top of sand; gas when struck	54	1595
Gray sandstone, flows oil and water	2½	1597½
White, soft sand, salt water	13½	1611
Hard white sandstone, hole full of salt water	2	1613
White sandstone	15	1628
Sandstone	10	1638
Blue sandstone	16	1654
Soft white sand	4	1658
Close formation	6¼	1669¼

"No correlation of the formations passed through is attempted, because the stratigraphic relations are not yet determined and it is known that the formations which are found in the regions from Tulsa north, in all probability, do not extend this far south. It may be, however, that some of the limestones recorded in the log occupy nearly the same horizon as some of those north of the Arkansas River.

"The rocks of the region consist of alternating sandstones, shales, and limestones, of which the shales greatly predominate, though sandstones are very abundant. Wewoka is situated about four miles west of what is at present considered the base of the Sapulpa group as described in this paper. Thus the Wewoka wells are begun at about the same horizon as those in the Flatrock and Turley pools north of Tulsa and just a little lower than the horizon at which the wells of the Hogshooter field are sunk. The thickness of the Tulsa group, which immediately underlies the Sapulpa series, is not known in this region, but it seems that the wells, which are usually about 1,650 to 1,700 feet deep must pass entirely below the horizon of the Calvin sandstone, the southern representative of the horizon of the Claremore (Fort Scott) formation. If such is the case the oil at Wewoka occurs at approximately the same geologic horizon as does that of the Shallow field of the Cherokee Nation."

Since the above was written there has been no further development in Seminole County until recently. During

1912 a well was drilled west of the town and was dry at 2,000 feet. Several other wells are located or drilling in Seminole County as follows: The Prairie Oil and Gas Company is drilling a well in sec. 11, T. 9 N., R. 9 E. They are starting with a twenty-inch hole and are intending to drill to 3,000 feet or more if necessary to make a thorough test. The Revenue Oil Company has a well drilling in sec. 32, T. 9 N., R. 8 E. Rigs are up or drilling is going on in sec. 11, T. 7 N., R. 7 E., and in sec. 29 of the same township.

The geologic conditions of Seminole County are very favorable for the occurrence of oil and gas. The rocks are sandstones and shales of Pennsylvanian age and borings should encounter about the same character of rocks as in the other pools south of the Arkansas River. Practically no detailed geologic work has been done in the county, but it is known that there is some gentle folding which should give favorable places for the accumulation of oil and gas.

Poteau.—The small gas field near Poteau, the county seat of LeFlore County, is of considerable importance at present and of still greater importance as an indication of the southeastward extension of the main field. The discussion of the geology and the structure of the county is given in another connection and a brief description is all that is necessary here.

So far nine wells have been drilled in the vicinity of Poteau as follows:

Well No. 1 was drilled in the middle of sec. 27, T. 7 N., R. 26 E. in July, 1910. When brought in it showed a capacity of 1,800,000 cubic feet of gas with a pressure of 304 pounds. After standing open for over two months the well was closed and in November guaged 5,000,000 cubic feet per day at a pressure of 355 pounds. About 300,000 cubic feet per day have been used from this well since November, 1910, and at present the well shows a capacity of 5,000,000 cubic feet per day and a pressure of 412 pounds.

Well No. 2 was drilled on the eastern side of sec. 21 of the same township. Gas was encountered at a depth of 1,803 feet. A week after the well was shut in it showed a capacity of 1,800,000 cubic feet and a pressure of 355 pounds. This well was lost in the summer of 1912 in an effort to remove the casing and 2-inch tubing which had been installed, but which collapsed shortly after being placed.

Well No. 3 was drilled in sec. 3, in the same township, 1 mile from Cameron. The depth is 1,300 feet. The well was allowed to stand full of water for 30 days before shooting and caved badly when attempts were made to clean it out. The capacity now is 600,000 cubic feet and the pressure 300 pounds. This well has been supplying Cameron with gas for the past 9 months.

Well No. 4 was drilled a short distance northeast of No. 3, near Cameron, by the Fort Smith Light and Traction Company. The pressure is reported at 250 pounds and the capacity at about 500,000 cubic feet per day.

Well No. 5 was drilled about the center of sec. 23, T. 7 N., R. 26 E. Gas was encountered at a depth of 1,500 feet and the capacity was about 1,000,000 cubic feet. The tubing and packer dropped shortly after the well was brought in and the well caved so badly when attempts were made to clean it out that the casing was pulled and the well plugged.

Well No. 6 was drilled about the center of sec. 34 of the same township, and shows 2,000,000 cubic feet of gas at 1,600 feet. The original pressure was 350 pounds, but it increased later to 412 pounds.

Well No. 7 is in sec. 34 of the same township. It encountered gas at a depth of 1,535 feet. The capacity is 5,000,000 cubic feet and the pressure 412 pounds.

Two dry wells have been drilled, one near Hill, about 4 miles east of well No. 4 and one about 2 miles west of well No. 3. These wells seem to have missed the sand which is productive in the other wells. Showings of oil were found in two of the wells, but not in sufficient quantity to be of importance.

The sand in the gas wells is reported as being about 220 feet thick except in the well at Cameron, where it was about 55 feet thick. The sand is very hard, about 15 feet per day being average drilling.

There has been no development very recently on account of lack of market for the gas.

According to Taff's mapping the wells are started near the top of the McAlester shale and since this formation is about 2,000 to 2,500 feet thick, the productive sand is almost certainly a sandstone lens or member of the McAlester. It is to be noted that the wells in the Coal County and the Poteau fields are started at approximately the same horizon and encounter the gas producing sands at approximately the same depth.

Coal County.—The development in Coal County is in the extreme northeastern part near the Pittsburg County line. The wells so far drilled are in T. 3 N., Rs. 11 and 12 E. Well No. 1 is in sec. 24, T. 3 N., R. 11 E., in Coal County and is reported to have had 67 feet of oil sand at 1,527 feet and is a gasser, making 6,000,000 cubic feet per day. Well No. 2 is in NE. ¼ of the same section and is reported dry at 1,200 feet, but the casing has not been pulled. Well No. 3 is in sec. 17, T. 3 N., R. 12 E., across the line in Pittsburg County and has a capacity of 12,000,000 cubic feet of gas per day with 117 feet of sand. Well No. 4 is in sec. 20 or 21 of the same township and has a capacity of 8,000,000 cubic feet of gas per day. Well No. 5 is now (July, 1913), going down on sec. 19 and is reported to have excellent sand and good oil showing, but with no gas. Plans are under way to pipe the gas from these wells to McAlester.

Some Bartlesville parties are reported to have leased 10,000 acres southwest of Lehigh in Tps. 1 and 2 S., R. 9 E., which they will begin to develop thoroughly at once. Three rigs are now at work in the county, that of Moran Test Oil Company in T. 3 N., R. 11 E., that of the Wolford Company in sec. 4, T. 1 N., R. 10 E., and that of the Clarion Oil Company in T. 2 N., R. 10 E.

The geologic conditions in Coal County are very favorable for the occurrence of oil and gas. The rocks are the sandstones and shales of the Pennsylvanian area south of the Arkansas River. The wells so far drilled start near the bottom of the Savanna sandstones on the top of the McAlester shale, and the productive sands are almost certainly sandstone members of the McAlester shale. The structure is a series of pronounced anticlines and synclines which have been mapped by Taff in the Coalgate folio. The present development is on the Savanna anticline, which begins about the southwest corner of T. 3 N., R. 11 E., and bears a little north of east across that township to the county line and on northward in the vicinity of Alderson. The anticline rises to a dome just about the Coal-Pittsburg county line and pitches rather steeply to the west, disappearing in the valley of Caney Boggy Creek. The northern limb of the anticline is much steeper than the southern.

The Coalgate anticline begins as a broad indistinct fold west of Phillips and narrows and pitches northeastward toward Coalgate and then rises again into an elongated domelike structure in Coal Creek valley. East of Coal Creek the axis pitches to the east and then becomes nearly level and continues to the northeast almost to Kiowa in Pittsburg County, where it dies out into the southern limb of the Kiowa syncline. Like the Savanna anticline, the Coalgate anticline has much the steeper dip on the northwestern limb.

The approximate location of the crests of these anticlines is shown in Plate II. All of the territory near the crests of these folds should be prospected since the structure is favorable and the prospecting already done has shown large quantities of gas and some showings of oil. In general, the southern limb of the anticlines are more favorable for prospecting on account of their being less steep than the northern limbs.

Other wells.—In addition to the development noted there are a few wells which have proved productive of gas at other localities in this region. Gas is reported in a well about 1,000 feet deep at *Vian* in southwestern Sequoyah County. This well is probably located on the Enterprise anticline. Four wells have been drilled at or near *Spiro* in northern LeFlore County, two wells near the crest of the anticline passing through that place are gas producers and two farther off the axis are dry holes. The capacities of the gas wells are reported at from 750,000 to 3,000,000 cubic feet per day. A well 4 miles north of *Red Oak* in Latimer County is reported to have a capacity of 4,000,000 cubic feet per day. A well at *Kinta* in southern Haskell County is reported to have a capacity of 2,000,000 cubic feet at a depth of 1,700 feet.

OCCURRENCES OF OIL AND GAS IN THE CRETACEOUS OR RED RIVER LIMESTONE AREA.

The geologic conditions of this area with reference to the accumulation of oil and gas have been discussed rather fully in a previous section (pp. 67-69) and the remarks need not be repeated here. The only development in the region which has attained any importance is the pool at Madill. Recently a small deposit of very heavy oil was found at a shallow depth near Mannsville.

Madill pool.—The Madill pool was discovered in the summer of 1906. The principal development was on the Arbuckle farm in the SW. ¼ sec. 25, T. 5 S., R. 5 E. Considerable drilling was done, but the pool was never extended very far beyond the limits of the Arbuckle farm and the number of producing wells was never very great. There has been no marked development in the pool since about 1910 when there were only a few producing wells out of a large number of holes that had been drilled. The production was never very large and for some time has been between one and two tank cars per month. The highest initial production of any of the wells was reported at 1,000 barrels, but according to some observers did not exceed 400 barrels. The oil is a very light oil, having a specific gravity of 47.5 degrees Baume, making it by far the lightest oil so far found in Oklahoma. The base is pure paraffin with no trace of asphalt. On distillation the crude yields about 60 per cent light oil, of which almost one-half is gasoline. The oil is shipped in tank cars from a loading switch near Madill.

OCCURRENCES IN THE REDBEDS NEAR THE ARBUCKLE AND WICHITA MOUNTAINS.

It has been shown in discussing the conditions in the Redbeds in relation to the formation and accumulation of oil and gas that neither of these substances has been found in the greater part of the Redbeds region, and that there are good geologic reasons why they should not be found here. It has also been shown that as the Arbuckle and Wichita mountains are approached the Redbeds thin greatly, and that it is possible to drill through them and to reach older rocks underneath. These older rocks are usually steeply tilted so that any oil and gas which they may have contained has had an opportunity to work up and collect in the lower sandy or gravelly members of the Redbeds. This condition is believed to exist in the different oil and gas fields or pools around the two groups of mountains, namely the Wheeler, Loco, Duncan, Lawton, and Gotebo fields.

The Wheeler pool.—The general geologic conditions of the Wheeler field are given fully in the following paragraphs which were furnished by F. Julius Fohs (of the firm of Fohs & Gardner, Consulting Geologists, of Lexington, Ky.), who made an examination of the pool very recently.

"This pool, which derives its name from an unbuilt townsite in Wheeler township in northeastern Carter County, Okla., is representative in structural features of one of the two types found in the Redbeds, a domed anticline, being similar in character and parallel to but at a shallower depth than the Petrolia pool in Texas. The other principal type of structure, developed in the Electra pool by Udden, shows that both the important structural types which control oil and gas accumulations are represented in the Redbeds.

"In a general way the anticline upon which the Wheeler dome is located strikes northwest-southeast, parallelling the general trend of the Arbuckle-Wichita uplift, and being directly in line with the Criner Hill uplift. It would appear therefore as probable that the direction of these post-Pennsylvanian uplifts was followed by later post-Permian folding of more gentle character, paralleling and following the old established lines of weakness. Cross-folding almost at right angles is responsible for the doming. The pre-Permian beds were very much more sharply folded, turned in fact almost upon edge, especially along the Criner Hill uplift as well as where the larger Arbuckle uplift is approached further north, as that the post-Pennsylvanian erosion which truncated them permitted the escape of most of the oil and gas contained, leaving them only the heavier residues in the form of the asphalt deposits. Thus drilling in this vicinity to greater depth than the base of the Redbeds whose maximum thickness in the Wheeler field is about 1,025 feet, appears unwarranted, and a sheer waste of money expended thereon. Heavy as this oil is—18 to 19 deg. Be.—it appears extremely reasonable that since there is sufficient in the way of shale-bed covering to have prevented the escape of more volatile constituents, that the origin may best be attributed to a reconcentration of the oil residues obtained during the process of erosion of the pre-Permian beds. It appears more than co-incident that the heavy asphalt deposits along the north side of the Criner Hill uplift turned on edge as it is, should be directly in line with the Wheeler dome. Further it is worthy of note that the oil springs at the surface in the Wheeler field, together with the asphalt rock croppings represent what were previously oil accumulations in these upper beds, a fact already generally recognized, but more than this, appear especially here because they were accumulations due originally to the dome structure, and therefore in a manner paralleling the main gas and oil sands below, facts that appear worthy of recognition in the search for other undeveloped pools.

"Three beds of commercial import appear in this field, the two upper ones being chiefly gas-bearing, the lower an oil sand with gas only at the crest of the dome. The uppermost lies about 385 feet above the second, and the latter 292 feet average above the lowest or principal oil sand. The depth to the top of the oil sand varies from 960 to 810 feet. The surface altitudes at the tops of the wells range from 1,010 to 1,078 feet.

"The main oil sand represents the basal sand bed of the Redbeds and varies in character from fine to very coarse almost gravelly sand, while its thickness varies from 10 to 60 feet, and locally is entirely absent either due to old near-shore channels or to its being deposited around old shale knobs, which means that even on the structure the oil is locally absent. The pool seems controlled by a dome where the top of the sand rises from 60 to 140 feet above sea level, without the 60-foot contour salt water being encountered while above the 125 foot contour gas rather than oil is present in all except one instance. The gas sands above are not strictly parallel, but appear to have the crest of the domes slightly to the southwest of that of the oil sand. The general trend of the anticline is northwest-southeast and the dome is necessarily elongated in that direction, having a productive length of three times its width. The gas sands vary in thickness from 3 to 20 feet. Water sands occur irregularly through the measures and locally the deep sand has a water cap.

"Chances for profitable pools northeast and southeast toward the outcrop of the Redbeds appear negative, chances for small pools northwest where other domes are encountered are more encouraging, but of doubtful profitable character, while southwest where the Redbeds thicken, and parallel domed folds occur, the chances are more promising, especially toward the Texas boundary line. We wish to acknowledge our indebtedness to the operators for their kindness in this investigation."

At present there are about 75 wells in the field, of which over 50 produce oil and about 10 produce gas. Almost all the production is from the holdings of the Santa Fe Railway. The initial production of the oil wells is reported by the company at from 2 to 42 barrels and the settled production at from 0 to 28 barrels. The initial capacity of the gas wells ranged from 1,500,000 to 56,000,000 cubic feet per day with most of them showing less than 5,000,000 cubic feet. The highest settled capacity is reported at 2,000,000 cubic feet, with most of the wells showing about 500,000 cubic feet. Some of the gas wells have failed entirely or have been lost for some reason. The state of development in July, 1913, is shown in figure 37.

The oil is piped to Ardmore and used for fuel by the Santa Fe. The gas supplies the city of Ardmore.

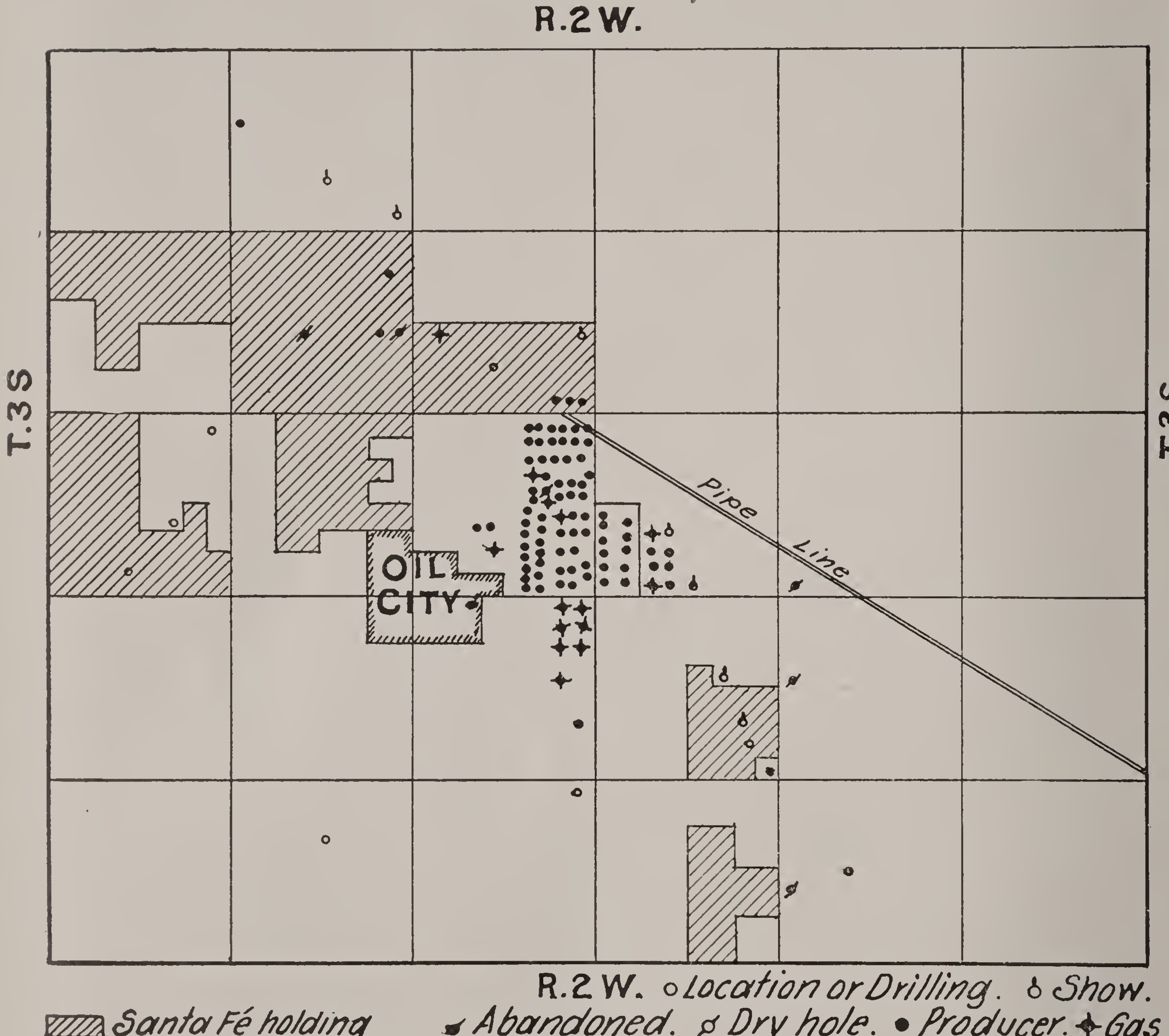


Fig. 37.—Development of the Wheeler pool.

Well at Healdton.—Considerable attention has recently been drawn to a well brought in in August near Healdton in the NE. ¼ sec. 8, T. 4 S., R. 3 W., about 6 miles from the Wheeler development and 28 miles west and 4 north of Ardmore. It was brought in as a flowing well and spouted 10 feet above the top of the derrick. The oil was encountered at a depth of 927 feet. The production has been reported as high as 400 barrels, but the consensus of opinion is that the settled production is about 75 barrels The well is owned by the Union Petroleum Company (Kritchlow and associates). The oil is much lighter than that from the Wheeler wells. A sample collected from a covered tank which had been standing full for several days tested 34 deg. B. at 60 deg. F. The oil is deep green to black in color. Another rig is up on sec. 5, T. 4 S., R. 3 W., northeast of the discovery well and a location has been made about one-half mile to the south.

Loco pool.—The Loco pool is situated in southeastern Stephens County east of Comanche. The geologic relations are apparently precisely similar to those of the Wheeler pool. The oil and gas are found near the base of the Red-beds and the accumulation is said to be controlled by an anticlinal fold. Surface deposits of asphalt are present in the vicinity. Three wells have been completed, all of which show 4 to 6 sands with oil or gas. The wells are located in secs. 1, 15, and 10, T. 3 S., R. 5 W. The well in sec. 1 shows 25,000,000 cubic feet gas capacity at 700 feet, and the one in sec. 15 had an initial production of 60 barrels of oil at 400 feet. Other wells are drilling and located and the pool promises considerable development in the next few months.

The nature of the rocks encountered in drilling in this region is shown in the following logs:

LOG OF WELL, GALLOWAY NO. 3, SW. ¼ SEC. 10, T. 3 S., R. 5 W.

	Thickness, Feet.	Depth, Feet.
Clay	3	3
Sand rock	10	13
Red shale	14	27
Red and blue shale	9	36
Blue shale	10	46
Sands and shale (trace of oil)	8	54
Sand (oil)	11	65
Blue shale	7	72
Red shale	8	80
Brown shale	4	84
Red shale	12	96
Shale and sand	7	103
Sand (oil)	9	112
Red shale	48	160
Red shale and sand	3	163
Brown shale	15	178
Sand (oil, 10 bbl.)	11	189
Brown shale	27	216
Lime	15	231
Brown shale	44	275
Red shale	4	279
Brown shale	7	286
Lime	10	296
Sand (pay oil)	11	307
Red shale	4	311
Brown shale	5	316
Sand (oil)	4	320
Red shale	10	330
Shale (pay oil)	12	342
Blue shale	13	355
Sand and salt water	10	365
Red and blue shale	14	379
Blue shale	13	392
Sand (oil 50 bbls)	15	407
Red and blue shale	5	412
Sand (oil)	5	417
Brown shale	27	444

LOG OF WELL, GALLOWAY NO. 1, SEC. 6, T. 3 S., R. 5 W.

	Thickness, Feet.	Depth, Feet.
Soil	5	5
Blue shale	10	15
White sand (some oil)	10	25
Brown shale	25	50
Limestone	5	55
Blue shale	10	65
White sand	25	90
Limestone	8	98
White sand	12	110
Red shale	15	125
White sand (gas)	15	140
Blue shale	5	145
White sand	10	155
Red shale	32	187
White sand (some oil)	33	220
Red shale	100	320
Sand (some oil)	15	335
Red shale	40	375
Blue shale	10	385
Sand (gas)	3	388
Blue shale	7	395
Sand (oil, 10 bbl.)	12	407
Blue shale	5	412
Red shale	93	505
Blue shale	5	510
Sand (oil, 11 bbl.)	15	525
Red shale	50	575
Blue shale	5	580
Red shale	15	595
Blue shale	25	620
Salt and sand	45	665
Blue shale	10	675
White sand (oil)	20	695
Blue shale	15	710
Salt sand	50	760
Blue shale	50	810
White sand	5	815
Lime	3	818
Blue shale	165	983
Water sand	2	985
Blue shale	70	1055
White lime	10	1065
White sand (oil showing)	5	1070
Blue shale	15	1085
Gray lime	50	1135
Blue shale	15	1150
Gray lime	20	1170
Blue shale	15	1185
Gray lime	25	1210
White water sand	5	1215
Gray lime	20	1235
Blue shale	2	1237
Gray lime	18	1255
Blue lime	5	1260

The limestones from 1235 feet to the bottom of the hole are impregnated with oil.

Duncan pool.—The development in the vicinity of Duncan consists of some gas wells in sec. 12, T. 1 N., R. 6 W., 10 miles east. A well defined anticline extends south from these wells through the eastern tier of sections of T. 1 N., R. 6 W., and then swings southeast across T. 1 S., R. 5 W., and probably beyond the southeast corner of the township south of Velma. The wells are on the east side of the anticline. There are four good gas wells about 800 feet in depth. One well shows 160 pounds pressure and 5,000,000 cubic feet daily capacity; the second well shows 17,000,000 cubic feet capacity with pressure undetermined; the third well, 321 pounds pressure and 13,000,000 cubic feet capacity; the fourth well, a pressure of 340 pounds with a capacity of 17,500,000 cubic feet. Gas from these wells supplies the cities of Duncan and Marlow and the company has franchises in Chickasha and Lawton. One well in section 12 was sunk to a depth of 2,100 feet, but was abandoned on account of trouble with the casing. Good oil showings are reported.

A well was sunk in 1912 on sec. 30, T. 1 N., R. 5 W., to a depth of 900 feet. A good showing of oil was reported but the well was abandoned on account of casing trouble. The depth of this well was not sufficient for it to be considered as being a test of the territory. Four sands are reported from the well.

The Stephens County Oil and Development Company has extensive holdings near the axis of the anticline in townships 1 N. and 1 S., R. 5 W. and in T. 1 N., R. 6 W. This company plans to sink four test wells in the near future in the southwestern part of T. 1 N., R. 5 W. and in the northwestern part of T. 1 S. of the same range. These wells will be carried to a depth of 2,500 feet in an effort to test the territory.

The presence of strong gas wells at the north end of the structure and of asphalt in the vicinity of Velma makes this territory appear very promising.

Lawton pool.—The Lawton pool is located about 5 miles east of the city of Lawton. The first well was drilled in 1904 and drilling has been almost continuous since that time, but it has been on a small scale and the field has never attracted a great deal of attention. There are at present only three or four producing oil wells. Twenty barrels per day is reported as the maximum production of a single well. Some of the gas wells have capacities of up to 500,000 cubic feet. The gas is piped to Lawton and the supply has not been in excess of the demand for domestic purposes. The production is from sands near the base of the Redbeds at about 320 to 400 feet below the surface. On account of the increased price of oil the field is somewhat more active at present than in the past.

Gotebo pool.—A considerable number of wells, almost 100, have been drilled south of Gotebo in northwestern Kiowa County. The geologic conditions are practically the same as for the other pools in the Redbeds area near the Arbuckle and Wichita mountains. The surface rocks are Redbeds sandstones and shales with some conglomerate. These rocks lie nearly level and lap over the granite and older Paleozoic rocks which are exposed in the mountains. Most of the wells are from 300 to 400 feet deep. The oil and gas probably are derived from the older rocks below the Redbeds. The structure of the pool has not been determined. The production of the wells is small and up to 1910 none of the gas wells had shown more than 500,000 cubic feet daily capacity. Data on wells drilled since that time are not available, but it is known that no phenomenal strikes have been made. Hutchison (Bull. No. 2, Okla. Geol. Survey) gives the following log as representing the conditions encountered in one of the deepest wells in the vicinity:

LOG OF WELL SOUTH OF GOTEBO, KIOWA COUNTY.

Character of Formation.	Thickness, Feet.	Depth, Feet.
Red and blue shale and sandstone	500	500
Thin limestone, shale and granite boulders	150	650
Hard blue limestone	80	730
Sandstone and shale, show of gas	20	750
Hard blue limestone	85	835
Red shale (caves badly)	15	850
Very hard limestone	270	1120
Brown slaty limestone	60	1180
White hard flinty limestone mud filled fissures	245	1425
Blue and black shale	200	1625
Grayish limestone	55	1680

Still in the limestone when the drilling was stopped.

Development at Granite.—During the years 1901-1906 seven wells were drilled in the vicinity of Granite in northeastern Greer County. One well on the townsite encountered granite at 380 feet and drilling was stopped. A well northwest of town found oil at a depth of about 180 feet, but the production was only about 3 barrels per day of a heavy oil. In an effort to increase the production by shooting, the well was destroyed. Two other wells in the same vicinity were lost. A deep well about 7 miles north of town was drilled to a depth of 2,135 feet. Several sands were encountered and several good showings of oil and gas were reported, but no production was developed. The Redbeds in this well had a thickness of about 900 feet, showing that the thickness increases very rapidly to the north of the mountains. Only sandstones, shales, and conglomerate were reported in the log. No development has been attempted in the vicinity of Granite since 1906.

IX.

CHARACTER OF THE OKLAHOMA OILS

In spite of the importance of Oklahoma as an oil producing State very little work has been done in the way of investigating the character of the oils. The only extensive series of analyses was made by the United States Geological Survey under the direction of Dr. David T. Day. The results of these tests are included in a table published in Bulletin No. 381 of the Survey. Since this publication is no longer available to the general public it is given here. The samples were collected in the latter part of March and the first half of April in 1908, with the temperature between 60 and 70 degrees. The samples were collected in metal cans, which were immediately soldered so as to prevent all chances for evaporation. One gallon samples were collected from the wells and five gallon samples from the pipe lines and storage tanks. For the benefit of those interested in the chemistry of oil Dr. Day's discussion of the methods of analysis is given in full. The date of collection, temperature of air when sample was collected, and the quantity of sample collected are omitted from the tables.

A set of very delicate specific-gravity spindles was made especially for this investigation, by C. Tagliabue & Sons. The samples were brought to a temperature of 60 deg. in a cylinder cooled in a water bath. The specific gravity was then taken, and the tables show also the conversion of this figure into degrees Baume. The samples were then distilled by Engler's method as modified by Ubbelohde. Thus 100 cubic centimeters of the crude oil, measured at 60 deg., were delivered by a pipette into a distilling bulb holding about 125 cubic centimeters. The dimensions of this bulb are those prescribed by Engler. The thermometer used was a nitrogen thermometer reading to 550 deg. C., which had been carefully standardized by the Bureau of Standards. The condenser tube, as prescribed by Engler, was 75 cubic centimeters long and had an inclination of 75 deg. The point of initial boiling was taken when the first drop of oil fell from the condenser tube into the receiving flask. To avoid loss by evaporation the condenser tube fitted into the graduated receiving flask, which was provided with a stop-cock to draw off the oil at 150 deg. and again at 300 deg. Note was also taken of the proportions boiling within each range of 25 deg., but these details are not published in the tables given herewith. The fraction between the initial boiling point and 150 deg., constituting the gasoline fraction, and the fraction between 150 deg. and 200 deg., constituting the kerosene fraction, were examined as to specific gravity with a picnometer. The residuum was weighed as soon as cool; then its specific gravity was taken in the usual way and the volume calculated. As will be noted, the total thus obtained for the different fractions includes the sum of all variations in the determinations. This total for many samples slightly exceeds 100 per cent, but for a greater number is considerably below that amount, owing to the presence of water—in fact, the percentage of water is thus rather clearly indicated.

The method of Kramer and Bottcher was used for determining the unsaturated hydrocarbons present in the crude oil and in the distillate between 150 deg. and 300 deg. The amount of gasoline was in many samples too small for systematic determination of the percentage of unsaturated hydrocarbons in it. The method consists in shaking 25 cubic centimeters of the crude petroleum with 25 cubic centimeters of sulphuric acid of specific gravity 1.83, corresponding to ordinary pure sulphuric acid, about the equivalent of that used in petroleum refining. The acid and oil are shaken in a small flask with a long neck, the neck holding 25 cubic centimeters. The flask is then filled with strong sulphuric acid until the oil which remains uncombined with the acid can be measured in the neck of the flask. The loss in volume between the original 25 cubic centimeters and the oil which remains undissolved by sulphuric acid is taken to represent the unsaturated hydrocarbons.

Paraffin wax was determined by the Engler-Holde method, two parts of absolute alcohol and one part of absolute ether being used as the solvent, from which the paraffin wax is precipitated on cooling to — 20 deg. C. The asphalt was determined by Holde's method, by weighing off 1 gram of residuum and shaking this with 40 cubic centimeters of gasoline which was free from unsaturated hydrocarbons and which boiled between 65 deg. and 95 deg. C. After shaking this is allowed to stand for forty-eight hours and the precipitated asphalt is dissolved in benzol, dried at 105 deg., and weighed.

Without any detailed discussion of the results, which are given clearly enough in the following tables, it is hoped that these analyses will be of considerable use to the producers and the geologic students of the individual pools. The main purpose of the examination is to afford a comparison of the oils of this region with the oils from other parts of the United States.

ANALYSES

OF

PETROLEUM FROM OKLAHOMA

Serial No.	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
				Tulsa County
1	J. I. Yorgee lease, Robt. Galbreath, Tulsa	3	638	Red Fork Pool.....
2	...... do	5	601	......do..............
3	Van Yorgee lease, Robt. Galbreath, Tulsa	1-7	1240	......do..............
4	Missouri Lincoln Trust Co. lease, L. E. Mallory & Son, Tulsa......................	1	1200	......do..............
5	Pump station at Red Fork, Prairie Oil and Gas Co., Independence, Kans........	*	....	......do..............
				Tulsa County
6	Prairie Oil and Gas Co., Tulsa, Bird Creek district	....	....	Bird Creek and Skiatook pools.
7	N. Chisholm lease, Creek & Indiana Investment Co., Sperry......................	1	1420	......do..............
8	...... do	4	1200	......do..............
9	Smith lease, Shawnee Oil Co., Sperry.....	1	1408	Skitaook pool......
10	...... do	4	1412	......do..............
11	Chisholm lease, Shawnee Oil Co., Sperry.	2	1466	......do..............
12	Grace Berryhill lease, Oklahoma State Oil Co., Kiefer............................	9-13	1500	Glenn pool..........
13	Pittman farm, sec. 7, T. 17 N., R. 12, Argue & Compton, Tulsa....................	11	1500	......do..............
14	Pump station, Prairie Oil and Gas Co., Kiefer	....	....	......do..............
15	Thos. Berryhill lease, Indiana Oil and Gas Co., Kiefer............................	7	1518	......do..............
16	Wm. Berryhill lease, Indiana Oil and Gas Co., Kiefer............................	15	1529	......do..............
17	W. B. Self lease, Prairie Oil and Gas Co., Tulsa	23	1523	......do..............
18	...... do	7	1553	......do..............
19	Corndoffer lease, sec. 18, T. 16, R. 12, Swasey Oil Co., Fort Worth, Texas.....	1	2340	Mounds pool ....
				Okmulgee County
20	Prairie Oil and Gas Co., Morris.............	....	....	Morris pool.........
21	Meridian lease, Brown Oil and Gas Co., Morris	1	1600	......do..............
22	...... do	4	1600	......do..............
23	Buchanan lease, Burns & Caton, Morris	1	1680	Bald Hill pool......
24	J. W. Buchanan lease, J. Harmon. Morris	1	1703	......do..............
				Muskogee County.
25	Evans lease, Julia Oil Co., Muskogee.....	1	1553	Muskogee pool, new field.
26	...... do	3	1473	......do..............
27	K. Stevens lease, Success Oil and Gas Co., Muskogee	2	1558	......do..............
28	J. W. Siebold lease, Success Oil and Gas Co., Muskogee	1	1574	......do..............
29	Fort Worth Development Co. lease, of Richmond Development Co., Muskogee.	1	1702	......do..............
30	G. W. Sadler lease, Huckleberry & Co., Muskogee	3	1735	......do..............
31	Prairie Oil and Gas Co., Muskogee.........	....	....	......do..............
32	Pioneer Oil and Gas Co., Muskogee........	1,2,3	1000	Muskogee pool old field
33	Connolly well, P. Connolly, Muskogee.....	....	1000	......do..............
34	Reeves well, P. Connolly, Muskogee.......	....	1000	......do..............
				Seminole County
35	Wewoka Realty and Trust Co., Wewoka	1	1625	Wewoka pool......
				Kiowa County
36	Ricketts lease, Whitewater Oil and Gas Co., Gotebo	2	365	Gotebo pool.........

*Samples for which no well number is shown were collected from pipe

Physical properties: Gravity at 60° F.: Specific.	Physical properties: Gravity at 60° F.: Degrees Baume.	Physical properties: Color.	Distillation by Engler's method: Begins to boil at (°C.)	Distillation by Engler's method: By volume: To 150° C.: Cubic centimeters.	Distillation by Engler's method: By volume: To 150° C.: Specific gravity.	Distillation by Engler's method: By volume: 150° to 300° C.: Cubic centimeters.	Distillation by Engler's method: By volume: 150° to 300° C.: Specific gravity.	Distillation by Engler's method: By volume: Residuum: Cubic centimeters.	Distillation by Engler's method: By volume: Residuum: Specific gravity	Distillation by Engler's method: By volume: Total (cubic centimeters).	Unsaturated hydrocarbons: Crude (per cent).	Unsaturated hydrocarbons: 150° to 300° per cent).	Paraffin (per cent).	Asphalt (per cent).
0.8368	37.3	Green	88	15.0	0.7195	36.0	0.7945	48.5	0.9073	99.5	22.4	....	2.60	0.0
.8323	38.2	Dark green..	93	9.0	.7220	40.5	.7814	48.5	.9038	98.0	17.6	1	4.39	.0
.8413	37.3	.... do	90	14.0	.7352	37.0	.7992	48.9	.8855	99.9	22.4	2	6.37	.05
.8358	37.5	Black	97	8.0	.7268	44.5	.7882	47.0	.9021	99.5	14.4	3	3.92	.35
.8594	32.9	.... do	110	4.0	.7430	38.0	.7948	55.8	.9103	97.8	18.4	1	4.88	.15
.8626	32.3	Dark green..	120	2.0	......	37.5	.8070	60.6	.9003	100.1	29.2	6	7.30	.28
.8495	34.8	.... do	100	7.0	.7380	38.5	.8018	52.8	.9021	98.3	29.2	9	2.87	.62
.8563	33.5	.... do	122	T.	......	40.5	.8030	57.0	.9021	97.5	14.0	11	8.41	.42
.8480	35.1	.... do	95	6.0	.7348	37.0	.7898	54.9	.9032	97.9	14.8	7	7.35	.23
.8439	35.9	.... do	98	5.0	.7440	36.0	.7858	58.8	.8997	99.8	12.8	10	9.74	.50
.8328	37.1	.... do	68	11.0	.7142	32.5	.7968	51.8	.8974	93.3	13.2	10	6.65	.14
.8459	35.5	Black	112	7.5	.7464	42.0	.7980	50.0	.9061	99.5	21.2	6	5.41	.11
.8459	35.5	.... do	105	8.5	.7566	42.0	.8001	49.9	.9032	100.4	22.8	7	6.98	.45
.8464	35.4	.... do	100	4.5	......	46.0	.7942	49.9	.9032	100.4	27.6	9	5.99	.24
.8439	35.9	.... do	105	8.0	.7508	44.5	.8008	48.0	.9091	100.5	20.8	6	7.53	.90
.8333	38.0	.... do	80	11.5	.7260	43.5	.7964	45.3	.9079	100.3	21.6	4	11.46	.35
.8373	37.2	.... do	94	10.0	.7328	41.0	.7968	47.6	.9021	98.6	16.8	5	3.12	.21
.8424	36.2	.... do	98	10.0	.7402	42.5	.7990	47.6	.9079	100.1	26.4	6	9.70	.51
.8631	32.2	Bright green	175	....	......	38.5	.8126	59.9	.8992	98.4	12.4	4	8.44	.62
.8459	35.5	Light green.	112	3.0	......	34.0	.7924	62.1	.8866	99.1	10.0	1	11.90	.0
.8383	37.0	Dark green..	82	10.0	.7260	30.0	.7988	51.7	.8861	97.1	13.0	3	9.46	.0
.8403	36.6	Green	75	13.0	.7338	31.0	.8008	56.4	.8895	100.4	13.2	8	6.75	.10
.8531	34.1	Dark green..	110	5.5	.7515	36.0	.8018	58.0	.9003	99.5	20.0	8	3.43	.15
.8578	33.2	.... do	131	1.5	......	35.5	.8096	62.4	.8992	99.4	16.4	3	5.70	.76
.8328	38.1	Green	97	11.0	.7332	36.0	.7960	52.8	.8866	99.8	15.2	4	7.64	.0
.8264	39.4	.... do	82	11.0	.7218	36.0	.7976	51.4	.8855	98.4	16.8	5	6.03	.0
.8314	38.4	.... do	93	12.0	.7298	38.0	.7984	50.3	.8861	100.3	15.2	3	2.24	.0
.8343	37.8	.... do	90	7.0	.7316	40.0	.7876	52.4	.8861	99.4	16.8	2	1.24	.0
.8333	38.0	.... do	90	11.0	.7090	37.0	.7986	51.2	.8861	99.2	16.4	8	1.52	.0
.8348	37.7	.... do	98	5.0	.7410	40.0	.7828	54.6	.8855	99.6	16.0	4	6.96	.0
.8358	37.5	Olive green.	99	3.5	.7415	41.0	.7816	55.5	.8838	100.0	17.6	2	12.45	.0
.8216	40.4	Light olive green.	110	5.5	.7415	46.0	.7812	43.7	.8745	95.2	12.0	4	3.88	.0
.8279	39.1	.... do	115	4.0	.7520	48.0	.7856	48.4	.8750	100.4	11.2	2	2.15	.0
.8328	38.1	.... do	140	T.	......	46.0	.7810	53.2	.8745	99.2	12.4	2	4.91	.0
.8844	28.3	Black	128	1.5	.....	30.0	.8266	67.3	.9067	98.8	30.0	3	6.28	.90
.8480	35.1	Black	115	3.5	.7399	46.5	.7828	51.5	.9097	101.5	29.6	15	5.56	1.30

lines or pump station.

Serial No.	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
37	Seney lease, Deering Oil and Gas Co., Gotebo	2	443	......do.............
				Pawnee County
38	Prairie Oil and Gas Co., Cleveland station	....	....	Cleveland pool.....
39	Laterette lease Test Oil Co., Cleveland...	16	....	Cleveland pool in city limits.
40	...... do	17	....	......do.............
41	...... do	15	....	......do.............
42	Ohio and Indiana Oil Co., Cleveland........	8-9	....	......do.............
43	Cory lease, F. M. Martin, Cleveland.......	1	1157	Cleveland pool, Jordan Valley Twp.
44	L. L. Cory lease, J. E. Martin, Cleveland	1	1174	......do.............
45	Berger lease, Prairie Oil and Gas Co., Independence, Kansas	7	1800	......do.............
46	...... do	4	1750	......do.............
47	Lowery lease, Louisiana Purchase Oil Co., Ceveland	2	1620	......do.............
48	...... do	6	1600	......do.............
				Osage County.
49	Prairie Oil and Gas Co., Bartlesville....	....	....	Bartlesvlile pool...
50	Lease 31, Colliver Consolidated Oil Co., Markham & Ball, Bartlesville.............	5	1487	......do.............
51	...... do	6	1480	......do.............
52	Lot 32, Illuminating Oil Co., Bartlesville	20	1500	......do.............
53	T. 26 N., Skelton-Moore Oil Co., Bartlesville	14	1088	Shallow Sand pool
				Washington County
54	Prairie Oil and Gas Co., Bartlesville.....	....	....	Bartlesville pool...
55	T. 27,, Williams lease, Stubbs & Lowe, Dewey,	4	1200	Dewey and north of Dewey
56	Berger lease, Woodward & Roll, Dewey..	1	525	......do.............
57	McEwen lease, Stubbs & Lowe, Dewey..	5	500	......do.............
58	Shaler lease, Bartles Oil Co., Dewey....	7	1250	Webber pool........
59	Stubbs & Lowe, Dewey.....................	2	1200	......do.............
60	(R. C. A.) Adams Oil and Gas Co., Washington, D. C.........................	1	1300	......do.............
				Rogers County
61	T. 24, R. 17, Horace M. Adams, Chelsea..	12	400	Alluwe pool.........
62	...... do	11	400	......do.............
63	Sec. 16, T. 24, R. 16, Steuben lease, H. M. Adams, Chelsea	38	500	Chelsea pool........
64	Sec. 14, T. 24, R. 16, Bennett lease, H. M. Adams, Chelsea,	1	498	......do.............
				Nowata County
65	Sec. 35, T. 27, R. 16, Susan Connor lease, New York and Pennsylvania Oil Co., Nowata,	1	735	Childers pool.......
66	Sec. 8, T. 26, R. 16, Jane Claggett lease, F. D. Bailey, Nowata......................	3	750	......do.............
67	Sec. 31, T. 27, R. 16, Wolf lease, Davis & Berrian, Nowata	1	812	Delaware pool......
68	Sec. 33, T. 27, R. 16, Edgar Bean lease, Van Vleck & Graham Oil Co., Nowata........	4	830	......do.............
69	Prairie Oil and Gas Co., Station 40, Nowata,	....	....	Delaware and Childers pools.
				Nowata and Rogers counties.
70	Prairie Oil and Gas Co., Station 38, Nowata,	....	....	Shallow Sand pool.

Physical properties.			Distillation by Engler's method.								Unsaturated hydrocarbons			
Gravity at 60° F.		Color.	Begins to boil at (°C.).	By volume.									Paraffin (per cent).	Asphalt (per cent).
				To 150° C.		300° C. 150° C.		Residuum						
Specific	Degrees Baumé.			Cubic centimeters.	Specific gravity	Cubic Centimeters.	Specific Gravity.	Cubic centimeters.	Specific gravity.	Total (cubic centimeters).	Crude (per cent).	150° to 300° (per cent).		
.8552	33.7	.... do	128	2.0	......	40.0	.7884	56.9	.9186	98.9	57.2	3	5.01	.31
.8485	35.0	Black	97	10.0	.7428	37.5	.8074	53.2	.8980	100.7	34.8	5	6.06	.20
.8516	34.4	Dark green..	100	9.5	.7794	35.0	.8166	55.4	.8980	99.9	38.4	3	7.75	.03
.8542	33.9	.... do	115	2.5	.7705	40.0	.8060	55.4	.8992	97.9	35.2	2	6.63	.15
.8516	34.4	.... do	103	7.0	.7586	36.0	.8124	56.4	.8980	99.4	39.2	2	7.86	.81
.8516	34.4	.... do	117	4.5	.7670	39.0	.8060	55.9	.8980	99.4	34.8	2	6.62	.30
.8464	35.4	.... do	110	5.0	.7530	44.0	.7992	48.8	.8974	97.8	32.4	3	5.55	.05
.8403	36.6	.... do	108	7.5	.7398	44.5	.7882	48.5	.8974	100.5	33.2	5	5.59	1.18
.8383	36.9	.... do	80	10.0	.7200	43.5	.7978	47.4	.9056	100.9	38.8	7	5.42	1.12
.8605	32.7	.... do	120	1.0	.7603	41.0	.8030	56.9	.8969	98.9	20.4	12	5.68	.92
.8459	35.5	.... do	85	15.5	.7452	36.0	.8119	49.4	.9032	100.9	26.4	....	4.38	.82
.8669	31.5	.... do	140	T.	......	39.5	.8139	60.7	.9038	100.2	25.2	4	7.26	.63
.8584	33.1	Dark green..	130	3.0	.7625	39.0	.8116	58.7	.8980	100.7	25.2	2	5.27	.18
.8521	34.3	Black	115	3.0	......	43.5	.7818	54.0	.8992	100.5	20.4	9	2.73	1.00
.8505	34.6	.... do	105	3.5	.7499	42.0	.7808	51.5	.9044	97.0	30.8	12	2.61	1.34
.8547	33.8	Dark green..	113	3.5	.7574	44.0	.7868	52.4	.9009	99.9	21.0	....	7.90	1.12
.8398	36.7	Black	76	11.5	.7101	35.0	.7869	51.9	.9050	98.4	21.2	8	.....	1.26
.8521	34.3	Dark green..	103	8.0	.7378	37.0	.8090	54.5	.9038	99.5	24.4	4	3.75	.23
.8605	32.7	.... do	103	3.0	......	42.0	.8008	55.7	.9103	100.7	18.8	1	6.07	.47
.8772	29.6	Black	128	1.0	.8549	32.0	.7972	63.3	.9024	96.3	38.0	2	3.50	1.43
.8605	32.7	.... do	80	9.5	.7299	28.0	.7968	58.5	.9241	97.0	34.8	....	3.68	1.26
.8368	37.3	Dark green..	70	13.0	.7214	32.0	.8008	51.9	.9067	97.9	20.8	4	3.01	.94
.8485	35.0	.... do	98	6.0	.7339	40.0	.7928	53.9	.9079	99.9	20.5	11	6.81	.99
.8547	33.8	.... do	95	7.5	.7559	39.0	.8128	53.1	.8906	99.6	30.8	14	2.26	.85
.8413	36.4	Dark green..	67	10.0	.7134	33.0	.7910	54.2	.9091	97.2	21.2	9	6.14	.55
.8413	36.4	Greenish blk	65	15.0	.7245	32.0	.7995	50.1	.9168	97.1	23.2	9	2.89	4.01
.8511	34.5	.... do	80	13.5	.7148	31.0	.8035	54.8	.9168	99.3	26.0	8	9.10	1.26
.8516	34.4	Dark brown	97	6.0	.7206	35.0	.7924	54.6	.9272	95.6	26.4	13	4.16	2.19
.8449	35.7	Dark green..	80	14.0	.7415	33.0	.8035	51.2	.9090	98.2	38.4	10	4.51	.75
.8439	35.9	.... do	78	11.0	.7270	36.0	.8024	51.1	.9091	98.1	22.0	7.5	4.59	.93
.8493	34.8	Light green.	65	16.5	.7435	35.0	.8195	47.4	.9156	98.9	18.4	8	4.19	1.69
.8424	36.2	Dark green..	81	9.0	.7182	38.5	.7966	51.6	.9138	99.1	12.8	10	8.23	1.74
.8500	34.7	Dark brown.	107	3.0	......	42.0	.7918	49.8	.9103	94.8	24.0	3	4.45	.26
.8537	34.0	Black	100	7.0	.7380	39.0	.8034	53.8	.9103	99.8	24.4	3	3.04	.12

X.

THE NATURAL GAS SITUATION

The development of the natural gas resources has been considered in connection with the oil development of the different pools so this matter needs no further consideration. Some brief statements as to the general conditions of the industry should be made.

In the early days of the oil development piping the gas from the State was prohibited and there was little demand for home consumption since there were practically no manufacturing industries in the Territory. As a result vast quantities of gas were wasted. Many gas wells were left open in the hope that they would drill themselves into oil, and no effort was made to conserve any of the gas produced by wells also producing oil.

The remarkably low rates at which gas was offered soon induced manufacturing enterprises to enter the field and when early in 1909 the law prohibiting the piping of gas from the State was repealed the production and value of the gas began to grow by leaps and bounds.

At present the demand for gas is such that straight gas wells are almost never allowed to run wild, and in few cases is it necessary to plug them to await a market. The development of the smelting industry at Bartlesville and Collinsville, and of glass manufacturing at Okmulgee and Tulsa has created a large home consumption. The supply in the pools in the extreme northern portion of the field has been drawn upon so heavily to supply the markets in Kansas and Missouri that many of the wells are rapidly taking water and both capacity and pressure are decreasing with corresponding rapidity. Many of the older pools are undoubtedly past their prime, but the discovery of new wells in proven territory and the development of such isolated pools as those in Coal County, at Poteau in Le-Flore County and at Duncan and Loco in Stephens County indicate that the supply of the State as a whole is by no means approaching exhaustion.

There is still great waste of gas in connection with the wells producing both gas and oil. The situation in the United States in regard to the waste of gas is summarized by David T. Day in Mineral Resources of the United States for 1911, Part I, published by the United States Geological Survey. Since practically all of his remarks are applicable to Oklahoma they are given in full.

WASTE OF NATURAL GAS.

"Recent literature on natural gas has been limited chiefly to essays on the magnitude of its waste. They have been timed, perhaps, for some sensational effect, but have been of slight importance as suggestive of methods of preventing waste.

"In contrast in this respect has been the increasing investment of large amounts of capital by the producers of gas, always with a view to checking waste and to rendering useful and profitable a larger and larger percentage of the total yield from the ground. The effect of these costly conserving efforts has been sufficient to limit the various kinds of waste to those for which there is some definite reason—that is, where some formidable obstacle is offered to the conservation of the gas.

"The chief causes of the waste of natural gas are as follows:

"1. *Free escape of the gas from natural gas wells that have not been closed in.*—A few years ago the development of any gas field with strong pressure was sure to result in one or more wild wells with great waste of gas, caused by inability to shut in the well. The waste thus caused has been so enormous as to stimulate great ingenuity in developing means of controlling such wells, so that it is not likely any gas wells of this character will in the future remain uncontrolled more than thirty days after being struck—even this length of time will be most exceptional. Only one wild well of this character now remains. This is one of the first wells drilled in the Caddo field. Its pressure has greatly diminished. No good excuse can be offered for the continued failure to close it, inasmuch as the companion wild well, not far distant in the Caddo field, was finally closed without any considerable difficulty. The obstacle to closing this wild well in the Caddo field is simply the cost involved as compared to the gain to the company owning the well. Unquestionably, the well should be closed. If this cannot be done by invoking the recent state law, community interests should subscribe the necessary outlay for the general benefit of the field.

"2. *Free escape of gas from oil wells.*—This is the greatest cause of gas waste in the United States. It is a normal incident of great importance in the opening of nearly all oil fields. In the opening stage of development of an oil and gas region, the situation is entirely in the hands of the oil man, as opposed to the gas man. The oil man's sympathy concerning the conservation of gas is distinctly a negative quantity, because of his belief that if the gas be allowed to escape, oil will usually follow it in the hole. This has been frequently the case; but quite as frequently salt water has followed the gas, with serious damage to the field. This free escape of gas from oil wells also remains as a continuing factor through the entire life of the field, for, in contrast to the great gas pressure frequently found in the opening of an oil field, the pressure later on is too small to yield an amount of gas that can be sold at great profit hence the oil man allows it to escape.

"The obstacle to the saving of this 'casing-head' gas consists in the interference during the process with the production of oil, and weight for weight or dollar for dollar the oil produced is generally very much greater than the gas.

"As to a remedy, legislation has been enacted in many states compelling a saving of this gas. Frequently this legislation has been so drastic in character as to prevent its practical enforcement. Reasonable laws controlling this waste can be enforced. This has been shown particularly in Indiana. An example has been given in Oklahoma of too drastic laws, leading to poor enforcement of any state regulations. Altogether, the most hopeful remedy that has been put into force in recent years consists in the co-operation of gas companies, by which much of this casing-head gas and that from isolated gas wells in oil fields is turned over at a profit by the oil man to the gas company. Again, the increased value of this casing-head gas in most oil fields, as a source of gasoline, is also aiding its conservation. Undoubtedly, increased technical efficiency will lead (as at present in a few localities in Pennsylvania) to the extraction of crude oil and gas from the same well by pumping under partial vacuum for the purpose of extracting the natural gas, gasoline, and even small quantities of heavier oils, which are volatilized under this greatly diminished pressure.

"3. *Abuse of gas by the use of its pressure to drive steam engine in oil fields.*—This form of waste has been dealt with so severely by legislation that it has practically ceased to exist, as has also the following abuse.

"4. *Abuse by jetting the gas into oil wells for the purpose of a gas lift instead of an air lift in oil production.*—The objection met with by the would-be conserver of natural gas in this case is that where there is no immediate market for gas, it is considered to have no value. The oil producer considers the waste in this manner as absolutely justified, and he takes the risk of punishment in temporarily continuing these practices. The remedy in most cases consists simply in an application of existing law.

"5. *Wasteful installation of gas burners and lights in oil well drilling.*—The temporary character of this work and the great necessity for a plentiful supply of fuel and for abundant lighting of the well practically takes this out of the category of waste. It is an emergency means to a worthy end, and the waste has been greatly exaggerated and calls for little remedial notice.

"6. *Waste by selling at flat rate.*—The idea prevails that waste of natural gas is a simple matter, consisting of a leakage of gas from the earth in many gas wells. Several very important items of waste, however, are due to the consumers after the gas has been carefully gathered from the wells and after it has become more valuable by transportation to the point of consumption.

Under the form of sale at flat rate there is no incentive to economical use and the objection to economizing the gas can only be met by metering the production. In Kansas and other places where the supply is becoming inadequate, the abolition of the flat rate must be put into effect rapidly.

"7. *Waste from open grates, insufficient furnaces, improperly adjusted mixers, and other causes, by consumers.*—The waste in consumption is most reprehensible because the gas is worth more per unit than at any oil field, all of the gas supplied has an abundant market, and the supply is usually less than the demand. The best way to remedy this waste is through agitation in the public press and by most careful efforts on the part of the distributing company, and this waste can be remedied if the consumption be made more efficient. The supply in most gas regions of the United States could thus be doubled, and there would be fewer cases of deficient supply.

"8. *Overheated buildings.*—This especial form of consuming a wasteful quantity of gas deserves most careful consideration, and its remedy lies in education toward better sanitary conditions of residences and factories."

The magnitude of the natural gas industry in Oklahoma and its rapid development are shown in the following table:

RECORD OF NATURAL GAS INDUSTRY IN OKLAHOMA, 1906-1911.

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	a344
1908	115	860,159	17,567	356	860,159	73	40	b374
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	718

aIncludes 87 wells "shut in" in 1907. bIncludes 100 wells "shut in" in 1908.

NATURAL GAS AS A SOURCE OF GASOLINE.

In the past few years a great deal of attention has been attracted to the manufacture or rather extraction of gasoline from natural gas. In discussing the nature of oil and gas, it was shown that these substances are made up of a series of similar chemical compounds. The simpler members of the series are gaseous, more complex are liquid and solid. There is thus a number of the compounds which are near the line between liquid and gaseous; that is, a small change in temperature or pressure or both may be sufficient to change the liquid to a gas or vice versa. Gasoline is composed of compounds of this sort and the lighter ones easily take on a gaseous form with a slight raise in temperature or a lessening of the pressure.

In the extraction of gasoline from natural gas, the gas is usually subjected to considerable pressure at low temperatures. Some gases will give gasoline on being cooled without an increase in pressure. The heavier portions of the gas are thus condensed to a light gasoline, while the larger portion of the gas, the simplest members of the series of hydrocarbons are not affected. Ordinarily 2 to 4 gallons of gasoline per 1,000 feet of gas are obtained but some gases produce as much as 10 gallons per 1,000 feet. Another method of obtaining gasoline from gas is by the vacuum process or gas pump. The discussion of the methods used in the extraction cannot be gone into here. Those interested in the subject are referred to Bulletin 10 of the United States Bureau of Mines, which can be obtained by writing the Director of the Bureau at Washington, D. C. By the end of 1911 there were 8 plants extracting gasoline from natural gas in Oklahoma with a daily capacity of 4,800 gallons. The total production was 388,058 gallons extracted from 144,629,000 cubic feet of gas, an average yield of 2.68 gallons per 1,000 cubic feet of gas. Other plants were added in 1912 and several others are proposed. The following plants are now operating:

List of companies producing natural gas gasoline.

Operator.	Location.
Alluwe Oil Co.	Delaware, Okla.
Arkansas Oil Co.	Sapulpa, Okla.
C. E. Shoenfelt, Blair Oil Co.	Muskogee, Okla.
J. G. Bradstreet	Muskogee, Okla.
Chestnut & Smith	Keifer, Okla.
Oklahoma Oil Co.	Keifer, Okla.
Consumers Ref. Co.	Cushing, Okla.
T. W. Franchot	Keifer, Okla.
Gasoline Ref. Co.	Muskogee, Okla.
P. F. Smith	Sapulpa, Okla.
Oklahoma Gasoline Mfg. Co.	Keifer, Okla.

Oklahoma Natural Gas Co. . . . . Mounds, Okla.
Oklahoma Petroleum & Gas Co. . . . . Keifer, Okla.
White Turkey . . . . Dewey, Okla.
Producers P. L. Co. . . . . Alluwe, Okla.

XI.

TRANSPORTATION

In the early days of the petroleum industry in the United States the methods of transportation were very crude. The crude oil was placed in barrels holding about 40 gallons, and hauled directly to market or to some navigable stream down which they were floated on barges. With the growth of the industry the tank-car came into use. The first tank-car consisted of an ordinary car truck with two tub-like tanks, each holding about 2,000 gallons. The modern cylindrical tank-car was introduced in 1871.

Attempts to transport oil through pipe lines were made as early as 1862, but the first lines were poorly constructed, so that the leakage was excessive, and it was not until 1865 that a line with sufficiently good joints was built to render this method of transportation really practicable. The use of pipe lines has increased very rapidly since that time, until by far the greater part of the production is transported by this means. The tank-car, however, is still used extensively.

The pipe lines are usually laid in straight lines from the producing fields to the refineries. The oil from the storage tanks at the wells is collected through small pipes into large tanks at the central receiving station. From these tanks it is forced into the large trunk lines by pumps of the Worthington type. Pumping stations are located along the line at appropriate intervals.

Almost all petroleum contains considerable quantities of paraffin, which collects in the pipes and would soon clog them if it were not removed. The removal is accomplished by means of a "go-devil," an instrument which is forced through the pipes by the flow of the oil and which automatically scrapes the paraffin from the inside of the pipe.

The noise made by the scraping of the "go-devil" can be heard above the ground. As the instrument passes through the pipe it is followed above ground by a man on foot who must keep constantly in hearing of the machine, so that if it should be stopped by any cause, it can be located without taking up long sections of the line.

In Oklahoma the first pipe lines were built by the Prairie Oil and Gas Company as extensions of their lines in Kansas. These lines carry the oil from the producing fields to refineries in Kansas and connect with the company's trunk lines to Whiting, Indiana, and to the eastern refineries.

In 1907 the field was entered by the Gulf and Texas companies from the south. These lines were each over 400 miles in length and were built with record breaking rapidity. The trunk line of each company is an 8-inch line.

The Gulf Pipe Line extends from the pumping station at Watkins in the Glenn pool to Sour Lake and Port Arthur, Texas. A second pumping station is located at Chambers, Okla., and others are at Leoni, Big Sandy, Lufkin, and Sour Lake in Texas. The distance between pumping stations varies from 78 to 91 miles. The line is practically straight throughout its length. The building of such a line presented many engineering difficulties, especially in the southern part of Oklahoma, where the trench for considerable distance had to be blasted from solid rock. In this region the pipe had to be hauled as far as 20 miles from the railroad and, in many instances, the sections of pipe, weighing 600 pounds, had to be carried a mile or more on the shoulders of the laborers on account of the roughness of the country. In spite of these and other difficulties the line was constructed at an average rate of two miles per day and was completed on schedule time. The capacity of the line is 14,000 barrels daily and 15 days are required to transport oil the entire length of the line; 5 days of which are required to relay the oil through the pumping stations.

The line of the Texas Company begins at Tulsa and extends southward through Henryetta, Stuart, and Armstrong, Okla., crosses Red River at Denison and continues through Sherman, Dallas, Corsicana, Concord, Bobbin, and Humble, Texas, to Port Arthur and Port Neches. The line was built during 1907, requiring practically a full year for completion. The daily capacity is from 17,000 to 18,000 barrels.

The line of the Oklahoma Pipe Line Company was built in 1910. This line is an 8-inch line, which gives access to the coast at Baton Rouge, La. The capacity of the line is rated at 17,500 barrels per day. The territory traversed by this line is even rougher than that crossed by the line of the Gulf Company and its construction was even a more difficult engineering feat than that of the older line.

The investment of these companies in Oklahoma is very large. The following table gives a synopsis of the lines and tanks owned by the Texas, Gulf, and Oklahoma Companies as reported to the State Corporation Commission in 1911. The report for the Prairie Oil and Gas Company is not given:

COST OF THE TEXAS COMPANY'S PIPE LINES AND STORAGE TANKS IN OKLAHOMA, JUNE 11, 1911.

Cost of pipe lines.

Line.	Miles.	Size of pipe.	Average cost per mile.	Total cost of line.
Red River to West Tulsa..........	167.62	8 in.	$6,652.14	$1,115,032.19
Stuart-Coalgate loop	23.04	8 in.	6,782.44	156,267.64
West Tulsa-Bartlesville	36.01	8 in.	5,935.38	213,732.96
Bald Hill-Okmulgee	6.05	6 in.	3,528.66	21,348.42
West Tulsa-Bird Creek............	14.34	6 in.	4,233.18	60,703.76
Bartlesville-Nowata	24.88	6 in.	4,250.31	105,748.90

Total length of lines, 271.94 miles. Total cost of lines, $1,672,833.87

Cost of Storage Tanks.

Location.	Number of tanks	Cap'y barrels.	Average cost.	Total cost.
West Tulsa	38	37,500	$ 9,953.95	$378,250.00
West Tulsa	2	55,000	10,966.65	21,933.30
West Tulsa	6	6,000	2,424.32	14,545.93
West Tulsa	10	2,000	1,311.01	13,110.12
West Tulsa	1	1,000	1,007.86	1,007.86
West Tulsa	8	500	1,128.32	9,026.61
Henryetta	4	37,500	10,500.00	42,000.00
Armstrong	2	37,500	10,500.00	21,000.00
Bird Creek	12	55,000	10,473.21	120,878.61
Keifer	10	55,000	11,274.40	112,744.04
Bald Hill	1	37,500	8,971.51	8,971.51
Bald Hill	1	25,000	7,256.43	7,256.43
Muskogee	1	55,000	11,822.68	11,822.68
Sapulpa	2	55,000	6,480.38	12,960.76
Bartlesville	2	37,500	8,311.80	16,623.61

Total cost of storage tanks, $792,131.46.
Total cost of pipe lines and storage tanks, $2,464,965.33.

COST OF PIPE LINES AND PUMPING STATIONS OF GULF PIPE LINE COMPANY, DECEMBER 30, 1910.

Watkins Station to Red River.

115.21 miles of main line.

Cost of pipe		$898,339.10
Cost of right of way, laying pipe, etc		189,296.12
Telegraph and telephone lines		79,856.47
Pumping stations		500,652.29
Watkins station	$ 91,323.10	
Grayson station	142,597.85	
Chambers station	139,226.26	
Ten mile station	127,505.08	
Total		$1.668,143.98

Watkins Station to Kelly Station.

Cost of pipe	$322,225.65
Cost of right of way, laying pipe, etc	70,204.66
Telegraph and telephone lines	24,248.51
Pumping stations	39,000.93
Other equipment	45,893.36
Total	$501,573.11
Total for lines and pumping stations in Oklahoma	$2,169,717.09

COST OF PIPE LINES AND PUMPING STATIONS OF OKLAHOMA PIPE LINE COMPANY, JUNE 20, 1911.

Main line, 152.15 miles		$1,025,568.97
Gathering lines 48.21 miles		134,842.82
Pumping stations		537,408.65
Council Hill station	$165,493.51	
Kinta station	149,919.40	
Wood station	171,355.71	
Hamilton station	12,026.08	
Bald Hill station	10,781.78	
Morris station	7,081.31	
Muskogee station	14,366.40	
Timber Ridge station	6,384.46	
Total		$1,697,820.44

The total cost of the equipment of the three companies in Oklahoma in 1911 was thus: $6,332,502.86. The investment of the Prairie Oil and Gas Company and of the private lines of the larger oil companies and the independent refineries will easily bring the total investment in pipe lines in the state to $7,500,000.00.

In addition to the oil, the investment in gas pipe lines is considerable. According to the report of the State Corporation Commission for 1911, the amounts invested in pipe lines by the larger natural gas companies are as follows:

Oklahoma Natural Gas Company	$1,442,918.18
Caney River Gas Company	398,145.26
Galbreath Gas Company	31,649.16
Osage and Oklahoma Gas Company	232,044.32
Henry Gas Company	124,995.29
Total	$2.229,752.21

XII.

REFINING*

The refining of petroleum is a comparatively simple process. As has been shown in the section on the nature of petroleum, the crude oil consists of a mixture of a large number of similar compounds of different boiling points. The refining consists simply in separating the different compounds by heating the crude oil. As the temperature is raised the lighter oils with lower boiling points come off first, and as the temperature is raised compounds of successively higher boiling points and specific gravities are driven off. By condensing the vapor as it comes from the still the crude oil can be separated into almost any number of fractions.

The separation is usually made into naphtha, gasoline, kerosene, lubricating oils and residuum. The percentages of each product differ widely with different crude oils. Many intermediate products are made for special purposes. The residuum is principally paraffin or asphalt, depending on the nature of the crude oil. The asphaltic residuum has found wide application in road making.

The Oklahoma crudes differ widely in composition as has already been shown. The crude from the Wheeler sand is the lightest found in the State and produces 40 per cent of gasoline. The crude from the Wheeler field near Ardmore contains no gasoline and a very high percentage of asphalt. The oil from the Muskogee pool contains practically no asphalt. The oil from the pipe lines in the northeastern part of the State, representing a mix-

---

*For the notes on the refining of Oklahoma oils the writer is indebted to Mr. E. N. Bowen of the Oklahoma National Refining Company.

ture of crudes from different pools, contains about 12 per cent gasoline, and 25 per cent kerosene. Most of the smaller refineries manufacture only gasoline and kerosene, and run the rest through to asphaltic oil for streets aid or to fuel oil. The refineries using the Muskogee crude also make a series of lubricating oils. Lubricating oils are also manufactured from the ordinary Oklahoma crude by the National Refining Company at Coffeyville, Kansas. The manufacturers claim these to be equal if not superior to those made from Pennsylvania crude.

Large amounts of Oklahoma crude are carried to refineries in Kansas, Indiana and the eastern States by the pipe lines of the Prairie Oil and Gas Company and to refineries in Texas and Louisiana by the lines of the Texas, Gulf and Oklahoma pipe line companies. The refineries of the Cudahy and National Companies are also large users of Oklahoma.

There are also several independent companies operating or under construction in the State. The following list gives the names of these companies with the location and daily capacity of their refineries:

LIST OF THE PETROLEUM REFINERIES IN OKLAHOMA.

Name of Company.		Daily Cap'y, Bbls.
Chelsea Refining Company	Chelsea	800
Milikan Refining Company	Vinita	1000
Phoenix Refining Company	Sand Springs	4000
Waters-Pierce Oil Company	Sand Springs	5000
Constantine Refining Company	Tulsa	1000
Texas Oil Company	Tulsa	5000
Uncle Sam Oil Company	Tulsa	600
Cosdon Refining Company	Tulsa	3000
Sapulpa Refining Company	Sapulpa	4000
American Refining Company	Okmulgee	3000
Indianahoma Refining Company	Okmulgee	800
Oklahoma City Refining Company	Oklahoma City	600
Southwest Refining Company	Bigheart	750
Ponca City Refining Company	Ponca City	500
C. B. Shaffer	Cushing	3000
Brown Refining Company	Cushing	500
Cleveland Petroleum Company	Cleveland	500
Muskogee Refining Company	Muskogee	1000
Cudahy Refining Company	Muskogee	500
Coalton Refining Company	Coalton	200
Magnolia Oil Company	Oklahoma City	Proposed

The local refineries last year consumed 15 or 16 per cent of the production, but when those under construction are completed over 30 per cent of the present production will be refined in the State.

XIII.

REVIEW OF CONDITIONS BY COUNTIES

In the following paragraphs an attempt is made to give a brief review of the conditions in relation to oil and gas for each county in the State. It is impossible to discuss each county fully, as this would involve endless repetition. The location of the county is given with respect to the geologic provinces so that those interested in a particular county may easily turn to the discussion of the area or areas in which it lies. Any variations in a county from the conditions of the areas as a whole are noted fully. The counties containing the principal pools are merely noted as being described in connection with the description of the oil and gas fields.

Adair County is entirely in the Ozark Mountain region and the discussion of the area as a whole applies to the county with very little modification. The Boone chert outcrops over practically the whole county and consequently any search for oil and gas must be made with the idea of penetrating this formation which is the Mississippi lime of the drillers. Since commercial quantities of oil or gas have never been found in or below the Mississippi lime in the Ozark region, prospecting in this county cannot be recommended.

Alfalfa County lies entirely in the Redbeds area and is at considerable distance from the eastern outcrop so that the thickness of the beds is probably about 1,000 feet. This condition, coupled with the fact that the surface rocks are very soft and give no exposures from which the structure can be determined, makes it highly improbable that oil or gas in commercial quantities will be found in the county.

Atoka County is situated in the southeastern part of the State. The western part of the county is included in the Arbuckle Mountain region, the northern in the Pennsylvanian area south of Arkansas River, the northeastern in the Ouachita Mountain region and the southern in the Cretaceous area. The only part of the county in which the prospects for oil and gas are at all good is the north-central. However, the structures which are regarded as favorable for accumulation in Coal County to the north die out before they reach Atoka County, so that the prospects cannot be regarded as very encouraging even here. The rocks in the portion of the county in the Ouachita Mountain region are so faulted that there is no chance of finding oil and gas in them. In the Cretaceous area, especially near the Arbuckle Mountains, it is possible that some small deposits may be found, but no surface indications are given as to the more probable localities.

Beaver County lies in the westward extension of Oklahoma known as the Panhandle. The surface rocks are mostly Tertiary sands and clays. These are underlaid at a depth of at most a few hundred feet by the Redbeds, which are exposed in the deeper canyons. The depth to which drilling would have to be carried to reach the base of the Redbeds is certainly prohibitive and consequently there is no indication whatever that oil or gas will be found in the county. The same remarks apply to the other Panhandle counties, Texas and Cimarron, and to Ellis County.

Beckham County is wholly in the Redbeds area and the probable thickness of the red rocks is so great as almost to preclude the possibility of finding oil and gas beneath the surface.

Blaine County lies northwest of the center of the State. It is entirely in the Redbeds area and the red rocks are certainly over 1,000 feet thick beneath the county. The only ledges of rock which can be traced very far are some gypsum beds, and these give no indication of structure favorable for accumulation. The chances, then, for finding either oil or gas in Blaine County are extremely small. It is reported in the newspapers, however, that funds have been raised to drill a test well near Watonga.

Bryan County lies entirely in the Cretaceous or Red River limestone area and the discussion of the prospects for oil and gas in that area applies in full to the county.

Caddo County is situated southwest of the center of the State. All the county except a very small area in the southwest part is in the Redbeds area and over most of the county these beds are too thick for the region to be considered as favorable for oil or gas. The southwestern portion is near the Wichita Mountains and some small deposits may be found in this part of the county. The conditions would be very similar to those of the Loco and Duncan developments in Stephens County.

Canadian County lies just west of the center of the State and is entirely in the Redbeds region. A deep well recently drilled at El Reno showed the Redbeds to be 1,700 feet thick and gave no promise of oil or gas. The conditions make the discovery of any quantity of either substance extremely improbable.

Carter County is in the south-central part of the State. The northeastern part of the county is in the Arbuckle Mountains and the western portion in the Redbeds area Most of the portion south of the mountains is underlaid by rocks of Pennsylvanian age and the extreme southeastern part by the Trinity sand of the Cretaceous or Red River region. The rocks of the county outside the Redbeds area—and the small area of Trinity sand—are so badly folded and faulted that the presence of oil or gas in quantity is very improbable. These older rocks pass out under the Redbeds area and the Trinity sand which lie almost level. The conditions in this part of the county are discussed fully under the Redbeds area and also in connection with the Wheeler field which is in this county.

Cherokee County is situated in the northeastern part of the State. The greater part of the county is in the Ozark Mountain region and the Boone chert is the surface rock of large areas. The southwestern part of the county is in the Pennsylvanian area and the shales and sandstones of the Winslow formation form the surface rocks. The finding of oil or gas in the county is highly improbable except in the southwestern portion and even here the chances cannot be regarded as favorable on account of the shallow depth of the Boone chert (Mississippi lime) and the faulting which is quite common.

Choctaw County. See discussion of Bryan County.

Cimarron County. See description of Beaver County.

Cleveland County lies just south of the center of the State. It is entirely in the Redbeds area and the thickness of the red rocks is probably so great as to throw the county out of the possible oil and gas territory. A test well is now being drilled in the northeastern part of the county.

Coal County lies in the southeastern part of the State. The prospects for oil and gas are rather fully discussed under the heading of Coal County in the section on Oil and Gas Development Outside the Main Field.

Comanche County is in the southwestern part of the State. A large part of the county is in the Wichita Mountain region and the remainder is underlaid by Redbeds, which form a covering of at most a few hundred feet in thickness over the older rocks. Oil and gas have been found east of Lawton and it is entirely possible that other deposits may be found near the base of the Redbeds at a little distance from the mountains.

Cotton County lies immediately south of Comanche and is entirely in the Redbeds region. The Redbeds, however, are probably not sufficiently thick to make it impracticable to reach their base. The general geologic conditions are similar to those of the Electra-Petrolia region in northern Texas and, if the structure can be determined to be favorable, the area is worthy of prospecting. The preliminary report on the structure of a part of the county is given in connection with the discussion of the prospects for oil and gas in the Redbeds.

Craig County is in the northeastern part of the State. The extreme southeastern part of the county is in the Ozark Mountain region. The Bartlesville sand outcrops in the county near Welch and is probably farther to the northwest deeply enough buried to act as a reservoir if the structure is favorable. Only the northwestern townships of this county can be regarded as very favorable for prospecting.

Creek County is considered in the Sapulpa and Cushing districts in the section on the Main Oil and Gas Field.

Custer County is entirely in the Redbeds area and is so far west that the red rocks are undoubtedly several hundred feet thick. Deep wells drilled at Clinton have shown nothing encouraging to further prospecting and the county cannot but be regarded as extremely unfavorable territory for oil and gas.

Delaware County lies entirely in the Ozark Mountain region and the entire surface is underlaid by the Boone chert (Mississippi lime) except some very small areas in the deeper valleys. The prospects for oil and gas in the Ozark Mountain region have been considered in a previous section. It may be repated here that no oil or gas has yet been found in the Boone chert of the rocks beneath it and that therefore the prospects in this county are very poor.

Dewey County lies immediately north of Custer County and the statements made concerning that county apply also to Dewey. There is practically no chance of finding oil or gas in the county.

Ellis County. See discussion of Beaver County.

Garfield County lies entirely in the Redbeds area. The thickness of the red rocks almost certainly exceed 1,000 feet and the surface rocks are so soft that there are no resistant ledges to permit the structure to be worked out even if it exists. These conditions make the county very unfavorable territory in which to prospect for oil and gas. A deep well was drilled near Enid some years ago without results and the city of Enid is now drilling another test.

Garvin County lies principally in the Redbeds area. In the western part the Redbeds are too thick for the territory to be regarded as favorable for prospecting. In the eastern part where the Redbeds are thin or absent and along the south side near the Arbuckle Mountains the conditions are more favorable, but no definite localities can be pointed out as better than any others.

Grady County lies southwest of the center of the State and is entirely in the Redbeds area. On account of the thickness of the Redbeds and the soft nature of the surface rocks which makes it difficult if not impossible to determine the structure, if any is present, the county must be regarded as extremely unfavorable territory for oil or gas.

Grant County lies under the eastern limit of the Redbeds area along the north line of the State. The thickness of the Redbeds in the eastern half of the county is not great enough to prohibit drilling to the underlying Red Rocks. However, the surface rocks are so soft and so deeply covered by soil that no structure can be made out. Consequently any development will have to proceed on a strictly wildcat basis. If the sands which are productive at Ponca City field extend west under Grant County they would be found at depths of 800 to 1,000 feet greater than at Ponca City, which would place the deeper ones practically out of reach. In view of these facts Grant County must be considered as unfavorable territory for prospecting, although it is not impossible that extensive wildcatting in the eastern part of the county may develop some paying wells.

Greer County lies in the southwest portion of the State and, except for a few small hills of granite, is entirely in the Redbeds area. Only the northwestern part of the county, near the Wichita Mountains, can be regarded as even tolerably favorable for prospecting. The development at Granite in this region is described in a previous section.

Harmon County is in the extreme southwestern corner of the State. All the surface is underlaid by Redbeds to undetermined depths. In view of the distance of the county from the Wichita Mountains it is extremely improbable that the base of the Redbeds is at a practicable drilling depth. The surface rocks are soft and give little or no opportunity to determine the structure. Consequently there is practically no chance of finding oil or gas in this county.

Harper County is in the northwestern part of the State. The Redbeds underlie the whole county to an undetermined depth and there are no indications of structure favorable for the accumulation of oil and gas. There is, therefore, practically no chance of finding either oil or gas in the county.

Haskell County is in the east central part of the State in the area of Pennsylvanian rocks south of Arkansas River. The general geologic conditions are favorable for the occurrence of oil and gas and at least three anticlinal folds are known in the county. (See Plate II). The Milton anticline crosses the southern part of the county with the axis lying very near the Rock Island Railway. The

Blaine anticline extends southwestward from Blaine to beyond Sansbois and the Enterprise anticline crosses the northwestern townships. Haskell County, therefore, can be considered as lying entirely in the probable oil and gas field.

Hughes County lies east of the center of the State. It is entirely in the area of Pennsylvanian rocks south of Arkansas River. The nature of the rocks is apparently favorable for the occurrence of oil and gas. No detailed work has been done on the structure, but it is very probable that such work will show favorable localities for prospecting. At the present the whole county must be considered as being in the probable oil and gas field, but the more likely places for prospecting cannot be selected.

Jackson County lies in the southwestern part of the State and is entirely in the Redbeds area. The greater part of the county is at considerable distance from the Wichita Mountains and hence cannot be considered as favorable oil and gas territory. The extreme eastern portion may be considered in the possible filed. A deep well drilled at Altus sometime ago was without result. Oil has recently been reported from a well at Creta, but the report has not been substantiated.

Jefferson County is situated in the extreme southern portion of the State. The Redbeds form the surface rocks of the entire county. The Loco oil and gas pool, in Stephens County, is only a short distance north of the county line, so that Jefferson County must be considered as possible oil and gas territory. In general the probability of finding considerable deposits decreases from north to south across the county.

Johnston County is principally in the Arbuckle Mountain region and the chances for finding oil or gas are extremely poor. The southern part of the county is underlaid by the Trinity sand in which the oil is found in the Madill pool. The sand does not attain sufficient thickness in this county, however, to make the presence of large bodies of oil probable.

Kay County is considered at some length as the Kay County District in the section on the Main Oil and Gas Field.

Kingfisher County is situated northwest of the center of the State and lies entirely in the Redbeds region. As is the case with the other counties in this region there is little evidence of structure, although there are some indications of an anticline near Okarche. The thickness of the Redbeds is so great that the probabilities for the discovery of oil and gas are very small.

Kiowa County is in the Wichita Mountains and Redbeds regions in the southwestern part of the State. The portion of the county to the north of the mountains is in possible oil and gas territory and there is some development at Gotebo which has been described in a previous section. In the portion in the Wichita Mountains the discovery of oil or gas is extremely improbable.

Latimer County lies in the east-central part of the State just west of LeFlore County. The rocks are those of the Pennsylvanian area south of Arkansas River in the northern part of the county and those of the Ouachita Mountains in the southern part. The Ouachita Mountain portion of the county cannot be considered as probable oil and gas territory, although it is possible that some deposits may be found in the region. The northern part of the county is in the probable oil and gas area. The rocks are the Pennsylvanian shales and sandstones and the structure is favorable for accumulation in some localities. The eastern end of the McAlester anticline enters the county from the west where Gaines Creek crosses the county line, and extends east about 10 miles, a point about 2 or 3 miles south of Wilburton, where the fold dies out. South of Patterson a branch of the anticline turns north and extends almost to that town. The fold is not symmetrical, the northern side or slope having much steeper dips than the southern and being in places almost vertical. The Brazil anticline is in the extreme northeastern part of the county. Brazil Creek flows very nearly on the axis of this fold from the head of the creek to where it crosses the line into LeFlore County. This is a low fold with fairly gentle dips. The valley of Brazil Creek should consequently be a favorable locality for prospecting. The extreme eastern portion of the Adamson anticline reaches the northwestern part of the county in the northeast part of T. 2. N., R. 17 E.

LeFlore County lies in the extreme eastern part of the State along the Arkansas line. The southern part of the county lies in the Ouachita Mountain region and the northern part in the area of Pennsylvanian rocks south of Arkansas River. The rocks exposed in the southern part are the Standley shale and the Jackfork sandstone and those in the northern part are the Caney shale, Atoka formation, Hartshorne sandstone, McAlester shale, Savanna formation, and the Boggy shale. The surface of the entire county is quite hilly except in the stream valleys. As has been said in the discussion of the area, the Ouachita Mountain region cannot be considered as a probable oil and gas area so the southern part of LeFlore County is not thought to be a favorable locality for prospecting. The northern part of the county, however, appears to be at least worthy of prospecting. The rocks are of the sort favorable for the occurrence of oil and gas and there is an abundance of folding which should afford chances for accumulation. The approximate location of the anticlines is shown on the map (Pl. II) in connection with the discussion of the structure of the area. The Howe anticline starts near the St. Louis & San Francisco Railroad in the northwest part of T. 15 N., R. 23 E., and extends almost due east for about 15 miles to a point about 3 miles south and a little west of Howe, then extends considerably north of east to a point about midway betweeen Howe and Monroe, where the anticline splits, one branch extending a little north of east past Monroe to the Arkansas line. The other branch, known as the Gilmore anticline, extends north from the fork to a point between Poteau and Gilmore, where it swings to the east and passes out of the State. The Poteau gas field is situated along this anticline. Both branches of the anticline are low broad folds. The syncline between them is known as Sugarloaf syncline from Sugarloaf Mountain, which is produced by the structure.

The Backbone anticline branches from the Milton anticline about 5 miles west of Bokoshe and extends a little south of east past that town about to the line between Tps. 24 and 25, where it merges with the Backbone fault. This fold is narrow and flat in the western part where the dip of the sides is from 5 to 10 degrees. To the east the fold becomes sharper and the dip becomes especially sharp on the south side where it is as much as 25 degrees.

The Brazil anticline is a low fold on which Brazil Creek flows. It enters LeFlore County from Latimer near the northeastern corner of the latter county and extends northeast past Walls and Brazil. About the center of T. 8 N., R. 23 E., it merges with the Backbone anticline.

The Milton anticline enters the county about midway between McCurtain and Milton and extends east-northeast to the Arkansas River south of Redland. West of Bokoshe the fold forks the one branch extending east is the Backbone anticline and the branch extending on to the northeast is known as the Redland anticline. The anticline is in general a low, narrow fold.

While there have been no phenomenal developments in LeFlore County, the northern part of the county must be considered as promising territory. The nature of the rocks and the structure are favorable in several localities and the gas field at Poteau proves that there are considerable quantities of gas at any rate in the underlying rocks. No oil has as yet been encountered, but the conditions are such as to render its presence in some of the folds probable.

Lincoln County lies northeast of the center of the State. The eastern margin of the Redbeds lies east of the middle of the county so that the greater part is in the Redbeds area. The red rocks are thin except in the extreme western part of the county and the whole area must be considered in the probable oil and gas field, but the probabilities of finding large bodies of either substance decrease rapidly from east to west across the county. The structure has not been fully worked out, but there are good indications of structure favorable for accumulation in the eastern part of the county.

Logan County lies north of the center of the State. It is entirely in the Redbeds area, but the thickness of the Red rocks in the eastern part of the county is probably not great enough to prevent development of oil or gas deposits in the underlying rocks. The chances for finding such deposits, however, are small at best and decrease rapidly from east to west across the county. The principal productive sands of the fields to the east are at practically prohibitive depths beneath Logan County.

Love County is situated in the extreme southern part of the State, principally in the Cretaceous region. While there is a possibility that some oil or gas may be found in the Trinity sand the distance from the Arbuckle Mountains renders the chances very small and the county as a whole cannot be regarded as favorable territory for prospecting.

McClain County is situated south of the center of the State. The county is entirely in the Redbeds area and the conditions are almost precisely similar to those of Cleveland County, which has been described.

McCurtain County is in the extreme southeastern corner of the State. A belt about 12 to 20 miles wide along the southern edge of the county is in the Red River limestone region and the remainder is in the Ouachita Mountain region. The prospects of oil and gas in each of these regions have been discussed rather fully in a previous section and the discussion need not be repeated here. The county must be regarded as improbable territory in which to find oil and gas. It is possible that detailed geologic work may prove the existence of areas in which prospecting would be justified, but no such areas can be designated at present.

McIntosh County lies in the east central part of tne State. It is entirely in the region of Pennsylvanian rocks south of Arkansas River, and is consequently in the probable oil and gas field. Some of the folds which are prominent farther east probably extend into McIntosh County, but their locations cannot be given. There has been some development in the northwestern part of the county.

Major County lies in the northwestern part of the State. It is entirely in the Redbeds area and is far removed from the eastern margin and from the Arbuckle and Wichita Mountains that the thickness of the red rocks is very great, probably in excess of 1,500 feet. The only ledges of rock which can be traced for any considerable distance are the gypsums on the south side of Canadian River and these lie practically level and show no indications of minor structure favorable for accumulation. There is practically no possibility of finding oil or gas in the county.

Marshall County lies entirely in the Cretaceous or Red River limestone area. The Madill oil field is in this county. The prospects for oil and gas are given fully under the discussion of the Madill pool and the prospects in the Red River limestone area.

Mayes County lies in the northeastern part of the State. The eastern part of the county is underlaid by the Boone chert and there is almost no chance of finding oil or gas east of the M., K. & T. Railway. In the western part of the county there is a possibility that some small deposits may be found in the sands immediately above the Mississippi lime, but the principal sands of the main field outcrop to the west of the county.

Murray County lies in the south-central part of the State. The greater part of the county is in the Arbuckle Mountain region and is consequently poor territory for oil and gas. Some development may be made in the region just north of the mountains, but even here the prospects cannot be considered encouraging.

Muskogee County contains the Muskogee oil pool which is described in another section. The extreme northeastern part of the county is in the Ozark Mountain region. All the rest of the county lies in the probable oil and gas territory.

Noble County is in the north-central of the State. All the county except the extreme northeastern part is in the Redbeds area. The remarks on the conditions in Lincoln and Logan Counties are applicable to Noble. Some drilling has been done, so far without success, and other wells are in prospect.

Nowata County is in the northern part of the main oil and gas field and has been considered fully under the head of the Nowata District.

Okfuskee County is situated to the east and a little to the north of the center of the State. The same sands which are productive near Okmulgee and Henryetta almost certainly underlie Okfuskee County, although they will be found at a greater depth than farther to the east. From some very hasty trips in the county it appears that the structure is favorable for accumulation. The whole county then must be considered as probable oil and gas territory, although not enough work has been done to make it possible to pick out the more favorable localities for prospecting. The development of the Okmulgee district has extended westward into the extreme northeastern part of Okfuskee County. A good gas well has been found at Okemah. A few dry holes have been drilled, but not enough to condemn any great area of the county. Prospecting is active at present and several wells are drilling or located. Practically the entire county is under lease.

Oklahoma County is about the center of the State. It is entirely in the Redbeds area and the red rocks are probably over 1,000 feet thick over the whole county. There are no surface indications of structure. The chances for finding oil and gas are, therefore, extremely small. A well was drilled near Spencer some years ago without finding anything of promise. A well is now being drilled at Oklahoma City.

Okmulgee County is considered as the Okmulgee District in the section on the main oil and gas field.

Osage County is considered as the Osage District in the section on the main oil and gas field.

Ottawa County lies in the extreme northeastern corner of the State. The rocks of the greater part of the county are the Mississippian rocks of the Ozark Mountains. The Boone chert occupies practically all of the county east of Spring and Grand Rivers. The northwestern part of the county is in the area of Pennsylvanian rocks, but only the basal portion of the Cherokee shale outcrops. The Bartlesville sand outcrops a considerable distance to the west of the county line. The prospects for finding oil and gas in the county are not favorable. It is possible that drilling in the extreme northwest portion might find some small deposits in the sandstones and limestones in the Chester, the upper formation of the Mississippian.

The presence of an asphalt deposit north of Miami and of heavy bitumen in the lead and zinc mines in the same vicinity prove these rocks to be petroliferous. If the structure is favorable farther to the northwest, the covering of shale is probably of sufficient thickness to form a good cap and to prevent the escape of the oil to the surface. It is improbable, however, that any very large deposits exist in this county.

Pawnee County is considered under section on the main oil and gas field.

Payne County lies to the southwest of Pawnee. All the county except the extreme northeastern portion is in the Redbeds area. The Cushing field is in Creek County just east of the county line and the recent developments have extended to the westward into Payne County. Some drilling has been done at the town of Cushing, at Ripley and at Stillwater, but the wells were not sufficiently deep to test the territory. The eastern part of the county is regarded as probable oil territory, but the chances decrease rapidly to the west.

Pittsburg County lies principally in the Pennsylvanian area south of Arkansas River and must be considered as probable oil and gas territory. The county is crossed by the Savanna, McAlester and Milton anticlines as shown in Plate II. The gas field which has been discussed as the Coal County field extends into Pittsburg County. The southeastern portion of the county is in the Ouachita Mountain region and is very unfavorable for oil and gas.

Pontotoc County lies southeast of the center of the State. The greater part of the county is in the Pennsylvanian area and is in the probable oil and gas field. A large area in the southern part of the county is in the Arbuckle Mountains and the prospects for oil and gas are very poor.

Pottawatomie County lies just southeast of the center of the State. With the exception of small areas in the eastern part, the county is in the Redbeds area. The red rocks thicken rapidly to the west and are probably over 1,000 feet thick in the western portion of the county. The chances for oil and gas are not very favorable, although there is a possibility that the eastern part of the county may prove productive.

Pushmataha County lies almost entirely in the Ouachito Mountain region, and in the present state of our knowledge this region must be regarded as very unfavorable territory in which to prospect for oil or gas, although it is possible that detailed work will show that part of the area is at least worthy of prospecting. The conditions in the Ouachita Mountains are discussed in some detail in a previous section.

Roger Mills County, like the adjacent counties in the Redbeds area in the western part of the State, cannot be considered as at all favorable territory for prospecting for oil and gas.

Rogers County lies in northeastern Oklahoma and is entirely in the probable oil and gas field. There is considerable development at different points in the county. (See the description of the Coody's Bluff-Alluwe and Collinsville pools.)

Seminole County is discussed fully in the section on oil and gas development outside the main field.

Sequoyah County lies principally in the Ozark Mountain region and the prospects for oil and gas are very poor. A belt along the south side of the county is in the Pennsylvanian area and is in the probable oil and gas field. Some gas has been found at Vian.

Stephens County is in south-central Oklahoma. It is entirely in the Redbeds area, but is between the Arbuckle and Wichita Mountains, so that the prospects for oil and gas at shallow depths are good. The Loco and Duncan fields, which have been described, are in this county.

Texas County. See discussion of Beaver County.

Tillman County lies in the Redbeds area in the southwestern part of the State. The Electra field in Texas is directly across Red River from Tillman County and the conditions are apparently the same in the Oklahoma as on the Texas side of the river. The discussion of the structure of the eastern part of the county is given under the section on the oil and gas prospects in the Redbeds.

Tulsa County is included in the Tulsa and Sapulpa districts in the section on the main oil and gas field.

Wagoner County is situated in the northeastern part of the State. The northeastern corner of the county is in the Ozark Mountain region and the Mississippi lime underlies most of the eastern part at so shallow a depth that the finding of oil or gas in quantity is very remote. The western part of the county is within the probable field and there is some development in different localities in this part of the county.

Washington County is considered as the Bartlesville district in the section on the main oil and gas field.

Washita County is underlaid entirely by a considerable thickness of Redbeds and no structure favorable for accumulation of oil and gas has been made out.

Woods County lies entirely in the Redbeds area and the Redbeds are probably over 1,000 feet thick under the whole county. The eastern part of the county has very little rock outcropping and the heavy ledges of gypsum in the western part show no indications of structure favorable for oil and gas accumulation. The deepest well so far drilled in the State is at Alva. Nothing to encourage further prospecting was found in drilling this well. The Redbeds were passed through at a depth of about 1,100 feet. The county cannot be considered as at all favorable territory for prospecting for oil and gas.

Woodward County lies immediately southwest of Woods County. There are no indications whatever of oil or gas in commercial quantities beneath the surface of the county.

INDEX