EXPLANATORY NOTE

The manuscript for this bulletin was submitted to the printer in April, 1910. Proof for the greater part of it was not returned until after Mr. Hutchison's connection with the Survey had terminated, in November, 1910. Most of the proof has been read by the present members of the Survey staff.

The rather unusual arrangements of plates and figures has been found necessary on account of the fact that practically all the maps, which were prepared under Mr. Hutchison's direction, bear a number referring to the Index map, shown as Figure 2. On this account the maps have been designated as figures, while the photographs are called plates.

OKLAHOMA GEOLOGICAL SURVEY
Governor Lee Cruce, State Superintendent R. H. Wilson, President A. Grant Evans, Commission.

Chas. N. Gould, Director.

BULLETIN NO. 2

PRELIMINARY REPORT ON THE ROCK ASPHALT, ASPHALTITE, PETROLEUM AND NATURAL GAS IN OKLAHOMA

By L. L. HUTCHISON

Norman.
March, 1911.

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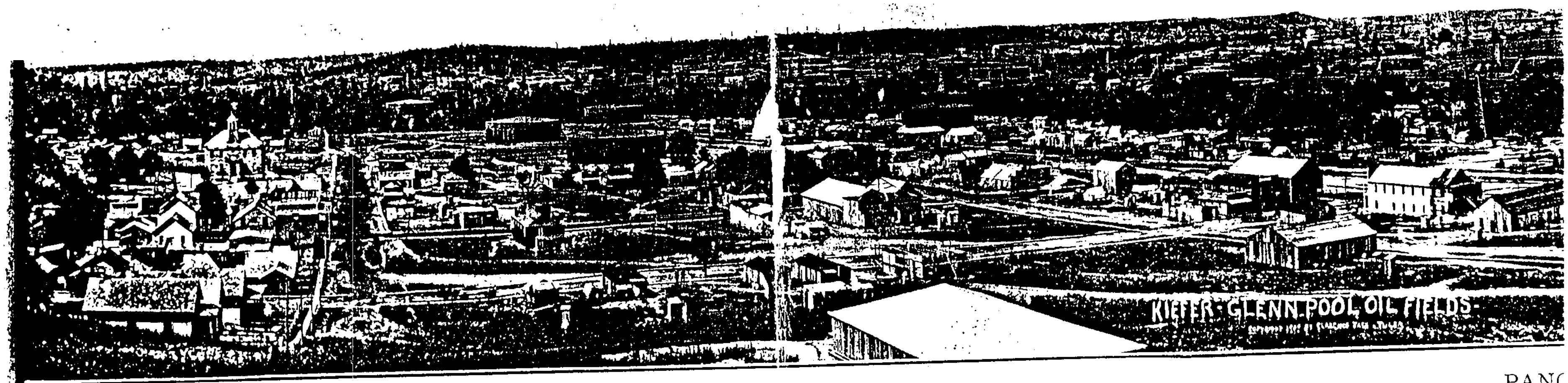
PART I

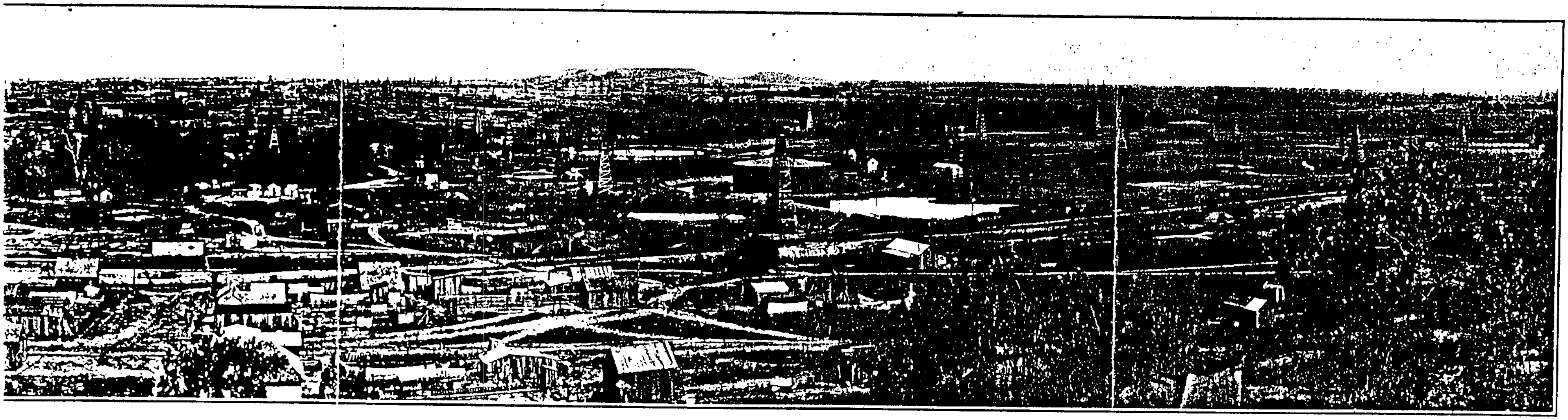
ROCK ASPHALT AND ASPHALTITE OF OKLAHOMA

ROCK ASPHALT AND ASPHALTITE IN OKLAHOMA



report is intended to be only preliminary. The time and funds available are inadequate for the special investigations necessary

1 Taff, Jos. A., U. S. Dept. Int. Cir. No. 6.



L FIELD.

ROCK ASPHALT AND ASPHALTITE IN OKLAHOMA

BY L. L. HUTCHISON.

CHAPTER I.

GENERAL STATEMENTS.

In presenting the following account of the rock asphalt and asphaltite deposits of Oklahoma, the aim has been to give a general notion of the nature of the materials discussed, their mode of occurrence, and as comprehensive a discussion of the general and local geology as present data will permit. The discussion concerning the occurrences east of the main line of the Gulf, Colorado and Santa Fe Railroad is based upon the writer's personal investigations, while that on the deposits in western Carter and eastern Jefferson and Stephens counties is based upon the field notes of Ben C. Belt who assisted the writer in the field investigations in 1909. Wherever the results of other investigators have appeared to be of advantage they have been freely used. The writer wishes especially to acknowledge the merit of the excellent papers and maps by Joseph A. Taff [1] and Geo. H. Eldridge,[2] both of the Federal Survey, which have been freely drawn upon as occasion presented itself.

The citizens of the region were uniformly courteous and assisted in the investigations whenever possible. To mention all who lent aid in the work would be to compile a complete roster of those with whom I conversed on the subject. There are, however, a few to whom special mention is due for extraordinary assistance, and occasion is here taken to thank these persons for their courtesies. Mr. Tom Wall, of Poteau, assisted nobly in the study of the deposits at Page; Mr. F. W. Temple, of Idabel; Dr. A. C. Nash, of Antlers; Mr. Thomas, and The Choctaw Asphalt Company, of Jumbo; Hon. Peter J. Hudson, of Tuskahoma; Mr. Newman, of Atoka; Mr. Tipton, of Ada; Messrs. Baughman and Lawrence, of Roff; Mr. Downard, of Ardmore; and Messrs. W. J. Williams and J. D. Kerby, of Sulphur, were all active in furthering the investigations in their respective communities.

This report is intended to be only preliminary. The time and funds available are inadequate for the special investigations necessary

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1 Taff, Jos. A., U. S. Dept. Int. Cir. No. 6.
Am. Jour. Sci., 4th ser., vol. 8, p. 219 et seq.
Am. Geologist, vol. 24, p. 318 et seq.
Bull. U. S. Geol. Survey No. 380.

2 Eldridge, Geo. H., The asphalt and bituminous rock deposits of the United States: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 1, 1901, pp. 262-320.

to determine the chemical composition and peculiar characteristics of the various asphaltite deposits; the per cent of bituminous saturation of the many deposits of rock asphalt examined, or the special qualities of either which render the individual occurrences more or less desirable for paving or other industrial purposes. Since, however, the question of asphalt paving is a very live one in Oklahoma, and the literature on the subject is meager, a chapter is devoted to general paving methods and suggestions are made as to what it seems may be good methods of using Oklahoma rock asphalt for pavements. These suggestions, however, are theoretical and only time and experience can prove their value.

Coal, asphalt, paraffin, naptha, petroleum, natural gas, etc., form a series of bodies composed of an intimate mechanical mixture of allied chemical compounds consisting of carbon and hydrogen and are, therefore, known as hydrocarbons. The end products of this series are marsh gas (CH_4) on the one hand, and graphite (C) formed as a last product of the metamorphosis of coal or other carbonaceous matter, on the other.

The following classification of hydrocarbons and kindred substances is here offered to show the wide range of these minerals in nature.

CLASSIFICATION OF HYDROCARBONS AND ALLIED SUBSTANCES.

Partial List of Natural Hydrocarbons.

I. Gaseous.
        a. Marsh gas.
        b. "Natural gas."
II. Bitumenous.
    A. Fluid.
        a. Naptha.
        b. Petroleum.
    B. Viscous.
        a. Maltha.
        b. Mineral tar.
        c. Brea.
        d. Chapapote.
    C. Elastic.
        a. Elaterite.
        b. Wurtzilite.
    D. Solid.
        1. Asphaltite.
            a. Albertite.
            b. Impsonite.
            c. Grahamite.
            d. Nigrite.
            e. Gilsonite (uintaite)
        2. Coal.
            a. Lignite.
            b. Sub-bituminous.
            c. Bituminous.
                1. Cannel coal.

            d. Semi-bituminous.
            e. Semi-anthracite.
            f. Anthracite.
                (Graphite.[3])
III. Resinous.
    1. Amber.
        a. Retinite.
        b. Gedanite.
        c. Glessite.
        d. Rumanite.
        e. Simetite.
        f. Krantzite.
        g. Chemawinite.
    2. Copalite.
    3. Bathvillite.
    4. Geocerite.
    5. Leucopetrite.
IV. Cereous.
    1. Ozocerite.
        a. Zietrisikite.[4]
        b. Chrismatite.
        c. Urpethite.
    2. Hatchettite.
    3. Napalite.
V. Crystalline.
    1. Fichtelite.
    2. Paraffin.[5]
    3. Scheererite.
    4. Hartite.
    5. Idrialite.

GROUPING OF NATURAL AND ARTIFICIAL BITUMINIOUS COMPOUNDS.[6]

I. Natural.
    A. Impregnating natural rock or earthy matter.
        1. Asphaltic limestone.
        2. Asphaltic sandstone or sand.
        3. Asphaltic shale.
        4. Asphaltic earth.
    B. Fluid.
        1. Refinery residuum. (Liquid state.)
        2. Exudations from the outcrop of petroliferous strata.
II. Artificial.
    A. Viscous.
        1. Gas Tar.
        2. Pitch.
    B. Solid.
        1. Refined Trinidad asphaltic earth.
        2. Mastic of asphaltite.
        3. Gritted asphaltic mastic.
        4. Paving compounds.
        5. Sheet roofings, etc.

The above classification is in part original and in part that given by Eldridge[7] and Richardson.[8] By inspection it is seen that it is impossible to establish hard and fast classes into which the various natural hydrocarbons may be grouped. To say, for example, that one coal is semi-anthracite and another closely allied to it is anthracite

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3 Not to be considered as a hydrocarbon but as an end product in the metamorphosis of coal.
4 Near ozocerites.
5 Native crystalline paraffin is rare.
6 The list is not complete.
7 Eldridge, Geo. H., The asphalt and bituminous rock deposits of the United States: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 1, 1901.
8 Richardson, C., The modern asphalt pavement, 1908.

is impossible, for the gradation of one into the other is so gradual that the line of separation is imperceptible; and the question of whether a mineral is grahamite or impsonite seems to resolve itself, in the main, into the individual conception of what constitutes a mineral species. The classification given here appears more satisfactory than any met with in the literature at hand.

On account of lack of agreement as to the meaning of the terms "asphalt" and "asphaltum," they have been purposely omitted in the table, and in general, from the text. Some authorities have proposed to limit the meaning of asphalt or asphaltum to denote only the purer forms of hydrocarbon compounds, here designated as asphaltites. Richardson[9] defines asphalt as "a mineral pitch, found in nature in a more or less solid state, melting at a temperature in the neighborhood of that of boiling water, and miscible in all proportions with heavy petroleum oils or fluxes to form a viscous cementing material, which is in use in paving and other industries." This is purely an industrial definition. The oil operator thinks of asphalt as the substance which gives the black color to many of our petroleums, and chemically his idea is as correct as Richardson's; while one living in the vicinity of asphaltic rock deposits commonly thinks of asphalt as a peculiar kind of rock. The term bitumen, it seems, has been mainly applied to petroleum, maltha, or mineral tar, and the solids here classed as asphaltites.

These ideas concerning the terms asphalt, asphaltum, and bitumen are so firmly fixed in literature and in the minds of many, that it seems inadvisable to use either, though the adjectives, "bituminous" and "asphaltic" are freely employed, as is also the term rock asphalt. As used here a "bituminous" rock is one whcih contains a perceptible amount of some natural hydrocarbon, whether it be solid, liquid, gaseous, asphaltic or otherwise; while "asphaltic sandstone," "asphaltic limestone," "sand asphalt," "lime asphalt" etc. are used to designate those respective kinds of rock, as they occur in nature, impregnated with asphaltic hydrocarbons; rock asphalt is used as a generic term referring to asphaltic rock, without reference to the kind of rock.

The classification and terminology here used doubtless merit criticism from some view points, but they seem to lend themselves better to a clear discussion of the geology and character of the Oklahoma occurrences of natural hydrocarbons than any yet offered by authorities at hand, and it is thought there can be little objection to their general use.

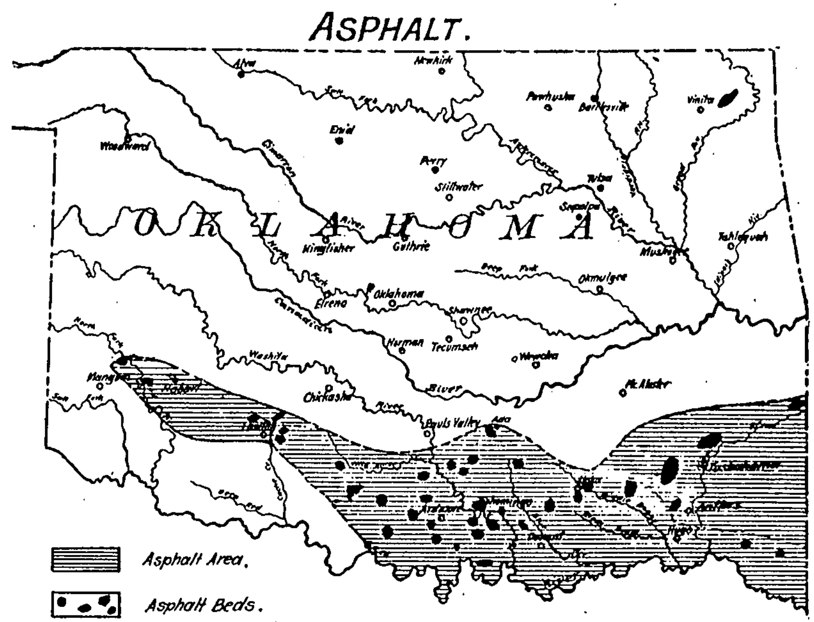
9 Richardson, C., Mod. Asphalt Pavement, p. 151.

CHAPTER II.

GENERAL GEOLOGY OF THE ASPHALT BEARING REGIONS.

INTRODUCTION.

Natural hydrocarbons, liquid, gaseous, solid or viscous—sometimes one or the other, or all four—have been found in notable amounts at various places in Oklahoma from Bokhoma to Granite, north as far as Ada and Page, and south to the Red River. The



GENERAL MAP OF ASPHALT BEARING REGIONS IN OKLAHOMA.

area, therefore, to be considered in a discussion of the geology of the probable asphaltum bearing belt of Southern Oklahoma includes that portion of the State lying between the thirty-fifth parallel of north latitude, and the Red River, and from the Arkansas line west to Granite. In preparing a general discussion of the geology of this district little claim is made for newness save in the object to be accomplished, which is to place before the reader a general review of the geology of that portion of the State in which the asphaltic deposits are found. The available literature of the subject has been used as a text and such additions have been made to the data contained therein as the writer's personal investigations seem to warrant. Specific credit is given where another's language is used, but to attempt to give detailed credit in every instance would be to convert this paper into a collection of foot notes. However, occasion is taken to make special mention of the valuable papers on the geology of various regions of the district by Taff,[10] Gould,[11] Eldridge,[12] Girty[13] and Larkin.[14] In general the nomenclature is that used by those writers.

Although it may seem awkward to begin the discussion of the subject at the center of the area—the Arbuckle Mountains—and then to bring in the surrounding portions, this method of treatment has been adopted in order to follow the natural geologic sequence, i. e., from the oldest to the youngest rocks. Time and space do not permit of an extensive treatment of the stratigraphy of the district in general, therefore, the geological discussion of the various regions is limited to a brief resume. The order of treatment is: (1) Arbuckle Mountains; (2) Wichita Mountains; (3) Ouachita Mountains; (4) Permian Redbeds; (5) Cretaceous Slope.

ARBUCKLE MOUNTAINS

INTRODUCTION.

The Arbuckle Mountains consist of a plateau or tableland, of moderate elevation, situated in Murray, Northern Carter, Southern Pontotoc, Johnston and Western Atoka counties. The maximum elevation is found in that part of the system which lies west of the Washita River. The average height of this portion of the plateau

10 Taff, J. A., Preliminary report geology Arbuckle and Wichita Mountains, Prof. Paper U. S. Geol. Survey No. 31, 1904.
Tishomingo, Atoka, and Coalgate folios of the Indian Territory, U. S. Geol. Survey.
Albertite-like asphalt of the Choctaw Nation, American Journal of Science, vol. VIII, Sept. 1899, p. 219 et seq.
Grahamite deposits in southeast Oklahoma, Bull. U. S. Geol. Survey No. 380, 1909.

11 Gould, Chas. N., Geology and water resources of Oklahoma, Water-Supply and Irrigation Paper U. S. Geol. Survey No. 148, 1904.

12 Eldridge, Geo. H., Asphalt and bituminous rock deposits of Indian Territory, Twenty-second Ann. Rept. U. S. Geol. Survey, Pt. 1, 1901, pp. 262-320.

13 Girty, Geo. H., Fauna of the Caney shale of Oklahoma, Bull U. S. Geol. Survey No. 377, 1909.

14 Larkin, Pierce, Preliminary report on the Cretaceous of Oklahoma: Thesis, University of Oklahoma Library, 1909.

is above 1,250 feet, while an altitude of a little more than 1,400 feet has been recorded on the NE. ¼, sec. 1, T. 2 S., R. 1 E.; SW. ¼, sec. 20, T. 1 S., R. 1 E.; and the S. ½, sec. 28, T. 1 S., R. 1 W. East of Washita River the surface of the plateau slopes gently southeastward until an elevation of less than 550 feet above tide level is recorded in sec. 26, T. 3 S., R. 9 E., where the last exposure of the Tishomingo granite is found.

The term, Arbuckle Mountains, as used in this paper, includes all the above region, the surface of which is composed of the older Paleozoic and pre-Cambrian rocks. The granite found at an elevation of less than 550 feet in township 3 south, range 9 east, is, therefore, considered just as truly a part of the Arbuckle Mountains as is that of West Timbered Hill, which rises to more than 1,400 feet.

The rocks of the Arbuckle Mountains proper consist of a thickness of 10,000 to 12,000 feet of sediments, chiefly limestones, which range in age from middle Cambrian to lower Carboniferous times and rest unconformably upon the pre-Cambrian crystallines (granites, etc.) of East and West Timbered hills and the Tishomingo region. These rocks are succeeded by a series more than 10,000 feet thick of conglomerates, sandstones and shales of Pennsylvanian age. The Arbuckle Mountains were uplifted before the deposition of the Permian Redbeds, but subsequent to the period during which the Glenn formation, upper Mississippian and lower Pennsylvanian, was deposited. The hiatus between the lower Pennsylvanian and Permian systems is marked by a profound unconformity south of the mountains, but so far this unconformity has not been reported as extending more than a few miles to the north of the range. The trend of the Arbuckle Mountains is N. 70° W., or the same as that of the Wichitas which lie sixty miles farther to the northwest. The main axis of the Ouachita Mountains is not in line with the axis of the Arbuckle and Wichita uplifts, but bears nearly east and west. This, with other differences of structure, indicates that the Ouachita uplift was not caused by the same forces that elevated the Arbuckles and Wichitas.

TOPOGRAPHY.

Broadly speaking, the Arbuckle Mountains are co-extensive with the outcrop of the rocks which are of Devonian age or older. When so considered they roughly form an isosceles triangle with the apex near the town of Ada, one end of the base in T. 2 S., R. 1 W., and the other in T. 3 S., R. 9 E. The base thus has a trend of N. 70° W. Since the time of general elevation of the region, Permian rocks have been deposited across the northwest end, and Cretaceous rocks across the southeast end of the uplift. The Permian or late Carboniferous strata have a general northwest dip at low angles, while the Cretaceous on the opposite side of the mountains dip southeast. This would seem to indicate that the post-Cretaceous elevation was more extensive in the Arbuckle region than in the surrounding country. There are Cretaceous deposits in Roger Mills, Beckham and Washita counties in the western part of the State which are of about the same age as those south of the Arbuckles. It therefore seems probable that during lower Cretaceous times the entire region of the Arbuckle and Wichita mountains was receiving sediments. Then, when the uplift came, elevation was more rapid in the region of these mountains and erosion accordingly more excessive. As erosion progressed the overlapping deposits are being carried back, thus exposing a continually broadening section across the uplift.

The profound crumpling and folding and at least the major portion of the faulting of the Arbuckle Mountains was accomplished at the time of the first great uplift, which was, perhaps, not later than middle Pennsylvanian. The elevation was followed by a period of pre-Permian erosion, succeeded by the advance of the Permian sea, in which the Redbeds were deposited from the northwest. It is not known how far southeastward the Redbeds sediments extended, but they probably did not reach south of these mountains.

During the period of erosion which preceded the deposition of the Cretaceous rocks the entire region of the Arbuckle uplift was worn down to a nearly flat plain, which has been preserved as a low tableland in the central part of the uplift where the rocks are hardest, while the softer strata of the sides have been worn down to lower levels. Thus conditions have given a terraced appearance to the uplift, when considered as a whole. It is the central core of hard strata and crystallines that remain as a low, sloping plateau which is here called the Arbuckle district.

The smaller details of the topography of the district are due mainly to the differential erosion of alternating beds of hard and soft strata. Long longitudinal valleys abound, and narrow ridges of harder rocks are frequent. The smaller drainage channels are often parallel with the strike of the formations, but some of the master streams, as the Washita and Blue Rivers and Rock, Mill and Pennington creeks, seem to have been superimposed upon the older strata. The edges of the higher parts of the plateau have been etched into a frill of gulches and narrow ravines by the short streams which drain it. This border erosion is perhaps better developed along the Washita gorge than in any other region.

GEOLOGY OF THE ARBUCKLE MOUNTAINS.

IGNEOUS ROCKS

The igneous rocks of the Arbuckle Mountains consist, in the main, of granite, granite-porphyry and aporhyolite. There are three areas of igneous rocks exposed: one north of Tishomingo, known as the Tishomingo granite; one near the southeast corner of T. 1 S., R. 1 E., and a third in the northwest end of the uplift, chiefly in the northeast corner of T. 1 S., R. 1 W. In the first named region wholo-crystalline pinkish or reddish granite, which covers an area of more than 100 square miles, predominates. The Cretaceous sediments overlap the southeastern portion of the area, while middle Cambrian sandstones overlie the western end. The sedimentary contact along the north, however, is occasioned by faulting, except in two unimportant instances, where the Cambrian sandstone again occurs. The other two areas which occur near the west end of the mountains consist, in the main, of granite-porphyry. The western and southwestern contract with sedimentaries is as a rule one of unconformable overlap of middle Cambrian sandstone, while the contact to the northeast is due to faulting, the porphyry being brought into contact with the limestone above the Cambrian sandstone.

The exact age of the granite, porphyry and associated igneous rocks, is indeterminable in the light of present data. It is known, however, that these rocks were subjected to erosion before middle Cambrian times, for a sandstone of that age, formed of material eroded from the igneous rocks themselves, and resting unconformably upon them, is the oldest sedimentary rock exposed in the region.

There are numerous dikes and stringers of other varieties of igneous rocks associated with the Tishomingo granite and with th porphyry of the west end of the range. The chief dike rocks of the granite area are quartz-monzonite, aplite, granite-porphyry and diabase. The general direction of the dikes is northwest and southeast along the greatest extension of the uplift but there are "cross dikes" and stringers which extend in other directions.

The quartz-monzonites are closely associated with the granite and are often apparently phases of it, occurring, it seems, in small areas or patches rather than as dikes. The aplite, however, is usually found as well defined dikes. This rock (which is usually pale pink to nearly white in color) is composed almost entirely of feldspars and quartz and is of an even, finely granular texture. The granite-porphyry dikes of the Tishomingo granite region are the least abundant of the associated rocks. Only one occurrence of a porphyry dike is reported. It is located in a small tributary to Rock Creek in sec. 1, T. 4 S., R. 5 E. The granite-porphyries are fine textured and brick red in color.

Diabase dikes are common throughout the granite area, but their occurrence is most frequent in the western end of the region. These basic dikes seem to have attained their greatest development a few miles northwest of Tishomingo, where they are reported as forming a "net work of stringers and sheets." The diabases are uniformly dark in color and vary in texture from a dense, finely porphyritic to a coarse granular mass closely resembling gabbro. Their composition, however, is quite uniform and it appears that these dike rocks should be, as a rule, classed as diabases. The diabase dikes usually weather more rapidly than the granite and can often be traced across the region as narrow, fertile bands, or sometimes as shallow, shrub-grown ditches.

The granite-porphyry of the Arbuckle Mountains occurs in the western part of the uplift and forms what are known as East and West Timbered Hills, which rise to an elevation of a little over 1,400 feet above sea level. These occurrences, while usually thought of as being of granite-porphyry, consist in fact, of granite-porphyry and aporhyolite, of various shades of pink, red and brown, of which the aporhyolite is an intrusive into the granite-porphyry. In places the aporhyolite is strikingly porphyritic in texture and shows a beautifully banded structure. Like the Tishomingo granite, the granite-porphyry-aporhyolite region contains numerous dikes of diabase which are similar in general characteristics and lithology to those described above.

SEDIMENTARY ROCKS

Reagan sandstone:—It appears that in pre-Cambrian times the region of the present Arbuckle uplift consisted of a granitic land surface with low relief. Subsidence, however, must have begun in early Cambrian times for mid-Cambrian fossils are found near the top of the Reagan sandstone, which formation shows unmistakable evidence of being at the base a beach, or near shore, deposit. It, however, grades upward into thin-bedded, well stratified sandstone, becoming calcareous and fossiliferous toward the top. Taff[15] gives the following section, beginning at the base, as typical of the Reagan sandstone at the west end of the granite region where it has its greatest development.

Section of Reagan Sandstone.

	Feet.
Quartzite and arkose conglomerate, composed of poorly sorted granitic materials	30
Coarse grit and sand, with some clay and green sand in upper part, generally well stratified	370
Thin-bedded and laminated sandstone, becoming calcareous in the upper part,	60

15 Taff, J. A., Prof. Paper U. S. Geol. Survey No. 31, 1904, p. 21.

The section as given is usually succeeded by several hundred feet of laminated, silicious, fossil-bearing limestone and shale strata to the top of middle Cambrian times, containing faunal remains similar to those of the upper members of the Reagan.

The Reagan contact with the porphyry of East and West Timbered Hills is similar to that with the granite, and the section given is typical for all parts of the formation save that the conglomerates at the base are composed of fragments of porphyry and associated dike rocks instead of granites, monzonites, etc. Green clay shales in the upper Reagan formation are perhaps more abundant here than in the Tishomingo region, and the green sands continue to a higher horizon in the fossiliferous calcareous beds.

Arbuckle limestone:—The Arbuckle limestone lies upon the Reagan sandstone. It appears, in general, to be conformable with that formation though Ulrich[16] has noted some shaly lentils which he thinks suggestive of an unconformity. The Arbuckle limestone has an aggregate thickness of from 4,000 to 6,000 feet and represents all of upper Cambrian and part of Ordovician times. Briefly described, beginning at the bottom, that portion of the formation which represents the upper Cambrian rocks consists of thin-bedded, shaly limestones with conglomeratic lentils. The rock gradually changes to a massive and hard, pink to yellow, distinctly crystalline limestone and dolomite, which weathers brown to black. This has a thickness of 500 to 600 feet. These rocks are succeeded by lighter colored, non-fossiliferous limestones and dolomites which continue apparently well up into the Ordovician, or to within about 450 feet of the top of the Arbuckle limestone; when they in turn are succeeded by more thinly bedded limestone strata associated with occasional shaly members and, very near the top, sandy beds. Fossils have been reported from the central massive members of the formation, but they are far more common toward the top where the strata become more shaly.[17]

The Arbuckle limestone is situated near the center of the uplift and extends from the southeastern end of the region, where it appears from beneath the Cretaceous overlap, northward and northwestward until it disappears under the Pennsylvanian sandstones and conglomerates and Permian Redbeds along the north side and west end of the mountains. The formation reappears as the limestone hills of the Wichita Mountains.

Wherever exposed the Arbuckle limestone is greatly deformed by faulting and folding. It is always crushed and crumpled, often

16 Ulrich, E. O., quoted by Taff, Prof. Paper U. S. Geol. Survey No. 31, 1904, p. 22.

17 For a list of fossils so far identified the reader is referred to Prof. Paper U. S. Geol. Survey No. 31, 1904.

standing on edge, but, owing to its great thickness and its position near the center of the uplift it has the greatest areal extent of any formation in the mountains.

Simpson formations—The deposition of the Arbuckle limestone was brought to a close by a general but gentle oscillation of the region which seems to have brought the greater part of the Arbuckle Mountain district above water for a short time, during which the top of the limestone was locally eroded. When submergence was again accomplished the sediments deposited were of a very different character. They consisted largely of sand, clay and calcareous silts which became the sandstones, clay shales and limetsones that make up the Simpson formation. Pure sand was laid down over parts of the surface of the Arbuckle limestone, while in other places sandy limestone or shale beds were deposited in contact with the older formation.

Thus, then, the basal member of the Simpson is in part a pure sandstone and in part an impure clay shale or limestone. Upon this base a great mass of greenish clay shale, thin crystalline and shelly limestone, and heavy sandstone beds were deposited, until an aggregate thickness of from 1,200 to 2,000 feet was attained. It is unnecessary for present purposes to give a detailed description of this formation. The following section, taken from Taff,[18] with slight modifications, is characteristic. The table is given from the bottom upward:

Section of Simpson formation on south side of Arbuckle uplift, west of Washita River.

		Feet.
1.	White to light-brown sandstone, occurring locally	0-100
2.	Thin limestone and shales interstratified with occasional thin sandstone	29
3.	Granular crystalline limestone in thin beds Contains an abundance of Ostracoda (Leperditia chiefly) and other fossils so rare as to appear wanting.	350
4.	Greenish shales with few thin limestone layers	245
5.	Thin-bedded limestone and shales interstratified Contains fossils in great abundance, chiefly Ostracoda of large and small species, and numerous gasteropods, pelecyopods, brachiopods, and trilobites.	295
6.	Sandstone (glass sand member)	33
7.	Shaly limestone The lower 50 feet highly fossiliferous, containing Ostracoda with numerous Bryozoa and bases of crinoid columns making a fauna sufficiently peculiar to be easily distinguished.	195
8.	Sandstone (glass sand member)	100-200
9.	Limestones and shales interbedded Some of the limestones are highly fossiliferous: **Orthis tricenaria, O. deflecta, Monticuliporoid Bryozoa,** highly ornamented cystid plates, and species of **Ctenodonta.**	400
10.	Sandstone	90
11.	Thin limestone with green shales interstratified	400

The Simpson formation promises to be of great economic importance, for the sandstone beds numbers six and eight are the great

18 Taff, J. A., Prof. Paper U. S. Geol. Survey No. 31, 1904, p. 23.

Nos. 1 and 2 together form the complete base of the Simpson, for No. 1 occurs locally.

glass sand horizons of the State. Numerous analyses of these sands have been made by the Survey and they are found to be often 99 per cent pure silica, with scarcely a trace of iron.

Viola limestone:—By reference to the above table it will be noted that the Simpson formation was gradually grading upward into limestone. This condition continued until the material became a very pure limestone. The character of this rock is so different from the Simpson that another formation known as the Viola limestone has been recognized. The upper layers of the Simpson usually contain some clay, are thinner bedded, darker, and more evenly stratified than is the base of the Viola, though the character is more or less variable on each side of the contact.

The Viola is a continuous deposit of white to light blue limestone from 500 to 700 feet thick, remarkably free from clay shale lentils and sandy beds. When first exposed the rock has a massive appearance. Weathering, however, soon etches the surface and the bedding planes are easily seen. These show the formation to be made up of regular layers varying from an inch or so to occasionally more than a foot in thickness.

Though there are slight variations which would enable one to divide the formation into two or there distinct members, the Viola limestone is one of the most uniform formations, both in thickness and character, in the Arbuckle mountains. On casual examination it is believed to be suitable for high grade building stone and the manufacture of good quick lime. The Oklahoma Portland Cement Company at Ada is proving its desirability as a Portland cement material.

The Viola has yielded fossils throughout. Sufficient work has been done upon the paleontology to cause the Viola to be correlated with the Black River, Trenton and Richmond stages of the Ordovician.[19]

Sylvan shale:—The Sylvan shale is a lenticular or wedge-shaped clay shale formation varying in color from dark blue to black and green. It has its greatest development west of the Washita River where it attains a thickness of about 300 feet, and from whence it gradually thins eastward until the estimated thickness at the east end of the uplift is only sixty feet. The Hunton limestone lies above the Sylvan shale so that it is bounded above and below by hard limestones, and since all the formations are, as a rule, tilted at high angles, this formation usually occurs as a narrow timber-covered valley, between limestone ridges.

The Sylvan shale is rarely well exposed, but it is known to be quite fossiliferous near the base of the formation. The best exposure the writer has seen occurs in the bed of Vine's Branch northwest of Dougherty. Here the shale is a black, distinctly stratified bituminous

19 For discussion see Prof. Paper U. S. Geol. Survey No. 31, 1904, pp. 26-27.

clay shale at the base and contains an abundance of graptolites and shells. The black basal member is succeeded by a greenish shale which shows little lamination.

Ulrich[20] has made a preliminary study of the fossils and finds them very similar to those of the Utica shale of Ordovician age, but as the Richmond fauna occurs in the top of the Viola limestone below it, the Sylvan is probably to be correlated with the Oneida-Medina sandstones of New York.

Hunton limestone:—The Hunton limestone formation, so far as obtainable data show conformably succeeds the Sylvan shale and is of Siluro-Devonian age. The transition from shale to limestone is very abrupt. The basal member of the Hunton is a massive bed of oolite which is locally replaced by hard bluish limestone. This formation is thickest on the south side of the uplift. Where it passes under the Redbeds a few miles northwest of Woodford it has attained a thickness of approximately 300 feet. It thins eastward from this point, however, and is absent from the section for a distance of ten miles or so along the south side of the mountains, east of the Washita River. It reappears beyond this gap, and has a thickness of about 160 feet at the east end of the Arbuckle Mountains, from which point its thickness gradually increases westward until a section along the north side of the mountains east of the Washita River measures about 200 feet.

In general the Hunton formation is divisible into three members on lithological characteristics. It is composed of thick-bedded and massive crystalline limestones, and thin earthy limestones and marls. A typical section from the south side of the uplift west of the Washita River follows:

Section of Hunton Limestone.[21]

	Feet.
LOWER MEMBER.	
Thick-bedded crystalline limestone succeeded by hard thin limestone with occasional marly layers. At the base of this limestone is an oolite, 4 to 5 feet thick, which locally is silicified	35- 40
MIDDLE MEMBER.	
Marly limestones and calcareous clays, with some hard limestone layers, more abundant in the lower part	170-190
UPPER MEMBER.	
Semi-crystalline limestones, in places cherty, interstratified with occasional thin marly layers	30

The middle Hunton, owing to the soft nature of the rocks, usually weathers out as a rounded trough between the treeless limestone ridges of the upper and lower members, thus giving a very characteristic appearance to the outcrop of the formation. Often the two ridges and intervening valley of the Hunton may be seen extending across the country for miles.

20 Quoted by Taff, J. A., Prof. Paper U. S. Geol. Survey No. 31, 1904, pp. 28-29.
21 Taff, J. A., Prof. Paper U. S. Geol. Survey No. 31, 1904, pp. 29-30.

Woodford chert:—The Woodford chert lies unconformably upon the Hunton limestone. It is probably of Devonian age and consists of chert, fissile shale and occasional limestone concretions. In places nearly pure chert or flint rests upon the Hunton limestone while in others, the contact is between black bituminous shale and the limestone. The formation has an estimated thickness of 650 feet and is present throughout the Arbuckle Mountains wherever its horizon comes to the surface.

Fossils are very rare in the Woodford chert. So far only a few invertebrate types have been reported and one species of plant. The invertebrates are *Lingula spatulata* and a *Productella* referable to the species *concentrica.* Fragments of petrified wood are common along the outcrop but only one specimen has been reported in place. This consists of a tree trunk on the south side of the mountains northwest of Norton. David White determined this specimen to belong to a species of *Dadoxylon* which is a Devonian type.

Sycamore limestone:—The Sycamore limestone is a lenticular limestone that has been referred to the Mississippian or lower Carboniferous age, apparently because of its position upon the Woodford chert, for so far as known it is non-fossiliferous. This limestone formation attains a maximum thickness of about 200 feet at the west end of the Arbuckle Mountains. It has been reported as occurring throughout the southern side of the uplift and eastward along the north side to the region of the Tishomingo granite. However, it thins eastward on each side of the uplift and is entirely absent, or represented only by local thin silicious limestones, along the northeast face of the mountains.

Caney shale:—The Caney shale succeeds the Sycamore limestone in regular sequence and has been described as of upper Mississippian age. Later investigations, however, have created grave doubts as to the correctness of this classification. In the eastern part of the Arbuckle region it occurs above the Woodford, apparently conformably,[22] and below the Wapanucka limestone, the lowest known Pennsylvanian limestone in eastern Oklahoma. The thickness of the Caney has, owing to poor outcrops, never been determined; it is estimated, however, at 1,600 feet.

The Caney shale appears to grade upward into the Glenn formation, which is thought to be Pennsylvanian in age. Maps showing the entire extent of the Caney shale have never been published, but it is known to occur surrounding the entire uplift wherever its horizon is exposed.

Glenn formation:—Throughout the southern extension of the Arbuckle uplift there is a great mass of sandstone and shale with occasional ledges of conglomerate, which in fact does not belong among the Arbuckle formations, but which was deformed at the time of the

22 Folio U. S. Geol. Survey No. 98, p. 5.

general uplift. This series of strata has been called the Glenn formation and classified as Pennsylvanian on the basis of fossils found near Berwyn. This formation occupies the region structurally known as the Ardmore basin from a point about two miles north of Berwyn southwest to the Criner Hills and from the Redbeds contact at Deese eastward to the Cretaceous overlap near Norton. The general strike of the beds, which are usually steeply inclined, is N. 70° W. The formation, however, contains many irregularities of structure and has never been studied in sufficient detail to determine its thickness.

If the Glenn formation has an equivalent north of the Arbuckle uplift it has not yet been determined.

Franks conglomerate:—The Franks conglomerate is an irregular formation composed of water-worn limestone, chert and granite boulders, local sandstone ledges and beds of shale. The boulders are fragments of the limestone and other rocks that were washed out into the surrounding sea after the Arbuckle uplift, that occurred in Pennsylvanian times. This formation is, therefore, Pennsylvanian in age. It has its greatest development in the western part of the region where it is many hundred feet thick. On passing eastward along the north side of the uplift, however, it decreases both in thickness and coarseness of material until its horizon is finally assumed by limestones.

So far as present data show there is no known equivalent of the Franks conglomerate south of the uplift, though there are reported to be some conglomerate beds above the Glenn formation in the Ardmore region.

STRUCTURE OF THE ARBUCKLE MOUNTAINS.

To those unfamiliar with the interpretation of earth movements the preceding discussion might appear to mean that the whole of the Arbuckle region was in a state of rest from Cambrian to Pennsylvanian times, and that great orogenic movements occurred at the latter period. Such, however, was not the case. The change from sandstone to shale usually means that the surface of the region receiving deposits has gradually moved downward until it is further from shore and the water deeper, so that only the finer silts reach that locality. A grading from shale into limestone, generally speaking, means that the depression progressed still further; that the land mass is further removed from the area in question and that the water is probably deeper. Changes in the kinds of sediment are also brought about by the wearing down of the land which is supplying the material. Thus, then, each succession of sandstone, shale and limestone; shale, sandstone, etc., means that either; (1) the sea floor has subsided and the region receiving sediments was farther from shore, or (2) the land supplying the materials which go to make up the rocks has been worn down so nearly level that the streams are slow and sluggish and carry only the finer mud and silt into the sea. Usually these two

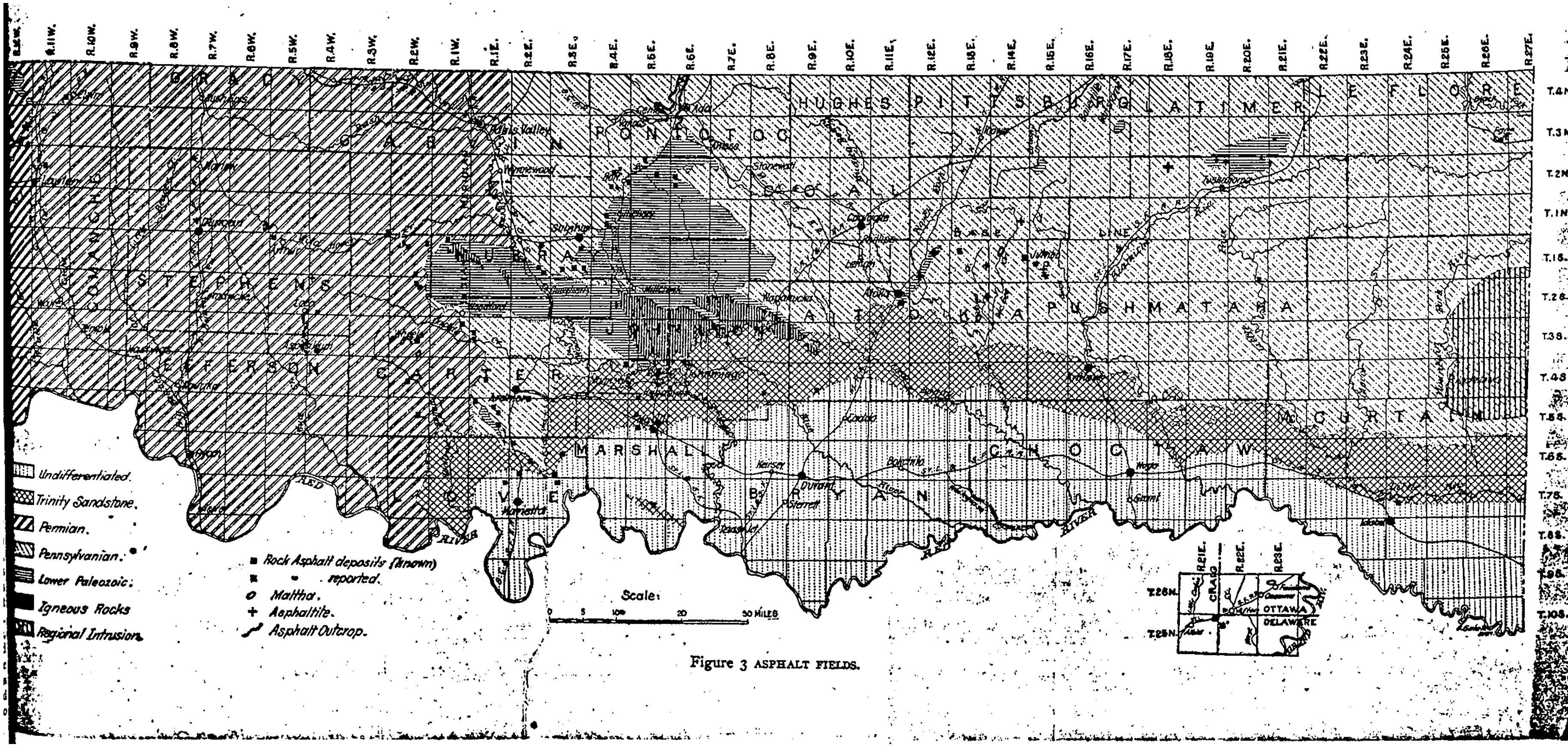


Figure 3 ASPHALT FIELDS.

processes are combined: that is to say, when the sea floor is sinking the adjacent land is also subsiding, thus bringing the water level and the land level nearer together, so that the mouths and sources of the streams are approaching the same elevation. In consequence the currents are lessened, and the coarse gravel and sand are dropped near the stream sources and only the fine material in suspension reaches open water.

By a study of the geological section of the Arbuckle Mountains, bearing the above facts in mind, one sees readily that the forces of elevation and depression were continually at work. In other words, the region was almost continually undergoing changes in elevation. These minor changes, however, were slow and deliberate, and elevated the region as a whole, and resulted in very slight deformation of the strata; in fact, if there was any folding or faulting at all in those earlier times the evidence of their occurrence has not yet been noted.

At the close of lower Carboniferous times great mountain making forces were brought to bear upon the region, and not only was it again elevated, but the thousands of feet of limestone, sandstone, shale and conglomerate which had been accumulating through past ages were crumpled and mashed almost like putty, and great faults or breaks were formed through the whole series so that the edges of formations slipped by each other, in some instances, for more than a thousand feet. It was during this early mid-Carboniferous period that the major portion of the present structure of the Arbuckle and Criner Hills regions was formed.

During late Carboniferous times there was another subsidence and the Permian Redbeds were deposited across the west end of the region, doubtless extending much farther southeast than they now occur. This deposition was followed by another long period of elevation and erosion, which was succeeded by a great depression, when the Cretaceous sea spread out over the whole region, and far to the northwest, and hundreds of feet of sandstone, shale and limestone were again deposited. The Cretaceous subsidence was followed by a general and uniform elevation of the entire country, since which the Arbuckle region has not suffered inundation.

The great forces, which, during Pennsylvanian times, folded and faulted the rocks of the Arbuckle Mountains threw the whole region into great upfolds, or anticlines, and downfolds, or synclines, comparable to the crests and troughs of waves at sea. These folds have a general northwest-southeast trend parallel to that of the mountain range. Taff[23] has named and defined seven of these great folds, four anticlines and three synclines. The names given are from the principal towns or other geographic features on or near the fold. The names of these great structural arches, named in order from north-

[23] Taff, J. A., Prof. Paper U. S. Geol. Survey No. 31, 1904.

east to southwest, are, Hunton anticline, Wapanucka syncline, Belton anticline, Mill Creek syncline, Tishomingo anticline, Washita syncline and Arbuckle anticline.

CRINER HILLS.

The Criner Hills is a small range of limestone hills about six miles southwest of Ardmore, that is about fifteen miles from the main Arbuckle range. They trend N. 41° W. The history and stratigraphy, and the relations of the Criner Hills to younger formations seem, in all essentials to be analogous to those of the Arbuckle Mountains. The contact between the lower Paleozoic rocks and the Glenn formation was produced by faulting, except along the northwest end and for a short distance on the northwest side, where the Glenn is unconformable upon the older rocks. In fact, this uplift may well be thought of as an outlying fault block of the Arbuckle range.

The topography of the Criner Hills is a miniature reproduction of that of the Arbuckles proper. The drainage is southeastward through Hickory Creek to Red River.

It is not known how far the faulting of the Criner Hills extends beyond the line of contact between Carboniferous and lower Paleozoic rocks but since the uplift is essentially a fault block coming up through Pennsylvanian strata it seems probable that it may extend considerable distances in both directions.

WICHITA MOUNTAINS

INTRODUCTION.

The first study of the geological features of the Wichita Mountains was made by Geo. G. Shumard, Physician to the Marcey expedition, which explored North Fork of the Red River in 1852. There was nothing further done in the study of the Wichitas until Robert T. Hill, in 1891, attempted to show a structural relation between the Ouachita and Wichita Mountains. In 1896 T. Wayland Vaughn made some observations on the limestone to the north of the main range of the Wichitas and in 1899 T. B. Comstock, in company with W. F. Cummins, made a reconnaissance of a part of the mountains. In the same year H. Foster Bain investigated the mineral resources of the mountains. It was followed by the work of J. A. Taff[24] in 1901, his report being published in 1904 as Professional Paper No. 31 of the Federal Survey. The year following (1905) Chas. N. Gould[25] prepared a report on the water resources of Oklahoma Territory in which he also discussed the geology of the Wichita Mountains.

24 Taff, J. A., Prof. Paper U. S. Geol. Survey No. 31, 1904, pp. 51-81.
25 Gould, Chas. N., Water-Supply Paper U. S. Geol. Survey No. 148, 1905.

TOPOGRAPHY.

The extreme length of the Wichita Mountains from the Carlton Mountains, on Medicine Bluff Creek near Fort Sill, to the last granite hill that disappears under the high prairie eight or ten miles west of Headquarters Mountain, at Granite, is seventy miles; while the extreme width from Rainy Mountain to the southwestern granite butte on North Fork of Red River, six miles southeast of Navajoe, is thirty miles. The mountains, however, do not consist of a continuous range throughout this region but of scattered ranges, peaks and short chains, the bases of which are buried beneath the surrounding plains.

The Wichita Mountains, for the purposes of this report, are divided into three groups, namely: (1) the main range; (2) western group, and (3) limestone hills. Taff[26] makes many smaller divisions but this grouping lends itself more readily to the purposes of brief discussion and is therefore used. The formations of the first two groups consist of pre-Cambrian igneous rocks—that is rocks of the granitoid types—while those of the limestone hills, as the term suggests, are chiefly limestone, though there is a large inter-fault block of granite-porphyry a few miles west of Richards.

The surface features of the main range and the western group are characterized by high jagged peaks and long ridges separated by narrow valleys. The topography of the limestone hills is similar, except that the ridges are more rounded and the peaks less jagged. The entire system is surrounded by the nearly level lying formations of the Redbeds plains of Permian age.

The Wichita Mountain drainage belongs to the Red River system, though much of the water from the vicinity of Cooperton and Rainy Mountain detours by way of the Washita River. The runoff from the east end and northeast face of the system is through Cache Creek, while that from the west end flows through North Fork of Red River.

GEOLOGY OF THE WICHITA MOUNTAINS

MAIN RANGE

The term main range, as here used, includes the Wichita and Raggedy Mountain groups of Taff, and extends from a point near old Fort Sill, northwestward about two miles beyond Cold Springs. The general trend is N. 70° W.

The mountain making formation of this region is the pre-Cambrian igneous core of an old mountain range which was elevated and deeply eroded during post-Ordovician times, and before the Permian. The exact time of the uplift cannot be determined, because the Permian Redbeds are not sufficiently removed to expose the sedimntaries above the Ordovician.

26 Taff, J. A., Prof. Paper U. S. Geol. Survey No. 31, 1904.

The rocks of the main range consist of granite-porphyry at the eastern end, which gives place to granite in T. 3 N., R. 13 W. The granite range is continuous nearly to Cooperton, when it is broken by Redbeds invasion, and reappears as a chain of low granite hills beyond the town. The granite is flanked on the northeast by a basic rock resembling gabbro. The west end of the range is composed of a similar basic rock which extends from a point two miles east of Cloverton to the western limit of the range. Like the igneous rocks of the Arbuckle Mountains, these are cut by frequent dikes of associated intrusives. Aporhyolite is frequent among the true granites. Diabase dikes cut through at various angles, and quartz stringers are quite common in the more basic occurrences.

The extreme width of this range is about thirteen miles, while its length is approximately forty miles.

THE WESTERN GROUP.

The western group of the Wichita Mountains consists of the small scattered knobs, peaks and short ranges extending from near Snyder, northwestward to the last remnant of igneous rock which appears above the level of the Redbeds northwest of Granite. These knobs and hills are composed entirely of granite, or its acidic associates, and are frequently cut by dikes both acidic and basic. The occurrences are too much scattered to admit of detailed discussion. The largest single body, known as Devil's Canyon Mountain, is situated in a big bend of North Fork of the Red River southeast of Lugert. The greatest extension of this mountain is about six miles, parallel to the trend of the system, while its greatest width is about three miles. Other peaks worthy of mention are Quartz, Headquarters, Navajo, Tepee and Dome mountains.

LIMESTONE HILLS.

This division of the Wichita Mountains consists, in the main, of a chain of limestone hills which parallel the main range from the southern corner of T. 4 N., R. 12 W. to Rainy Mountain Mission, a distance of 25 miles. The stratigraphy, so far as exposed, is analogous to that of the Arbuckle Mountains and the classification and description there given applies equally well here. There is an occurrence of granite-porphyry east of Blue Creek in the northeast corner of T. 4 N., R. 13 W. which is overlain by the Reagan sandstone, this being succeeded by the Arbuckle limestone, while three rounded limestone knobs near Rainy Mountain Mission are composed of Viola limestone. These limestone hills, together with some small outcrops of the Arbuckle limestone occurring south of the main granite range at Fort Sill and northwest of Lawton, constitute all the known lower

Paleozoic sediments of the Wichitas. The structure of the sedimentaries is usually monoclinal. The prevailing dip is at high angles away from the granite in the middle of the range, but local crumpling and faulting are of frequent occurrence.

PERMIAN BEDS.

In discussing the general geology of the Arbuckle Mountains it was stated that the Redbeds extend unconformably across the western end of the Ordovician, Devonian and older Carboniferous rocks. This contact extends southeastward from the western extremity of the Arbuckle uplift to Caddo Creek, thence southward to the Cretaceous overlap, where it is partly covered by Cretaceous formations. The exact line of contact of the Pennsylvanian and Permian rocks north of the mountains has never been determined. A preliminary survey in 1904, by Chas. T. Kirk, seems to indicate that the base of the Permian is probably along a northeast-southwest line passing through Purcell toward the west end of the Arbuckles. If this is correct the Redbeds formation is not confined entirely to Permian rocks, but extends downward well into Pennsylvanian strata.

The Permian formations usually dip northwestward, away from the Arbuckle uplift, at low angles. As they approach the Wichita Mountains, they become more and more level and in the vicinity of the Wichitas the dip is slightly away from those mountains in all directions. These dips, however, are probably due to deposition upon a sloping sea bottom rather than to deformation. West of the Wichita Mountains the Permian formations continue to the State line.

As a rule the Redbeds show little or no structure other than that due to irregular sedimentation. There are, however, a few localities where local folding and faulting have occurred. Local faults are known to exist near Arthur and in the vicinity of Loco, while a small anticlinal fold occurs a few miles northeast of the little town of Hope.

The sedimentation of the Redbeds formations was very irregular. Sandstones are lenticular and as a rule cross-bedded, while the character of the shales is constantly changing from a pure clay shale to a sandy texture. From the vicinity of the Arbuckle Mountains westward to a point twenty miles beyond the Wichita range, the Redbeds are composed of sandstones, clay, and arenaceous shales. West of the Salt Fork of the Red River, however, several ledges of gypsum and a dolomite member appear, interstratified with the clay shales which are usually of a red color.

The Permian Redbeds have yielded very few fossils. Several localities which contain plant remains are known in the northern part of the State. One locality which yields invertebrate fossils is near Whitehorse. There are several places, both in Oklahoma and Texas, where vertebrate remains have been found. The paleontology of the Redbeds has not yet been carefully worked out, but all available data seem to indicate that the rocks of the series was deposited during Permian times.

THE CRETACEOUS SLOPE

The Cretaceous slope occupies that portion of Oklahoma which borders the Red River and extends northward from that stream an average distance of about fifty miles. It extends from the southeast corner of the State, westward to a point a few miles beyond the Gulf, Colorado and Santa Fe Railway. The rocks usually dip southeastward at low angles. The chief topographic features consist in long low ridges or chains of hills, having a general east and west trend, caused by the outcrop of alternating hard and soft strata. The drainage is southward into Red River, usually by small streams, though the Washita, Kiamitia and Little rivers pass through the region.

The basal member of the Cretaceous series is known as the Trinity sandstone. It varies in thickness from 400 to 1,500 feet and consists, in the main, of rather fine grained, unconsolidated beach sands. The remainder of the series in Oklahoma consists largely of limestones and shales of the Fredericksburg and Washita groups. A formation known as the Woodbine (or Silo) sandstone occurs near the Red River.

So far as has been discovered the asphalt of this region all occurs in the Trinity formation, which is also probably the oil and gas-bearing horizon at Madill.

REGION OF PENNSYLVANIAN ROCKS

The Pennsylvanian rocks, as included in the map accompanying this report, are exposed in a region bounded on the north by parallel 35° north latitude, lying northwest of the great Choctaw fault, and north and northeast of the Arbuckle Mountains. The region extends west to the Pennsylvanian-Permian contact, and east to the State line. It includes the great coal-bearing area of Oklahoma extending from Coalgate to the Arkansas line. The stratigraphy of the region is not of special interest in this report, inasmuch as the rocks are not known to contain asphalt at any place.

The lowest formation exposed is the Wapanucka limestone, which occurs just above the Caney shales already described. A great series of shales, sandstones and coal succeeds the Wapanucka limestone aggregating a thickness of perhaps more than 10,000 feet. These formations have been mapped in detail in the Atoka and Coalgate folios and in a general way in several papers on the Choctaw Coal Fields, by Taff.

OUACHITA MOUNTAINS

The portion of the Ouachita Mountains lying in Oklahoma occupies a V-shaped region lying between the Choctaw fault and the outcrop of the Cretaceous rocks. The Choctaw fault passes from near Atoka northeastward past McAlester and Wilburton, thence eastward to the state line. The northern line of Cretaceous deposits extends from near Atoka southeastward past Antlers to the State line, beyond Eagletown. The maximum elevation of the mountains occurs near the southwest corner of T. 3 N., R. 26 E. where Rich Mountain reaches a height of a little over 2,850 feet above sea level. The minimum altitude recorded in what may be properly considered the Ouachita region is a little less than 350 feet at the point where Mountain Fork River crosses the line between townships 5 and 6 south. The range in altitude is about 2,500 feet.

The rocks of the Ouachita Mountains consist of a great mass of sandstone and shale of Carboniferous age, probably Pennsylvanian; certain basic intrusions and associated metamorphic rocks in northeastern McCurtain County; cherty shale, with occasional siliceous limestone strata exposed in six areas in various parts of the region. But little detailed information has been published on the rocks of the Ouachita Mountains except in the northeastern corner of the Atoka quadrangle where Taff[27] has described a number of formations.

TOPOGRAPHY.

The Ouachita Mountains consist of groups and ranges of prominent hills and mountains usually separated from each other by broad plain-like longitudinal valleys.

The most prominent group is the Potato Hills north of Tuskahoma. These hills consist of a number of small dome-shaped mounds and rounded cones, composed of Talihina chert, which rarely exceed 1,300 feet in height. Their arrangement is in roughly parallel rows, but considered as a whole they form an oval shaped group rather than a range or chain.

Kiamichia Mountain extends from the Arkansas line westward to Tuskahoma as a single high ridge through which there are no passes. At Tuskahoma the general trend is southwestward. This change in direction coincides with the change in strike of the mountain-making formations southwest from Tuskahoma. The range spreads out and is split into several smaller and lower ridges, that extend south nearly to Antlers, and southwest to the northeast corner of T. 3 S., R. 13 E. The Kiamichi River breaks through the northern ridge of the mountain near Tuskahoma and flows along a longitudinal valley as far as Kasoma, near which point it becomes a transverse stream.

27 Taff, J. A., Folio (No. 79) U. S. Geol. Survey.
Bull. U. S. Geol. Survey No. 280, p. 286 et seq.

Rich Mountain, which extends from Arkansas west about twelve miles into Oklahoma, is the highest mountain in the region. It is succeeded by Winding Stair Mountain which extends northwest about thirty-five miles, and is in turn succeeded by chains of lower hills. Jackfork Mountain lies west of Tuskahoma between the head waters of two branches of Jackfork Creek.

Winding Stair Mountain is succeeded on the north, Kiamichi Mountain on the south, and Jackfork Mountain on the west by smaller ridges and lower ranges which finally disappear beneath or merge into the surrounding plain.

The Kiamichi River, the principal stream of the mountains, rises near the Arkansas line in the gorge between Kiamichi and Rich mountains, and flows west through a rapidly widening valley as far as Tuskahoma, where it breaks through the Kiamichi Mountain and flows southwestward to Antlers. At this point it swings abruptly to the southeast and flows into Red River a few miles southeast of Sawyer. Throughout its course from the state line to Tuskahoma the Kiamichi River flows near the south side of a broad inter-montane valley, and where the stream turns southward through the mountain, the valley extends on to the west. A few miles south of Talihina the broad valley is divided by the Potato Hills. It, however, reunites west of these hills to form the valley of Jack Fork Creek, which is again divided in the northeast corner of T. 2 N., R. 17 E. by Jackfork Mountain. That arm of the valley which passes north of the mountain is reduced to a pass between the west end of Jackfork and "Baldy" mountains but the south arm is kept open by Buck and Forbes creeks and spreads out west of Jack Fork Mountain to form the McGee Creek valley, arms of which are continuous as far as Atoka.

All the known asphaltite deposits of the Ouachita Mountains, except the occurrence at Page, are either in this long inter-montane valley or contiguous to it.

GEOLOGY OF THE OUACHITA MOUNTAINS.

IGNEOUS AND METAMORPHIC ROCKS

The igneous rocks of the Ouachita Mountains consist of basic dikes, extending nearly east and west where they are exposed along Mountain Fork in the region east of Hochatown in eastern McCurtain County. Phillite, slate, schist and quartzite such as usually accompany like intrusions into sandstone and shale sediments are associated with the intrusives. A very striking feature of the region is the great abundance of quartz stringers and dikes which penetrate the metamorphics for from five to fifteen miles in all directions from the exposures of intrusives. The road southwest from Hochatown to beyond Lukfata Creek is strewn with angular quartz boulders weathered from dikes of almost pure quartz, which cut the changed sediments in all directions.

There has been no detailed study of the igneous region, nor so far as known, has it been previously reported in Oklahoma. Investigations made in the region during the last season demonstrated that there are basic intrusions east and southeast of Hochatown. From data obtained it is probable that the region occupied by the intrusive rocks is approximately as tentatively mapped.

SEDIMENTARY ROCKS

The sedimentary rocks of the Ouachitas consist of a vast thickness of sandstone, shale, and chert, the age of which has not been definitely determined. As generally understood the rocks consist largely of deposits of Ordovician and Carboniferous age. Five formations are represented so far as present data show.[1] These are: Stringtown shale, Talihina chert, Standley shale, Jack Fork sandstone and Caney shale, the latter being succeeded by the Atoka formation.

Stringtown shale:—The Stringtown shale as reported by Taff[28] consists of black and blue shales, of Ordovician age, which occur in two locations in the region of the Ouachita Mountains. One occurrence is in the Potato Hills north of Tuskahoma, the other is between Black Knob Ridge and Atoka, and extends from Stringtown to the Cretaceous outcrop. The exposure in the former place is occasioned by the wearing away of the Talihina chert which overlies the Stringtown shale, while the latter outcrop occurs along the upthrown side of the Choctaw Fault. About 600 feet of the formation are exposed but the base is not yet in sight.

The Talihina chert:—The Talihina chert formation, of Ordovician age, is about 1,200 feet thick and consists of a black bituminous shale and chert at the bottom, grading upward into greenish shale toward the center, which in turn gives place to novacculitic chert at the top. So far as known this formation occurs in but two regions, the Potaato Hills and Black Knob Ridge.

Devonian and Silurian rocks:—The occurrences of Silurian and Devonian rocks seem to be very meager and relatively unimportant. Rocks said to be of these ages are found in four small, widely separated areas. Cherts and black shales of probable Silurian and Devonian ages are reported from the northwestern part of T. 2 N., R. 15 E. and in the corresponding part of T. 3 N., R. 17 E.; while some chert, probably of Devonian age, is found near the northeast corner of T. 1 N., R. 13 E. and in the northeast part of T. 4 N., R 21 E. None of these outcrops has been mapped in detail nor given formation names; nor is their stratigraphic position well understood.

Standley shale:—The Standley shale of Carboniferous age is a shale and sandstone formation estimated to be 5,000 feet or more thick. The formation is composed of blue, black and greenish shales interstratified with thin-bedded, usually friable, sandstones which, in rare

28 Taff, J. A., Bull. U. S. Geol. Survey No. 380. p. 290.

instances, attain a thickness of 100 feet. On account of its friable nature this series of rocks weathers very easily. It is the valley-making formation of the Ouachita Mountains. The valleys of Kiamichi River, Ten Mile, Jackfork, McGee and Potato creeks are cut down into the Standley shale between beds of steeply dipping sandstones which belong to the Atoka and Jackfork formations.

The age of the Standley shale is an unsettled question. In the Atoka Folio[29] it is described as "following the Talihina chert in gradual transition," and is classified as Silurian in age. A few years later the same authority[30] says the Standley is of Carboniferous age and mentions several widely separated occurrences of chert and cherty shale which he says are: of Silurian and Devonian age. The Talihina chert, however, is classified as Ordovician in both papers, while Girty[31] is of the opinion that the Standley is unconformable above the Talihina.

Jackfork sandstone:—The Jackfork sandstone occurs apparently conformable above the Standley shale, and consists of massive ledges of fine grained brown sandstones, some of which are more than fifty feet thick, interstratified with thin shale beds. The entire section is not known to be exposed at any point, but from such studies as have been made it is estimated to be not less than 5,000 feet thick.

The Jackfork is the great mountain-making formation of the Ouachita Mountains. Its most extensive exposures are in Jackfork, Kiamichi, Rich and Black Fork mountains. So far as known this series of beds has yielded no fossils, and definite classification is therefore impossible. It was first classified as Silurian,[32] but additional data seem to point to its being Carboniferous in age.[33]

Caney shale:—The Caney shale which consists of about 800 feet of black and blue shale, with occasional boulders of foreign material, lies above the Jackfork sandstone, and is now tentatively classified with rocks of Pennsylvanian or mid-Carboniferous age.[34] The age and stratigraphic relations of this formation, however, are as yet not well understood. The Caney shale of the Ouachita Mountains has the same lithological and faunal characteristics as that of the Arbuckle Mountains, and is undoubtedly of the same age, but the formations which it overlies in the two regions are entirely different in all respects. The first classification, in which the Caney was considered to be of Mississippian age, was based on observations made in the Arbuckle

29 Taff, J. A., Atoka folio (No. 79), Geol. Atlas U. S., U. S. Geol. Survey 1902, p. 4.

30 Taff, J. A., Grahamite deposits of southeastern Oklahoma: Contrib. Econ. Geology, 1908, Bull. U. S. Geol. Survey No. 380, 1908, p. 289.

31 Girty, Geo. H., Fauna of Caney shale of Oklahoma, Bull. U. S. Geol. Survey No. 377, 1909.

32 Taff, J. A., Atoka folio (No. 79), Geol. Atlas U. S., U. S. Geol. Survey, 1902, p. 4.

33 Grahamite deposmits of southeastern Oklahoma: Contrib. Econ. Geology, Bull. U. S. Geol. Survey No. 380, 1908, p. 289.

34 Girty, Geo. H., Fauna of Caney shale of Oklahoma: Bull. U. S. Geol. Survey, No. 371, 1909.

region, but when it was founnd that the Standley and Jackfork are probably Carboniferous a revision seemed necessary, and the Caney is now tentatively considered Pennsylvanian in age. The question, however, seems to be still open.

Atoka formation:—The Atoka formation is composed of alternating strata of sandstone and shale, and has an aggregate thickness of 3,000 to 6,000 feet. The sandstones are most abundant in the lower half of the formation, and have their greatest known development in Winding Stair Mountain, where they attain a thickness of several thousand feet, and become the mountain-making rocks of the region.

The Atoka formation is well developed throughout the south side of the Choctaw coal field where it immediately underlies the Hartshorne sandstone. It is of Pennsylvanian age and is the only formation of the Ouachita Mountains, the age of which is definitely determined. The Atoka occurs just above the Wapanucka limestone northeast of the Arbuckle Mountains and forms a considerable portion of the rocks in the area described as "Region of Pennsylvania Rocks" in the discussion of the Geology of the Arbuckle Mountains in this report.

STRUCTURE OF THE OUACHITA MOUNTAINS.

The sturcture of the Ouachita Mountains has never been described with even approximate accuracy, nor indeed, can it be until the stratigraphic relations are better understood. It is hoped that several folios soon to be published by Taff will throw light on the subject. The Choctaw fault forms, roughly, the quadrant of an ellipse with one end of the major axis at Atoka and may be considered the key to the gross structure of the entire system. The Kiamichi River is a longitudinal stream throughout almost its entire course in the mountains, and by reference to the map its parallelism with that portion of the course of the Choctaw fault shown is readily seen.

The strata of the region are often crumpled and abruptly folded. Faults are known to occur at Jumbo, in McGee and Jackfork valleys, and in Black Fork Mountain. In each case mentioned the faults locally contain merchantable deposits of impsonite, grahamite or gilsonite. Just how much of the arrangement and location of the principal mountains and valleys is due to folding and how much to faulting is uncertain, but it is believed that folding has played the more prominent part.

CHAPTER III.

ROCK ASPHALT DEPOSITS.

INTRODUCTION

The area of Oklahoma within which rock asphalt deposits occur lies south of the Canadian River, or to be more exact, south of the parallel of 35° north latitude, except the undeveloped region near Afton in Ottawa and Craig counties, and extends from the Arkansas-Oklahoma line to the west end of the Wichita Mountains in Greer County. Rock asphalt deposits of promise have been examined in nearly every ocunty lying wholly within this region except Choctaw, Coal, and Tillman counties, and of these it is believed that at least Choctaw will be found to contain asphaltic deposits worthy of development.

The field study preliminary to this report revealed several features of interest connected with rock asphalt deposits. One of great scientific interest is the heterogenous occurrence of lens-shaped deposits within the horizon of the Trinity sand, a formation of Cretaceous age, in the southern part of the State, especially in Marshall County. The deposits of bituminous rock of this county are all of sand asphalt, cotnained within the Trinity, which is 400 feet or more in thickness. Though detailed observations were not taken, the study lead to the conclusion that these asphaltic lenses are not all within the same horizon or level of that formation and that they are not confined within the limits bounded by lithological changes; in fact they seem to have been oil pools suspended, as it were, in the Trinity in much the same manner in which Munn[35] says the oil pools of the Sewickley quadrangle, Pennsylvania, are in the "Hundred foot sand" of that region, except that in this region the asphalt bearing lentils do not, ordinarily, show a conglomeratic character. It is believed that a study of these "fossil oil pools" may shed light on probable methods of oil and gas accumulation.

Another point of interest is the frequent absence of faulting in connection with the asphaltic deposits. It has long been considered that the asphaltic impregnation of the rocks of southern Oklahoma was, as a rule, along fault lines, and that the bituminous matter is the residuum of oil which has been conducted from deeply buried oil pools along the fault planes as channels. The investigations of the

35 Munn, M. J., Studies in the application of the anticlinal theory of oil and gas accumulation: Economic Geology, Vol. IV, No. 2, 1909, pp. 141-157.

past summer, however, do not bear this out. The Brunswick and Buckhorn districts in Murray County contain a number of faults each, but it seems that the faulting is not essential for impregnation, because those beds which are asphalt bearing along the faults are also richly bituminous at points well removed from faulting. It therefore seems that the effect of the faulting, crumpling, and upturning of the strata has been, in the main, to expose the oil bearing formations, and allow the escape of the volatile oils, thus leaving the non-volatile asphalt in the place formerly occupied by the petroleum pool, rather than that faulting has permitted the escape of petroleum from oil deposits, the original seat of which still lies buried at great depths. However, in the case of some of the mines in the Brunswick district, which occur along pronounced faults and at a horizon (the Viola) above the Simpson, which is known to have been highly petroliferous at other places, it seems quite probable that the zone of impregnation may have been enriched by uprising petroleum from the Simpson.

There are, however, some notable exceptions to the general rule that faulting is not essential to saturation. There are a few deposits of rock asphalt along lines of fracture in the Permian Red-beds of Stephens and Jefferson counties in which the rocks are locally saturated with asphaltic bitumen on both sides of the fault. The same rocks are non-bituminous at distances from the fault and there is reason to believe that the rocks underlying the Redbeds are of the same age as the highly asphaltic series of Pennsylvanian beds in Carter County. In these cases it is believed that the fault plane has acted as a conduit through which the asphalt has risen.

ROCK AND VISCOUS ASPHALT OF THE WICHITA MOUNTAIN REGION

ROCK ASPHALT DEPOSITS.

The known deposits of rock asphalt in the vicinity of the Wichita Mountains consist of sandstone saturated with asphaltic bitumen. There are altogether five occurrences which have been examined by members of the Survey staff. Four of these occur near the east end of the mountains in Comanche County, a little above the base of the Permian Redbeds, as mapped by Taff[36] and Gould, while the fifth one is near Lugert in western Kiowa County. Several other occurrences are reported from near Rainey Mountain Mission but these reports have not yet been verified.

Location number one:—This location consists of a sandstone asphalt quarry in sec. 26, T. 4 N., R. 11 W. about three or four miles west of Elgin, a station on the St. Louis and San Francisco Railroad. The deposit was worked a few years ago by the Lawton Asphalt

36 Taff, J. A., Geology of Arbuckle and Wichita mountains: Prof. Paper U. S. Geol. Survey No. 31, 1904, map op. p. 54.

Company, and considerable quantities of the material were used for paving the streets of Lawton. The exact condition of the pit is not now known, but from earlier reports it is probably not exhausted.

Location number two:—Location number two is on the NE. ¼ sec. 24, T. 2 N., R. 11 W., about six miles northeast of Lawton. It consists of a small, poorly exposed outcrop of sandstone saturated with asphaltic matter, and an oil seep or spring. The oil spring is situated in a small ravine near the north line of the above described land. The flow is very slight, and the spring is insignificant as a source of crude oil. The rock asphalt examined was found near the southwest corner of the same quarter section on which the spring is located. The deposit has never been prospescted systematically and its possible value is unknown, but from what could be seen during a hasty reconnaissance it is believed that the deposit would probably pay if developed.

The structure at this place is monoclinal. The prevailing dip seems to be S. about 20° E. at low angles, though the false bedded and lenticular character of the formation rendered accurate observations impossible.

Location number three:—The rock asphalt deposit here described as location number three is a deposit of sand asphalt located near the center of the W. ½ NW. ¼ sec. 21, T. 2 N., R. 12 W., about six miles northwest of Lawton. The occurrence, which is along a zone of local faulting, has been exploited to considerable extent, but the asphaltic content appears to be too low for profitable mining, except as an adulterant for rock asphalt richer in asphaltic matter.

Location number four:—Location number four consists of a fine conglomerate which contains a low per cent of asphaltic matter. The deposit occurs in the south bank of the North Fork of Red River about one and one-half miles west of Lugert, a station on the Kansas City and Orient Railroad eight miles south of Lone Wolf. The formation in which the bituminous matter is found is lenticular in form, of limited extent, and appears to be an out-wash conglomerate from the near-by mountains. It has never been prospected sufficiently to reveal its character where there is considerable overburden, so the value of the unweathered material is not known. However, the asphaltic content at the outcrop is not sufficient to make the deposit appear valuable.

Location number five:—The occurrence here described is a deposit of rock asphalt in SE. ¼ sec. 29, T. 5 N., R. 12 W. which was reported by Pierce Larkin. The occurrence is in the Permian Redbeds about eight miles southwest of Apache, and near the Limestone Hills. The extent and character of the deposit are unknown.

VISCOUS ASPHALT DEPOSITS.

So far as known at present the viscous asphalts of the region under consideration occur near the west end of the Wichita Mountains in the vicinity of Granite and Mangum. The first discovery was made during 1901 when a very heavy asphaltic petroleum was discovered a few miles north of the town of Granite at a depth of 168 feet. About the same time a hole was drilled a few miles east of Mangum, from which a small amount of heavy asphaltic petroleum is reported to have been taken.

During the present year the Ruggles Granite Company was prospecting its quarry site about two miles west of Granite and encountered a small deposit of semi-viscous bitumen at a depth of about fifteen feet in the solid granite. The amount present has never been determined but it is not supposed to be in paying quantities. Some pieces of considerable size (1"x2"x3") were blown from the hole by the blast and one of them was presented to the writer by Mr. Ruggles. The most interesting feature of the sample is the fact that, though it came from a depth of twelve or fifteen feet below the surface of the granite, *it contains large fragments of blue clay shale in* an undisturbed condition, thus showing that the asphaltic material is *intimately associated with clay shale in the granite* and strongly suggesting a possible genetic relation between the *sedimentary* rocks and the *asphaltic bitumen.*

ORIGIN OF THE ASPHALT.

The known deposits of rock asphalt in the vicinity of the Wichita Mountains, as previously stated, occur near the base of the Permian Redbeds. These beds, owing to their highly-oxidized and non-fossiliferous condition, are incapable of having given rise to hydrocarbons, hence the bituminous matter has doubtless been transported from the place of its origin to the present position. So far as exposed by erosion the same series of fossiliferous and bitumen bearing strata surround the Wichita Mountains as is found in the vicinity of the Arbuckles. It is therefore thought that the asphaltic material locally impregnating some of the sandstones in the region under discussion had its origin in the older strata below the Permian and has since been transported to the superimposed Redbeds.

The heavy petroleum discovered near Granite and Mangum are thought to be of similar origin, but it does not at first seem possible to attribute the origin of the bituminous matter at the Ruggles quarry to that source, owing to its occurrence in pre-Cambrian granite. The association of clay shale with the bituminous matter, at first suggests that the deposit is probably an inclusion within the granite. If such is the case the included material must necessarily be of pre-Cambrian age, for wherever the contact between the Cambrian sediments and the granite is exposed it is seen to be by unconformable overlap unassociated with evidences of metamorphism. Nor does the shale with the bitumen seem to have been altered. This unchanged condition of the clay shale forces us to the conclusion that the material discovered was probably found in a nearly horizontal joint, many of which exist in the granite of the region, where it had collected with the clay shale.

ROCK ASPHALT OF JEFFERSON COUNTY

The rock asphalt of Jefferson County so far as is at present known occurs in the northeastern part. So far only three deposits have been studied by the Survey. Like the rock asphalt of western Carter County, the Jefferson County occurrences are found in the Permian Redbeds.

Location number one:—This location consists of 160 acres of segregated asphalt land in the center of sec. 25, T. 3 S., R. 5 W. The northwest forty acres of the tract has never been under lease, but the east half and the southwest quarter were under lease to the Tar Springs Asphalt Company in 1904, and is probably still held by that company. During the early development of the Oklahoma asphalt industry a refining plant was built on this deposit for the purpose of extracting the asphalt from the sandstone. The plant, however, was burned, after which the operations have consisted in hauling the sand asphalt to Comanche, from whence it was shipped for paving purposes.

The sandstone ledge which carries the asphaltic material is about twenty-five feet thick, and is exposed for about 100 yards along the bank of a ravine. The entire extent of the body is not known, but it probably occurs under the greater portion of section twenty-five.

The normal dip of the rocks of the region is southwestward at low angles, there is, however, evidence of local crumpling in the vicinity of this occurrence for the dip is 3° S. 25° E.

In general the deposit is suited to hillside quarrying which is the method so far used. Drainage is accomplished by gravity, and the overburden, which consists mainly of detrital matter, is easily removed with a team and common road scraper.

Location number three:—The deposit of rock asphalt here described as location number three is situated about one mile east of number two in the NE. ¼ sec. 33, T. 3 S., R. 4 W. It also consists of an unprospected deposit of sand asphalt, probably a continuation of the same formation that occurs at number two.

These three locations are all of the occurrences of rock asphalt in Jefferson County of which the Survey has knwledge, but it is not believed that they represent nearly all of the rock asphalt possibilities of the county.

ROCK ASPHALT OF STEPHENS COUNTY

Rumors of extensive rock asphalt deposits near Dixie, Alma, Velma and Loco have come to the office but only one has thus far been examined by a member of the Survey staff. It is a local impregnation in sandstones belonging to the Permian series. The occurrence studied is along a fault line in the SE. ¼ sec. 6, T. 1 S., R. 5 W. about one and one-half miles northwest of Arthur and 12 miles east of Duncan. The sandstones on either side of a fault seem to have been impregnated with asphalt from heavy petroleum which probably percolated upward along the plane of the fault. The fracture trends N. 50° W. and the displacement, at the point where the asphaltic material occurs, is estimated to be thirty-five feet. A fault which exhibits the same characteristics as the one in section six was noted at Arthur and is presumed to be a continuation of the same fracture. Northwestward the fault appears to be deflected toward the north and changes into an anticlinal fold which probably disappears in T. 1 N., R. 6 W. Heavy asphaltic oil is reported from farm wells along Wildhorse Creek in the southeastern part of T. 1 N., R. 6 W. and the gas well about three miles northeast of Hope is within the limits of the fold.

The sand asphalt near Arthur has never been developed though it was prospected several years ago. It is impossible to give an estimate of its probable value. It seems, however, that it is at least worthy of further investigation.

Judging from common reports concerning southeastern Stephens County it is believed to contain numerous valuable rock asphalt deposits.

The deposit of so-called "asphaltic coal" about three miles west of Alma is discussed in the chapter on asphaltites in this report.

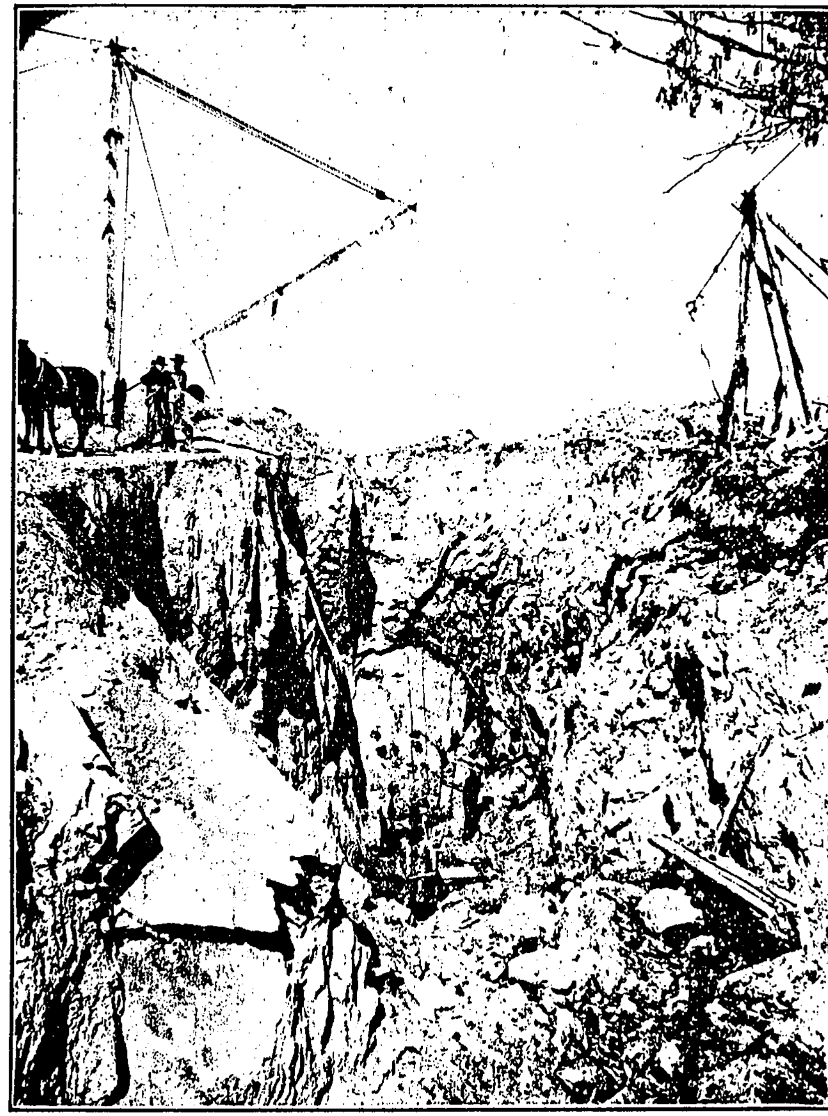
ROCK ASPHALT OF GARVIN COUNTY

The only known deposits of rock asphalt in Garvin County are situated in the southwestern portion in the vicinity of Hennipin and Robberson. The only occurrence so far studied by a member of the Survey staff was visited by B. C. Belt during the present year. It is located in SE. ¼ SW. ¼ sec. 36, T. 1 N., R. 3 W. and consists of a fine-grained sandstone, of Permian age, saturated with asphaltic bitumen.

The sandstone varies from five to twenty feet in thickness and bears some evidence of crumpling. No extensive quarrying has been done, though several prospect pits have been dug. The deposit is so situatd that it could be operated by hillside quarries and drained by gravity.

The United States Geological Survey issued a report in 1901 which contained a paper by Elrdidge[37] on Oklahoma asphalt and bituminous rock deposits. In speaking of the region which is now, southwestern Garvin County he says:

At the western end of the Arbuckle Mountains, in the vicinity of Hennepin, Homer, and Elk, and even as far west as Robberson, a number of oil seepages in the water of wells, springs, or prospect pits were reported to the writer. These were accepted as evidence of the general distribution of oil in as yet undetermined quantities, but the only places visited were the Williams ranch, 3 miles southeast of Hennepin, where a seepage of oil occurs on the water in a small prospect pit in limestone, the only asphalt found being along thin seams in the fractured rock; a small pit exposing an inferior bituminous limestone on the Elk road, 2½ to 3 miles southwest of Hennepin, and the Nelson prospect, 2½ miles southeast of Elk. A specimen reported from the Robberson occurrence indicates it to be a surface deposit from an old maltha spring.



ROCK ASPHALT MINE NEAR ARDMORE.

37 Eldridge. Geo. H., Asphalt and bituminous rock deposits of Indian Territory: Ann. Rept. U. S. Geol. Survey No. 22, pt. 1, 1901, pp. 263-319.

ROCK ASPHALT OF CARTER COUNTY

Carter County, of which Ardmore is the county seat, is located in the south-central part of the State immediately north of Love County. The topography is very irregular. The topographic features of that portion of the county which consists of Permian Redbeds is mainly due to stream erosion in formations which have suffered but little deformation, while those of that part which is composed of Pennsylvanian and older Paleozoic rocks is chiefly due to differential erosion of formations which were crumpled, faulted and upturned by the forces which produced the Arbuckle Mountains and Criner Hills.

In discussig the geology of Carter County it is not necessary to say more than that the west two thirds of the county consist of Permian Redbeds and the eastern third of Pennsylvanian and lower Paleozoic formations, with the exception of a few square miles in the southeastern and south-central portions which are of Cretaceous age. In fact, formations belonging to every age from upper Cambrian to Comanche Cretaceous, except Jurassic and Triassic, are represented in this county.

The rock asphalt of Carter County occurs chiefly in the Glenn formation of Pennsylvanian age and in the Permian Redbeds. The conditions peculiar to each occurrence will be discussed as fully as available data will permit. Each occurrence is given an arbitrary number beginning with the deposit on Hickory Creek about four miles northwest of Overbrook.

Location number one:—Location number one consists of a large deposit of fine grained sand asphalt located in the NW. ¼ NE. ¼ sec. 26, T. 5 S., R. 1 E. The outcrop of the bituminous rock is along a fault line which has a local trend of N. 35° E. The exposure, about 30 yards wide by 440 yards long, is located on the downthrow side of the fault, and dips 14° N. 55° W.

The land is owned and operated by the Downard Asphalt Co. of Ardmore. In 1906 that company opened up three hillside quarries, which have been in almost, if not quite, continuous operation since. Drainage is accomplished by gravity. The product is hauled to Overbrook from where it is shipped.

Rock asphalt is also unofficially reported from the NW. ¼ sec. 36, T. 5 S., R. 1 E., and the SE. ¼ sec. 22, of the same township and range.

Location number two:—This location, in the NW. ¼ SE. ¼ sec. 14, T. 5 S., R. 1 E., is on a body of segregated asphalt land, consisting of 340 acres. Some years ago a mine was operated on this land to supply rock asphalt for refining purposcs. This enterprise, however, did not thrive and the mill was shut down and abandoned.

The asphaltic material occurs in a fine-grained sandstone along a zone of mashing, probably a strike fault, in nearly vertical strata of the Glenn formation of Pennsylvanian age. The deposit dips 75° north, 35° east. The zone of saturation extends along the strike of the rocks for a distance of one-fourth of a mile or more, though the outcrop at the old mill is only about 300 feet by 40 feet. The overburden varies from nothing to twenty feet of alluvium.

The quarries which have been operated are of the open pit type. Drainage could be accomplished by gravity to a depth of about ten feet. Below that level, however, pumping would doubtless be necessary though it is barely possible syphoning would be found practicable but no observations were made to establish the possibility.

This deposit is only one and one-half miles from the Santa Fe Railway but the nearest shipping point is Overbrook about five miles to the southeast.

Location number three:—Location number three is situated on the SE. ¼ NW. ¼ sec. 10, T. 5 S., R. 1 E. on unsegregated land. The asphaltic material occurs along the bedding plane of an upturned fine-grained sandstone of the Glenn formation. The structure is difficult to determine in detail but there is evidence of slipping and perhaps faulting along the strike. The impregnated rock is exposed over an area approximately twenty by fifty yards, but doubtless extends to considerable distance under the debris and stream wash of the vicinity.

The occurrence is adapted to hillside quarrying and could be drained by gravity to a depth of forty or fifty feet without great difficulty. Ardmore, the nearest shipping point is about six miles distant.

Location number four:—This location is situated in the SW. ¼ NW. ¼ sec. 5, T. 5 S., R. 1 E., on land owned by M. W. Coffee of Lonegrove. The material is a fine grained sand asphalt which occurs in the Glenn formation. The structure is monoclinal with a dip of 40° south 35° west. The deposit has never been prospected but is of promise. The area of rock asphalt exposed is about twelve by forty-five feet. It disappears under residual soil etc., and likely extends conisderably beyond the area exposed. The overburden is soil and loose detrital material. Drainage could be accomplished by gravity to a depth of about twenty-five feet. At present the deposit is seven miles from a shipping point but it is less than three miles from the Rock Island survey to Waurika.

Location number five:—Location number five is the site of the Continental Asphalt Company's old mill on the NE. ¼ NW. ¼ sec. 21, T. 4 S., R. 12 E., situated on land belonging to Geo. L. Smith of Cowlington, Oklahoma. The Continental Company began operations in 1898. Their purpose was to quarry the sand asphalt and separate the asphaltic material from the sandstone, by mechanical process. The plant did not pay and operations were suspended, and the machinery removed. The Downard Asphalt Company of Ardmore is reported as now holding the lease though the quarry is not being operated.

The asphalt exposure is limited to the old quarry pit, which was full of water, so it was impossible to make careful examination of the occurrence. From what could be seen, however, it appears that the sandstone which has been worked consists of two members separated by about five feet of shale. The south member is twenty-five feet thick and appears richest in asphaltic bitumen, while the north one is approximately ten feet thick and poorly impregnated. In general the structure is monoclinal with a dip of 75° north 50° east. There are unmistakable evidences of strike faulting, but it seems to have been very local, and is probably nothing more than slipping along the bedding plane induced by the intense folding.

Like all Carter County occurrences so far discussed this deposit occurs in the Glenn formation. The quarry, which is reported to be forty feet deep, is of the open pit type and could be drained by gravity to a depth of perhaps twenty-five feet. It is located about six miles northwest of Ardmore, the nearest shipping point.

Location number six:—This occurrence consists of sand asphalt on the SW. ¼ sec. 19, T. 3 S., R. 1 E., on land which belongs to Paul Alexander, and is located about one mile northwest of the postoffice of tiff. Several prospects were opened by the Downard Asphalt Company in 1907 since which time operation has been maintained with considerable regularity.

The sandstone is impregnated along the bedding plane. The structure, narrowly speaking, is monoclinal due to overturning of the strata, which dip 85° north 40° east, though the location is on the northeast limb of the great Ardmore syncline.

The quarries are situated in Caddo Creek bottom. The product is hoisted from the pit, which was about twenty-five feet deep when visited, by horse power cranes. The outcrop extends for a quarter of a mile across the country and has been prospected at several places. Water causes but little trouble as the pit is easily unwatered with a small pump. The product is hauled to Ardmore, thirteen and one-half miles to the southeast, from whence it is shipped. Though Berwyn is a little nearer the roads are not so good. The rocks of the region belong to the Glenn formation of Pennsylvanian age, probably near the base.

Location number seven:—Location number seven is the old asphalt mine on Henry House Creek nearly two miles northwest of the occurrence just described. In all essential respects it is similar to number six and occupies approximately the same geological horizon. It is not now being operated so far as is known.

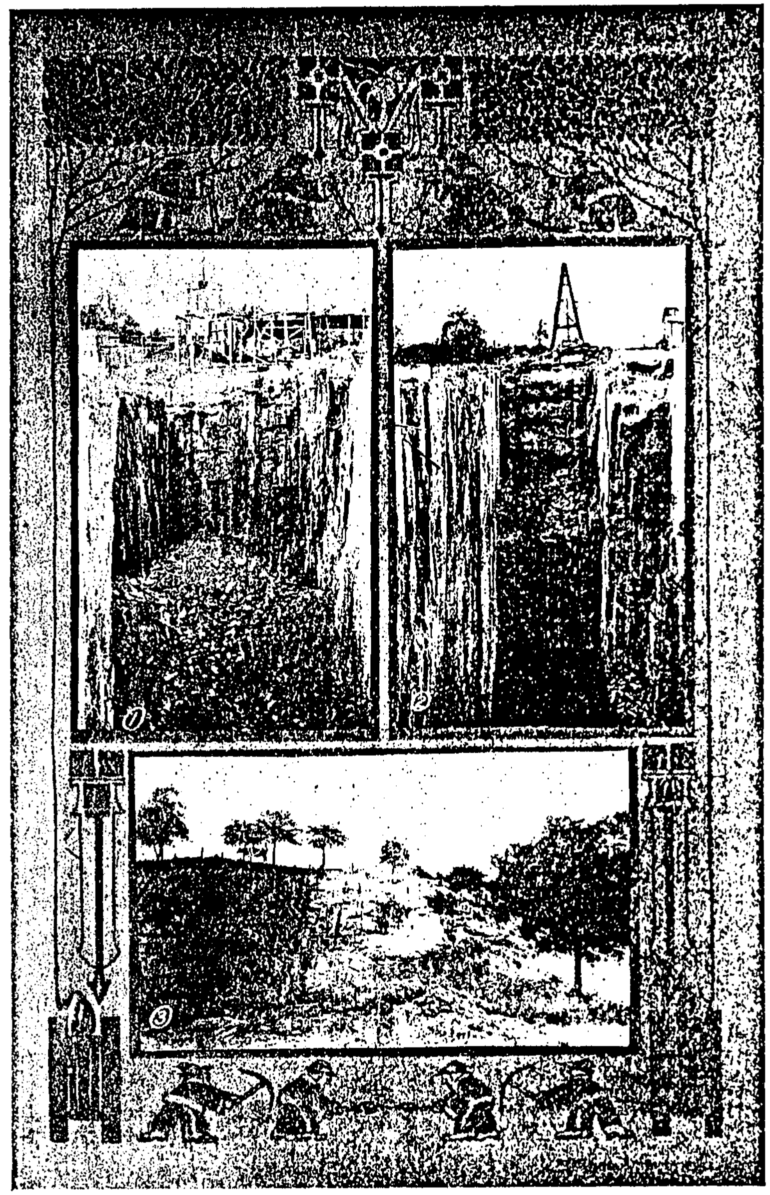
Location number eight:—This location is the 1,280 acres of segregated asphalt land between Woodford and Tiff. It is now under lease by the American Mineral Wax Company, which has an extensive plant for the extraction of the bituminous matter from the sandstone. The quarries are located on a heavy ledge of fine-grained sandstone in the Glenn formation. Cross bedding on a small scale is frequent, though as a whole the sandstones are evenly bedded in thin strata. The zone of richest impregnation is about 45 feet thick though the sandstone containing it is exposed at numerous places for a thickness of nearly 150 feet. The outcrop can be traced for a half mile or more across the country. The dip is 90° at the eastern quarry, though it varies locally, and the strike is north 55° west, or parallel to the strike of the Arbuckle Mountain formations.

The character of the quarries and outcrop are well illustrated by the photographs in one of the plates of this report. There is, as a rule, little or no overburden ownig to the fact that the sandstone ledge outcrops as a ridge between shales. The heavy oils impregnating the sandstone are often forced to the surface by heat and descending water so that beds of brea, or viscous asphaltic materials, are common.

Location number nine:—This location consists of a small oil spring in the northeast corner of sec. 10, T. 2 S., R. 2 W. There appears to be little or no associated rock asphalt. The occurrence is in Permian Redbeds, but the bituminous matter doubtless comes from the old buried formations of Pennsylvanian age, as this deposit is in strike with the formation which contains the asphalt at and near Woodford, and the Redbeds themselves have never been known to yield bituminous matter, or other hydrocarbons, except where those substances were referable to older strata that are known to contain oil and gas at other places.

Location number ten:—This consists of a bituminous sandstone in the Permian series, situated in NW. ¼ sec. 11, T. 2 S., R. 2 W., on segregated land. A quarry and refinery were once operated at this site and the product hauled to Ardmore, but operations have been suspeded. The mineral consists of a fine-grained sandstone about thirty feet thick which strikes north 40° west and dips about 4° southwest. The entire extent of the ledge is unknown. The exposure of asphaltic sandstone is about 100 yards long. As in location number nine the asphalt, it seems, is referable to the buried Glenn formation. The quarries were operated by the hillside method and drained by gravity. The failure of the enterprise was probably due to the long haul (twenty-five miles) to a shipping point and the attempt to extract the asphalt from the sandstone instead of using it as rock asphalt.

Location number eleven:—This is another occurrence of sand asphalt apparently of Permian age, but the bituminous matter is perhaps properly referable to the Glenn formation. It is located in the SW. ¼ NW. ¼ sec. 34, T. 1 S., R. 2 W. The structure of the region is gently anticlinal and the rock asphalt occurs as a ledge about



1 ASPHALT PIT AT WOODFORD MINE, LOOKING EAST. HUTCHISON, '09.

2 ASPHALT PIT AT WOODFORD MINE, LOOKING WEST. HUTCHISON, '09.

3 OUT-CROP OF ASPHALT-BEARING LEDGE AT WOODFORD MINES. HUTCHISON, '09.

ten feet thick near the axis of the fold. The outcrop is intermittent, but the deposit extends for a distance of several hundred yards along the bank of a small stream. The overburden consists of from four to eight feet of residual matter. The deposit is so situated that hillside quarries could be operated to advantage, and drained by gravity.

Location number twelve:—Location number twelve consists of an outcrop of asphaltic sandstone along a creek in the SW. ¼ sec. 9, T. 1 S., R. 2 W. The sandstone, of Permain age, is fine grained and even textured. The ledge is approximately eight feet thick and outcrops for only about fifty yards. The structure is monoclinal, with a dip of about 4° toward the southwest. Where the rock is not exposed it has an overburden of six or eight feet of residual soil and sand. It has never been developed and its possibilities are unknown.

A drill hole was sunk to a depth of 900 feet in the vicinity some years ago with the hope of getting oil but the result was unsatisfactory.

Location number thirteen:—This deposit is found near the center of the east side of sec. 21, T. 3 S., R. 2 W., in the midst of the Wheeler oil and gas field. It was first described by Eldridge[38] in 1901. His description which is concise but complete, is as follows:

> At Wheeler is one of the largest oil seepages in the United States. The only parallel in size known to the writer is one still forming near Fort Washakie, Wyo. the Wheeler spring is long since extinct, as is shown by the appearance of the material and by the inclusion of fragmental asphalt derived from it deep in a deposit of 4 or 5 feet of alluvium along portions of an earlier channel, this being shown by the erosion, upon the same lines, of a modern channel which has cut alluvium, asphalt, and underlying beds. The conditions of occurrence are indicated ....where the asphalt of purer type is seen forming the superficial layer, succeeded below by sandstone alternately shaly and solid, and all varyingly impregnated with bitumen, the per cent diminishing with increasing depth. With the sandstone are associated red and gray argillaceous shales, and the whole series is probably of the Permian, which is prevalent in this region. The superficial asphalt rests upon a somewhat uneven surface of the approximately horizontal strata, and is from 6 inches to 3 feet thick—a hardened petroleum residue, resulting from the volatilization of the lighter oils, with perhaps a certain amount of oxidation, the common transformation in the case of all deposits of like nature.........This asphalt is primarily black: earthy, or clear and wax-like in texture; brittle yet tenacious, and under a slight rise in temperature becomes of gum-like consistency. In the face of the gully that is eroded in the deposit, the upper 1 foot maintains the richest, purest, and most unaltered appearance, the portions below becoming successively browner, more earthy, and easier to break.........The deposit is of interest in its bearing upon the presence of oil at depths and is another evidence of the possibilities of the region which have already been suggested in the references to oil-bearing waters of springs, wells, and prospects.

This deposit has never been exploited for asphalt. Its occurrence was one of the factors considered in the location of the Wheeler oil field and, different from like experiments in other parts of the State, this one was successful. The deposit is in Permian rocks and the drilling seems to confirm the theory that the oil and gas are coming up into the Redbeds from the Pennsylvanian rocks below.[39]

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38 Eldridge, Geo. H., Asphalt and bituminous rock deposits of Indian Territory: Part I, 22d Ann. Rept. U. S. Geol. Survey, 1901, p. 314-15.

39 For description of the Wheeler oil field see Part II. this report.

There are three other deposits of sand asphalt and brea in the vicinity of Wheeler but they are in all essentials similar to the one described so they only need to be mentioned here. One is in the NW. ¼ NE. ¼ sec. 21, another near the center of the E. ½ of sec. 19, and the third is in the E. ½ SE. ¼ sec. 35, all in T. 3 S., R. 2W. None of these deposits have been developed for asphalt or brea, but all have occasioned prospecting for oil. The first mentioned is surrounded by oil and gas production, the second was found dry, while a shallow well with a very small production of heavy oil was drilled north of the deposit in section thirty-five.

Location number fourteen:—There is an authentic report to the effect that there is a deposit of rock asphalt in the Permian Redbeds near the northeast corner of sec. 21, T. 4 S., R. 2 W. about two miles north of Hewett, but no member of the Survey staff has examined it and its value and probably desirability are unknown. A similar occurrence is reported from the SW. ¼ sec. 13, T. 5 S., R. 2 W., about five miles southeast of Hewett. It likewise has never been examined, but is reported as being of promise. The survey for the railroad extension from Ardmore to Waurika passes between these deposits.

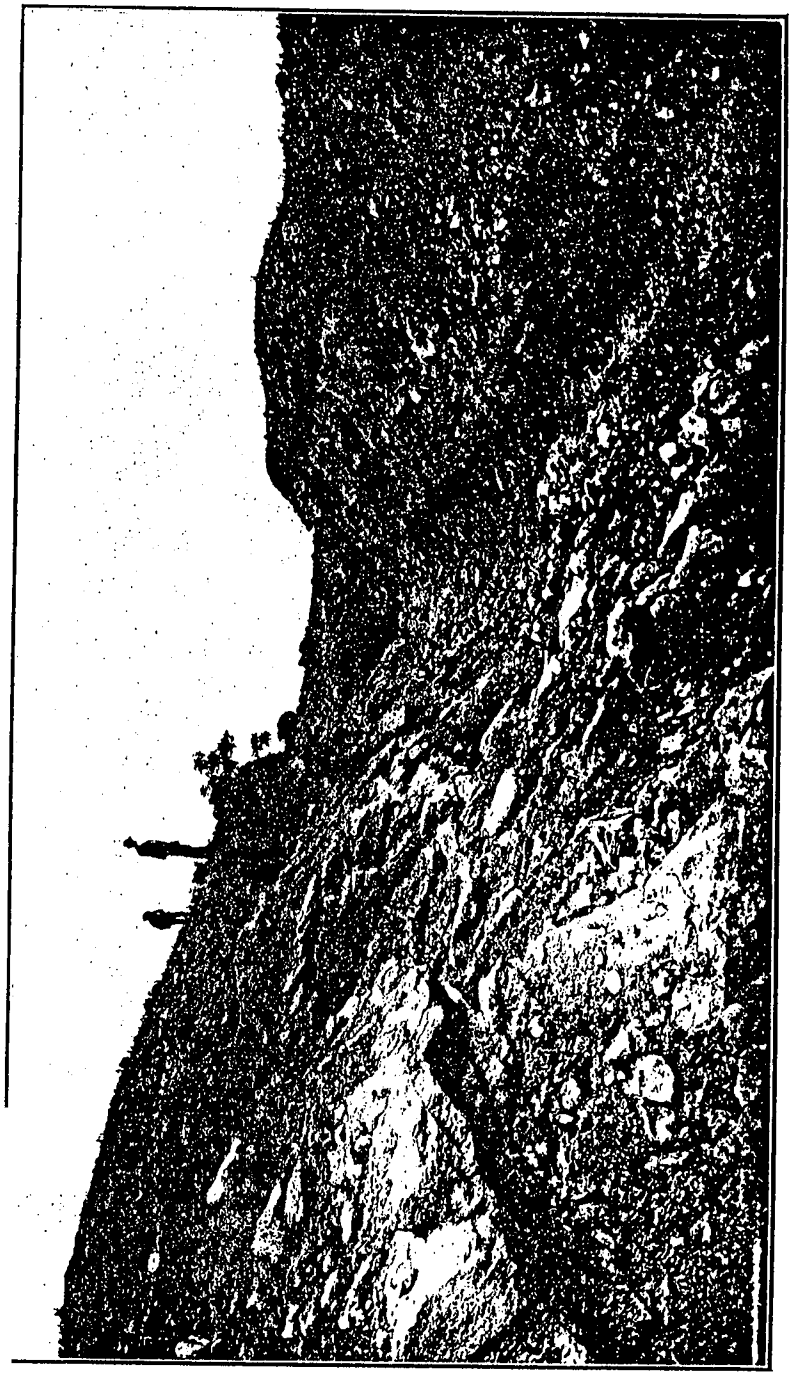
There are no known deposits of the pure asphalts (asphaltites) within the county but it is among the first in the richness and extent of rock asphalt deposits.

ROCK ASPHALT OF MURRAY COUNTY

The first detailed report of the rock asphalt deposits within the present bounds of Murray County was prepared by Geo. H. Eldridge for the United States Geological Survey at Washington, and published by that bureau in 1901.[40] The paper was based on very careful field observations, and was complete at the time of its publication. It will, therefore, be heavily drawn upon in the following pages, such additions being made as development warrants.

For convenience of discussion Eldridge divided the region into three districts which he called the Buckhorn district, the Brunswick district and the Washita Canyon. There seems to be no reason for changing his classification except that the Buckhorn district is made to include all occurrences south of Sulphur in T. 1 S., R. 3 E., except the Brunswick mines about four miles northeast of Dougherty. The Brunswick district comprises the land covered by the lease of the Brunswick Asphalt Company, and the Washita Canyon district includes the minor occurrences of rock asphalt along the bluffs on both sides of the river by that name.

40 Ann. Rept. U. S. Geol. Survey No. 22, pt. I., 1901, pp. 273-312.



BUCKHORN ASPHALT MINE, 4 MILES SOUTH OF SULPHUR.

THE BUCKHORN DISTRICT

At the time of the Eldridge report there were 12 openings in what is called the Buckhorn district. Eldridge's description and discussion of these pits is by local names and numbers but for the sake of uniformity they are here discussed as locations. The discussion begins at the east side of the area and passes westward.

Location number one:—This occurrence consists of two prospect pits near the south line of the SE. ¼ of section 14. The deposit was never developed, though sand asphalt was found in what is thought to be commercial quantities. The sandstone is a member of Taff's[41] Simpson formation and is of lower Ordovician age. Local structure and conditions as described by Eldridge[42] are as follows:

The general strike for the locality is N. 50° E., the dip 20° SE., but in both pits the strata look horizontal. The thickness of the sandstone is said to be over 10 feet, but 2 feet only show above the water of the pits. The rock carries a moderate per cent of bitumen, is brownish black and tough. The bitumen is held in the interstices between the grains of rounedd quartz which constitute its mass. A small per cent of lime may also be present. A peculiarity of this sandstone is a white venation that follows joint or fracture planes, of which there are many. Close examination shows the veinlets to be of rounded quartz grains in a white, earthy cement of undetermined composition. The veinlets are usually from a few inches to 3 or 4 feet long and from one thirty-second to one-half inch wide. On the face or plane of a joint, if the rock be there opened, they show as a thin film. In addition to the venations, mottling of black and white, similar to that seen in other localities, is also present. The bed is overlain by yellow quartzite and clay.

Location number two:—The quarry here described as location number two is a stratum of highly fossiliferous, argilaceous limestone which yields 14 to 15 per cent asphaltic bitumen. It is situated on the SE. ¼ SE. ¼ sec. 23, one mile south of location number one, and about one-half mile northwest of Buckhorn postoffice. Eldridge describes this occurrence as Quarry number two in the report cited at the beginning of this discussion. Judging from the present condition of the quarry but little has been done since Eldridge's report was written. His description follows, in part:

This quarry, the property of the Gilsonite Paving and Roofing Company........ is........at the eastern end of the Buckhorn district. The strike of the beds is here S. 62° W., the dip northward about 30°. The strata quarried are probably referable to the Lower Coal Measures........The prevailing rock is brownish black on fresh surface, dark gray after exposure. It is fine-grained to granular, and in portions of the bed bears a high per cent of comminuted molluscan shells, together with many in a state of more or less complete preservation, all beautifully nacreous. The shell contents thus form a characteristic feature of the bed. A certain degree of porosity is also apparent throughout the rock. In occasional instances the bed is more or less minutely seamed with pure asphalt, apparently from the filling of fissures produced by cracking, or possibly by solution. The asphalt thus occurring is black, but gives a brownish streak and powder........The material of this rock is fine-grained and is rich in bitumen......

In the breast of the quarry as exposed at the time of the examination there was observed a steeply inclined (62°) vein-like body of bitumino-calcareous material, about 18 inches wide. This could be traced N. 70° W. for 25 or 30 feet along the back of the stratum forming the breast, when it split into a number of veinlets, each of which quickly pinched to naught. The vein rock is mottled brown and black, indicating an uneven distribution of the component materials. The texture is exceedingly fine-grained to homogeneous; the fracture brittle, with tendency to conchoidal form, which is more strongly developed as the per cent of bitumen increases........

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41 Taff, J. A., Preliminary report on the geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma: Prof. Paper, U. S. Geol. Survey, No. 31, 1904, p. 23 et seq.

42 Twenty-second Ann. Rept. U. S. Geol. Survey, pt. I., p. 305.

From the appearance of the material, the vein may have originated in either of two ways: First, a fissure having been formed, perhaps at the time of the general crumpling, it may have been subsequently filled with bitumen carrying a variable per cent of amorphous carbonate of lime acquired in its passage through the body of the limestone; or, second, a channel having been formed by solution, either complete or in a degree to render the rock on its course exceedingly porous, filling may then have been accomplished in the same manner as in the first instance.

The rock of the No. 2 mine is the richest mined by the Gilsonite Paving and Roofing Company. The amount that has been quarried is considerable, the open cut being nearly 400 feet long, the bed having been removed to a depth of between 20 and 30 feet. The extent of the bed beyond the present quarry lines is undeterminable except by a close succession of drill holes or a continuation of quarrying itself........It is believed that to the north, within 300 yards, the deposit is interrupted by a........fault; to the south it is possible that the bed may recur on a temporary southward dip, but, again, the area in this direction is probably limited. Eastward the presence of the enriched limestone is questionable, for already at this end of the pit are encountered faults and foreign beds. The western extent of the stratum may prove to be several hundred feet, but the outcrop can be definitely traced only a short distance.

Location number three:—This location is locally known as Number one prospect, and occurs in the NE. ¼ NE. ¼ sec. 28, T. 1 S., R. 3 E., about 300 yards southwest of location number two. It consists of quartzose limestone of Pennsylvanian age, which, though carrying some asphaltic bitumen, is worthless owing to its irregular character and content. The structure is in alignment with that of the occurrence discussed above

Location number four:—This location is in the S. ½ SW. ¼ NE. ¼ sec. 22, T. 1 S., R. 3 E., and is of especial interest because it was exploited by underground mining methods instead of by quarrying. It is the only place in Oklahoma where rock asphalt has been taken out in this manner. The mine is reported to have been opened in 1896 and was operated to a depth of 180 feet where the face was about 70 feet by 18 feet Water prevents examination below 25 or 30 feet from the surface. Aggregates of crystal calcite became so numerous in the main asphalt bearing zone that it no longer paid to work the mine, as the cost of getting the material to the top was nearly $2.00 per ton.

Eldridge describes this occurrence as *Number three (limestone) Mine* on pages 298-299 of the report above referred to. His description of the character of the deposit is quite complete and is, in part, as follows:

This mine, the property of the Gilsonite Paving and Roofing Company, is located........in the center of the Buckhorn district. It is opened by an incline on the No. 3 limestone, mining methods having been followed rather than quarrying, by reason of the dip, about 30°........The limestone has been fully described in discussing the geological sections........but for the purpose of comparison between mines and quarries it will be repeated here.

The upper 5 feet of limestone is coarsely crystalline; drab, weathering yellow-gray; distinctly fossiliferous; a trace of bitumen in the lower portion.

The 10 feet below is, in the main, fine grained.. From 2 to 4 feet from the top, however, is a band carrying numerous small calcite bodies, round and elliptical, drab in color, and in general in marked contrast with the surrounding mass of rock. The rock is somewhat varyingly charged with bitumen up to a maximum of perhaps 6 per cent, a sample obtained from the upper portion of the mine yielding 5 per cent........Veinlets of bitumen occur, passing alike through the general rock and the calcite bodies. The lower 2 feet of this zone is less rich and browner than the overlying portion.

The next 4 feet is fine to coarsely crystalline; light brown to black, more generally the former; fossiliferous and bituminous........The lower 5 to 10 feet of this bed are crystalline, drab, and non-bitumenous.

The entire bed of limestone is more or less joined, an impoverished chocolate-brown zone ¼ to 2 inches wide quite invariably lying on either side of the fracture planes.

The portion of the bed mined includes only the second and third layers from the top, the rich zone of 10 feet and that immediately underlying, 4 feet thick. The product thus far derived from these two beds probably amounts to several hundred tons. The mine is equipped with hoist and steam drills, and the company has at this point a small machine shop and store. Near by, also, is the factory at which mastic and street topping are made. The mine was closed at the time of the investigation.

The mine is not now being operated. Both the store and mill located at the mine have been idle for several years.

Location number four:—This location consists of an old sand asphalt quarry a few hundred yards northeast of location number three, situated about 200 feet east of the old fatcory building of the Gilsonite Paving and Roofing Company, and belonged to that corporation. Operations have been suspended for several years and the quarry is now filled with water, forming a pond, so the exact conditions could not be observed. The pond is about 75 feet wide and 450 feet long.

The sandstone locally called the Bodine sandstone by Eldridge, is a member of the Simposn formation described by Taff, reference to which was given on a previous page. The average of the bituminous content is reported to range between six and eight per cent though it varies locally. The extent of the impregnated zone is not known, and cannot be determined except by prospect borings. There seems to be little doubt but that this sandstone is an old oil sand which has been exposed by elevation and erosion, so it is believed that the asphalt-bearing bed extends well beyond the limits of territory thus far exploited.

Location number five:—This location consists of a large sand asphalt quarry known as the Moss pit located on SW. ¼ SE. ¼ sec. 15, about a half mile north of location number four. It was opened on a sandstone member of Taff's Simpson formation, locally called the Dixon sandstone by Eldridge. The site is reported to have been prospected as early as 1890, but the quarry, owned by the Rock Creek Natural Asphalt Company, was not opened until seven years later.

The zone of sufficient richness to repay quarrying is about eight feet thick and extends laterally the length of a breast, approximately 400 feet long, which has been worked back about 300 feet from the outcrop. The per cent of bituminous matter varies from about seven to ten. The enriched portion is succeeded below by a soft white sandstone, the line between the two being usually well marked, though locally there are two to three inches of brown impoverished rock asphalt at the contact. Above the deposit there is a thickness of eight or ten feet of impoverished and weathered asphaltic sandstone overlaid by from fifteen to thirty feet of Pennsylvanian conglomerate. The extent of the deposit below the bottom of the present quarry is problematical. Outcrops in various directions show the continued presence of bituminous matter and there is a "tar spring" in a ravine about 200 yards north of the pit. It is very probable, therefore, that there is more rock asphalt remaining in the ground than has been taken out. The quarry is idle at the time of this writing but was operated during the past summer, the raw product being sold for paving purposes.

Location number six:—This location, known as the Bodine quarry, is situated on the NW. ¼ SE. ¼ NW. ¼ sec. 22. It was opened on a member of the Simpson formation, locally called the Bodine sandstone by Eldridge,[43] and is controlled by the Rock Creek Natural Asphalt Company. Westward the deposit is cut off by the Bodine fault, but the horizon extends east past location number four, described above. It is not known whether or not the zone of impregnation is continuous between these two quarries. The dip of the rocks at the pit is about 25° southeast. The quarry has never been as extensively worked as the Moss quarry, and the thickness of the pay zone is not definitely known. It is reported that a drill hole thirty-two feet deep stopped within the saturated sandstone. This apparently great thickness is partly due to the inclination of the beds, but with the local dip (25°) the bed must be over twenty-five feet thick in order to drill into it the depth above stated. The rock is made up of rounded quartz grains, with approximately seven to eight per cent of asphaltic bitumen filling the interstices. The rock carries the calcario-quartzitic bodies so common in the East Kirby quarry to be described later.

Location number seven:—This location comprises three quarries known as the Kirby quarries, located about two-thirds of a mile northwest of the asphalt mine near the old mill and store, and situated on the NW. ¼ NW. ¼ sec. 22, and the NE. ¼ NE. ¼ sec. 21, and is the property of the Rock Creek Natural Asphalt Company. The first quarry opened, known as number one, is between the other two, all of which are on the Dixon sandstone, the member of the Simpson formation from which the product at the Moss pit is obtained. The east pit is number two and the most westerly is the last opened on that site. These openings are reported to have been made in 1895 and 1896. It was not learned how long they were operated, but they have been idle for the past few years. Eldridge[44] describes them as west, middle and east quarries. His description is complete and, in part, is as follows:

The west quarry lies in a low, flat knoll of small diameter, the other two in the rolling ground to the east........

This quarry is opened in the southern slope of the knoll; on the northern slope, less than 200 feet distant, the productive sandstone of the quarry shows but a trace of bitumen. The explanation probably lies in non-impregnation of this portion. At the eastern end of the quarry the enriched zone of the bed........may be seen to feather out, although here as to the north the general width of the sandstone itself is maintained. The entire area of the bitumen-bearing sandstone

43 Eldridge, Geo. H., Ann. Rept. U. S. Geol. Survey No. 22, pt. I., p. 303.
44 Eldridge, Geo. H., Ann. Rept. U. S. Geol. Survey No. 22, pt. I., cited above.

is, therefore, even smaller than the diameter of the hill. It appears to be, in fact, the western end of a comparatively small body that has its eastern limit at some point perhaps a little beyond the eastern edge of the east quarry........

The overburden attains a maximum thickness over the quarry of between 10 and 15 feet. It is very hard and requires heavy blasts for its removal. The method of stripping, however, is simple, and after this has been accomplished to a sufficient distance and the quarry cleaned of the debris, the bitumen-bearing sandstone itself is removed, loaded on wagons, and shipped to the railway.

Eldridge's description (pp. 301-2 previous citation) of the middle quarry (Number one) is more complete than can be written from my reconnaissance notes, so it is quoted in part.

The middle quarry lies immediately east of the west, but at a level between 15 and 20 feet lower. The difference in level is, perhaps, primarily an effect of the Bodine fault; on the other hand, it may be ascribable to mere erosion from the summit of the bed, the protective cap of conglomerate having been first removed. In the latter event the lower level of the enriched rock in the middle quarry indicates an originally deeper impregnation of the bed and a consequent extraordinary unevenness in the separating plane between the rich and barren zones. An occurrence of this nature is quite possible, yet, in view of the proximity of the Bodine fault, the difference of level, it is believed, is best attributed to stratigraphic throw. But the irregularities in the details of impregnation are none the less well illustrated in the rapid succession, in the north wall, of highly enriched, black, oily sandstone; a brown, friable sandstone with the interstitial bitumen dried and lifeless, and barren rock with but scattered specks of bitumen amid the grains of quartz. These bodies of rock of differing composition and color are separated from one another in the face of the quarry by lines waving from vertical to horizontal and sharp or sharply transitional, indicating the irregular form assumed by the impregnated portion of the bed and the manner of passage from barren to rich portions. The prevailing conditions suggest high enrichment for a part of the sandstone, none whatever for another, with a narrow intermediate zone, a few inches to 2 feet in thickness, in which infiltration may not have been as complete as in the richer portion, or from which, for some cause, the more volatile parts of the bitumen have now escaped and left only the dried residue in the interstices of the quartz grains........

The barren portion of the sandstone is soft, friable, and variably ferruginous. Beneath the bitumen-bearing zone it is gray to white; overlying this, at the surface, it is white, brown, orange, or red, the iron, the source of the colors, seeming to have been as peculiarly and irregularly distributed, and with as sharply-defined bounding lines, as the bitumen in the other portions of the rock........

The middle quarry appears to have been opened on the northern slope of the fold occupying the low northeast-southwest ridge between the Kerby and Bodine pits, the strike of the sandstone being about W. 40° E. with northerly dip of 5° to 7°. It is not clear from the outcrops whether the sandstone is continuous at this point to the southern slope of the fold just referred to, or is interrupted for a short distance.

Quarry number two, the east quarry of Eldridge, appears today about as described by Eldridge, so that author is again quoted in part.

The east quarry lies about 150 yards east of the middle. It is opened on the same bed as the latter, but continuity of the bituminous body is not established between the two. Like the middle, it is opened on the gentle northern slope of the same fold. The quarry has yielded the largest product of the three of this group, the pit being about 100 feet in diameter, the thickness of the bed worked, from 8 to 10 feet. The rock carries a comparatively high per cent of bitumen, perhaps 8 or 9, which, however, is said to contain a notable amount of volatile oil, an occurrence not met, according to statement, in the rock of the west and middle quarries.

A conspicuous feature of the bed is the presence in its upper 2 feet of many bodies of a white, quartz-like rock, which impart to the layer, especially on its surface as stripped, a marked mottled white and black appearance, the mottling of various degrees of coarseness. The line of separation between the black and white is usually sharp. The two portions show quartz grains as their predominant constituent, but the white is found to carry in its interstices a heavy percentage of carbonate of lime, while the black shows either but a faint trace (with HCl) or none at all. The line of separation between the chemical constituents, as shown by reagents, is quite as distinct as that of color, and the two are coincident. If, too, there be a thin line of white threaded through the black again the white shows the carbonate of lime reaction, the black, not. It can hardly be questioned that the sandstone held a calcareous cement unevenly distributed through its upper portion, and that when the bitumen came to be taken up it was received into all those interstices that were unoccupied, but was barred from those already filled with lime, including even the veinlets. The foregoing feature is not uncommon in the bituminous sandstones of the Buckhorn district.

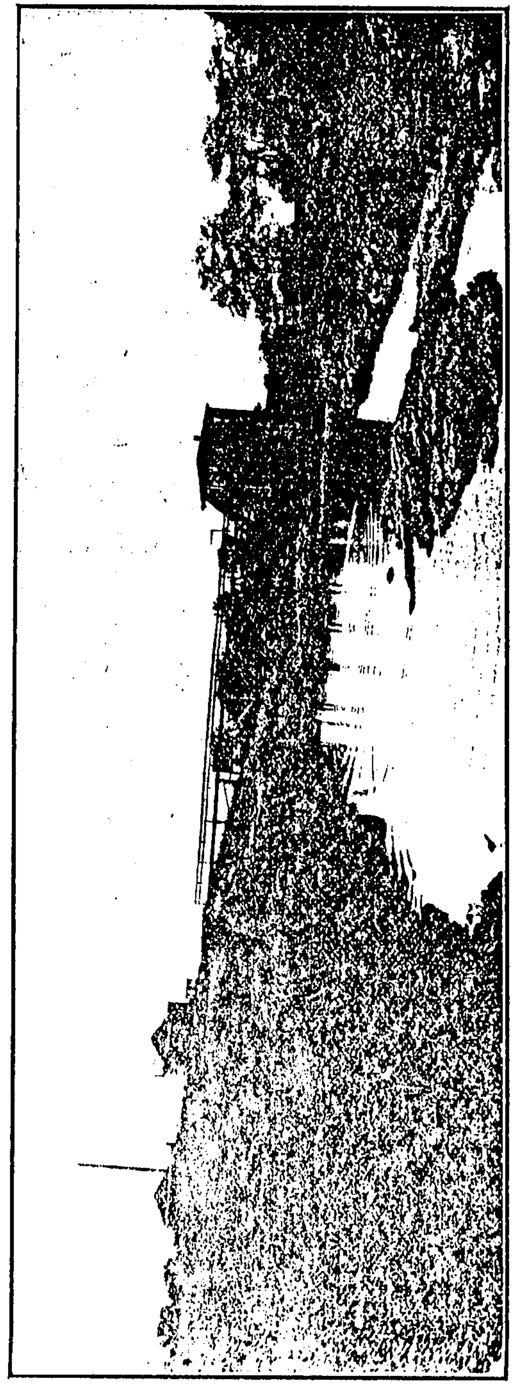
Location number eight:—This is an occurrence of sand asphalt in a lentil within the Franks Conglomerate of Pennsylvanian age. It is located about two and one-half miles north of the old lime asphalt mine at the Gilsonite Company's mill and about a mile south of the townsite of Sulphur. Originally it consisted of a sand asphalt resembling, in some respects, that at the Moss pit. It has apparently been entirely worked out so that only the old opening and quarry detritus are left to mark the site.

Location number nine:—This location is the site of what is known as Number four quarry of the Gilsonite Paving and Roofing Company, situated in SW. ¼ SE. ¼ sec. 21. The product consists of lime asphalt, probably from what is known as the Viola limestone. The limestone formation has a total thickness of 342 feet at this place, and here dips southeast at high angles, probably 70°. The quarry embraces 128 feet of the total thickness, the lower 75 feet having never been opened and the upper 139 having been rejected on account of the presence of a high per cent of calcite which carries no asphaltic material. The character of the rock varies from place to place but is usually massive. The texture is earthy, granular, and crystalline. The granular crystalline rock is considered most satisfactory and has been more extensively quarried than the other types. The per cent of saturation is about five or six, but varies locally..

The quarry is now idle though it has been one of the most important in the district. The present breast is about 400 feet long and from 15 to 75 feet high. The product was quarried for paving purposes and shipped from Dougherty, about seven miles to the southwest on the Santa Fe Railroad.

Location number ten:—This location is what is known as quarry number eight, belonging to the Rock Creek Natural Asphalt Company, and is situated on the SE. ¼ SE.¼ sec. 21, and is about one-eighth of a mile northeast of location number nine. The opening is in the same formation as is the one last described and comes from the same horizon of the formation. As it comes from the quarry the rock contains an average of 5 to 6 per cent of bituminous matter. The texture is granular to coarsely crystalline, but more or less calcite is generally present either as intrusions from higher levels or as segregations. It was quarried by hillside and open cut methods but was never extensively operated, though there appears to be a very large supply of the material accessible.

Location number eleven:—This location is situated on the NE. ¼ SE. ¼ sec. 21, about 200 yards northeast of location number ten. It consists of a small hole in the same limestone that was worked at location number nine, quarry number four of the Gilsonite Paving and Roofing Company, and at the old mine near the mill discussed in



ASPHALT MILL AND MINE NEAR SULPHUR, OKLA.

this report as location number four of the Buckhorn district. The zone of enrichment is about ten feet thick and varies in bituminous the value of the product to some extent. In general the formation is about the same as at other points where this horizon has been operated, content at different levels. The presence of calcite bodies depreciates but the zone of impregnation is narrower, and the component strata thinner.

Location number twelve:—The occurrence here mentioned as location number twelve consists of a reported deposit of lime asphalt on SW. ¼ sec. 16, east of the segregation, on land belonging to W. J. Williams of Sulphur. It is not developed but is reported to be of promise.

Location number thirteen:—Like location number twelve this occurrence consists of a reported deposit. It is said to be sand asphalt and is located on the NW. ¼ sec. 28 about one-half mile southwest of the old Number four quarry of the Gilsonite Paving and Roofing Company. Its value and possibilities are unknown.

Location number fourteen:—This occurrence consists of a sand asphalt deposit on the segregation in the SE. ¼ SE. ¼ sec. 17, along the south bank of Rock Creek. It is described as the Ralston quarry by Eldridge in his report so often referred to, but is locally known as the Legrand quarry. The sandstone is a member of the Simpson formation of Taff and is therefore doubtless the same as one of the sandstone horizons farther southeast, either at the Kerby and Moss quarries or at the Bodine pit, but an exact correlation is not possible in the light of present data. Eldridge (page 294) is again quoted for detail.

This quarry, under the control of Messrs. Ledbetter & Legrand, of Ardmore, Okla., is opened juts above water level in the bluffs of Rock Creek, about 2 miles west-northwest of Schley, and about 8 miles northeast of Dougherty, the nearest station on the Gulf, Colorado and Santa Fe Railroad. The deposit where exploited is a richly impregnated, massive Ordovician sandstone, about 15 feet thick, lying beneath a cap of from 75 to 100 feet of Coal Measure conglomerate. The bitumen contents amount to between 10 and 12 per cent as the average of the present face. In hot weather the bitumen seeps from the rock in the form of maltha. The rock is black on fresh fracture, but weathers gray. It is tough, tenacious, and of gummy consistency when exposed to even a slight elevation of temperature, as by the sun or the warmth of the sand. Under the sun's rays great pieces slowly crack and fall from the quarry face—a common occurrence, however, in the case of all sandstones of like nature. The composition of the rock is of medium-sized, rounded, subangular and angular quartz grains, held together in bitumen. Upon the removal of the latter the residue falls to pieces—a mere mass of loose, white sand. The odor is strong. The age of the sandstone is........ Ordovician, but the time of its impregnation is uncertain. It may have been either prior or subsequent to the deposition of the overlying, unconformable conglomerate. The fact that the lower members of the latter formation are somewhat impregnated with bitumen is not conclusive evidence in either direction, for they might have been infiltrated with or from the sandstone itself. There are, however, occasional pebbles of bituminous sandstone sufficiently isolated from the enriched portion of the conglomerate bed to suggest their derivation from the Ordovician after impregnation. The extent of the enriched bottom of the Ordovician sandstone can be satisfactorily determined only by boring. The exposure along the creek has a length of 150 feet. The strike of the bed appears to be N. 10° W., the dip, 10° westward, carrying the deposit rapidly below the creek level. With the frequent change in strike and dip, however, consequent upon the very considerable folding which the strata in the Buckhorn district have undergone, it is possible that the bed may occur in concealed outcrop at more than one point along the debris and timber-clad bluffs of Rock Creek. Equally, it may rise to within a few feet of the surface in the region above, covered, however, by a thin deposit of the conglomerate.

This quarry has been developed but little during the last few years so Eldridge's description still holds good in all essential respects. It is not known whether Messrs. Ledbetter and Legrand still control the lease or not.

Location number fifteen:—Location number fifteen consists of sand and conglomerate asphalt near the line between the northeast quarter of section 20 and the northwest quarter of section 21. The principal part of the occurrence is on the north side of a small ravine. During warm weather the asphalt oozes from the sandstone and conglomerate as maltha. The only prospecting that has been done on the property is one small pit, therefore little is known of its extent. The maltha seepages, however, extend for several hundred feet along the ravine and it appears that the location should repay prospecting.

Location number sixteen:—This location consists of a sand asphalt pit on the NW. ¼ NE. ¼ sec. 29, T. 1 S., R. 3 E. on land belonging to Bob Wright of Dougherty, at present under lease to the Downard Asphalt Company of Ardmore. The development consists of a pit about 50 by 100 feet. It is reported to be down 38 feet in the rock asphalt, but as there was water in the bottom of the quarry the exact depth was not determined. Hand drills are used in preparing holes for blasting, and the material is hoisted by a geared horse whim and crane. The overburden consists of from 6 to 10 feet of stream wash and gravel which was left by Rock Creek when it was flowing at a higher level than at present.

A few years ago a company from California, prospecting for oil, drilled a deep well about 150 yards southwest of this location. The drillers reported that the sand asphalt was present to a depth of 700 feet. The strata in this immediate vicinity lie nearly level and consist of the sandstones and shales of the Simpson formation, previously referred to. This impregnated zone is doubtless the equivalent of the Dixon or Bodine sandstones of Eldridge and is perhaps the same formation that has been quarried at location number fourteen, known as the Legrand quarry, but an exact correlation cannot now be given. The report that there is 700 feet of sand asphalt at this point seems excessive, unless there has been a very pronounced thickening both of the sandstone formation and of the impregnated zone.

The land lying just north of that on which this location is situated has been prospected and has been found to contain large deposits of sand asphalt overlaid with from 5 to 20 feet of stream gravel and wash. The deposit is also known to outcrop in the bluffs of Rock Creek several hundred feet south of the quarries and is present for a conisderable distance northeastward up the stream. From the data obtained by a hurried investigation this seems to be one of the largest deposits, if not actually the largest, in the State. The per cent of impregnation, it appears, would run from seven to eight, but no analyses of the material are at hand.

Quarries of this immediate vicinity, if favorably located can be drained by gravity to a depth of 25 feet or more during periods of low water in Rock Creek. The nearest shipping point is Dougherty, about six miles to the southwest, on the Gulf, Colorado and Santa Fe Railway. The wagon road from the quarry to the station follows Rock Creek the greater part of the distance and is excellent for a mountainous country.

THE BRUNSWICK DISTRICT.

The Brunswick District consists of a tract of segregated land located about four miles northeast of Dougherty on the W. ½ sec. 25, and all of sec. 26, T. 1 S., R. 2 W. The segregated land is now under lease to the Brunswick Asphalt Company. At the time the region was visited by Eldridge there were four openings in the district as described, of which quarry number four, on land afterwards segregated, was the most important. Little or no prospecting has been done in the district since that report was written, though quarry number four has been operated at intervals.

The rocks of the district, according to Eldridge[45] consist of Pennsylvanian conglomerates, the Caney shale, then thought to be of Mississippian age, and Lower Helderberg and Ordovician limestones.

The Lower Helderberg, now known as the Hunton limestone, is rather difficult of recognition throughout the greater part of the area. Only the upper limestone of Ordovician is present, identified, apparently, on lithological characteristics. It is Eldridge's number four limestone of the Buckhorn district and is the Viola limestone of Taff.[46]

The structure of this region is very complex and in view of the fact that Eldridge has devoted a great deal of time to a detailed mapping and description of the district it was not thought necessary to duplicate the work. That author's[47] description follows, in part:

Structurally the Brunswick region includes a small portion of the northeastern slope of an anticlinal fold several miles in extent, which is one of the many that go to make up the eastern Arbuckle system. For nearly the entire area mapped the prevailing dip is about 30° to the northeast, but in the ridge in the southwestern portion the beds are sharply crumpled into minor folds that occupy the axial region of the anticline........

Simplicity of structure in the northern arm of the anticline within the Brunswick area is completely lost in the extensive and complicated faulting that has taken place; but this very faulting, coupled with erosion, has been the

45 Eldridge, Geo. H., Asphalt and bituminous rock deposits of Indian Territory: Ann. Rept. U. S. Geol. Survey No. 22, pt. I., 1901, p. 306.

46 Taff, J. A. Preliminary report on the geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma: Prof. Paper, U. S. Geol. Survey, No. 31, 1904.

47 Eldridge, Geo. H., op. cit. p. 307.

means of exposing the rich bituminous limestone of the Ordovician and enabling the winning of a product of considerable industrial importance. There are two well-defined systems of fractures trending, respectively, N. 50° W. and N. 20° W., the former the more highly developed. In addition to these, there are others of minor value, but so numerous as to locally cause almost a comminution of the beds. This is especially the case in the region of the main forks of Brunswick Creek, where the effect has been even further heightened by sharp crushing of the shales that there exist. Such faulting has been not only the cause of repeated reduplication of the measures, but also the source of much confusion in the correlation of the beds involved.

The development of the region as described by Eldridge is representative of present conditions. About the only notable difference is the additional tonnage which has been removed from the quarries. The site described by that author as quarries numbers 1, 2 and 3 are thought to be west of the segregated land, while his quarry number 4 seems to be on segregated land, the E. ½ SW. ¼ sec. 25, T. 1 S., R. 2 E. These points, however, are not clear, as he gives no land descriptions in his paper on the Brunswick district.

Location number one:—This location is the site discussed by Eldridge (p. 309) as "No. 1 quarry." It has never been of economic importance, but his description of the lithology of the occurrence is so complete that it seems worthy of space. It is as follows:

This is a mere prospect in a limestone outcropping in the banks of the dry channel at the eastern base of West Ridge. The strike is locally N-S; the dip 20° E. Petrographically the limestone consists of (a) an ordinary granular to finely crystalline rock, impregnated with bitumen and looking at times as rich as the average No. 4 Ordovician limestone; (b) a calcite variety, also impregnated with bitumen, but not always in sufficient amount to render the rock of value; (c) white chert, barren except for the seams into which the pure asphalt was forced at the time that, or after, the general deposit became impregnated. Stratigraphically the bed as exposed is divisible into two layers, an upper of 6 feet and a lower of 4 or 5 feet. The upper has the appearance of an ordinary bed; the lower is a bed composed entirely of lenticels of limestone, calcite, and chert, all dovetailing one with another. These lenticles average 2 feet in horizontal extent by 6 to 7 inches in vertical. The upper division of the bed is the more even in texture and in impregnation and, though calcitic, is wanting in chert. It is not to be counted a high-grade rock, although decidedly higher than the lower one, which is in fact worthless. The lower half of the upper division is also the richer. The rock as exposed in the bluff has been greatly fractured, especially, it would seem, the chert, which in instances looks as though it had been shot through the limestone in angular fragments, imparting to it a brecciated appearance. Shales immediately overlie the bituminous limestone, carrying in their mass, especially just above this limestone, other thin, crystalline, yellow limestones. Greenish-gray clays underlie the bituminous limestone lower down the gulch.

This occurrence is the most westerly of those shown on Eldridge's map and is thought to be the pit on the SW. ¼ NE. ¼ sec. 26, T. 1 S., R. 2 E.

Location number two:—This location consists of quarries numbers two and three of Eldridge. One is on the SE. ¼ NE. ¼ sec. 26, the other on the NW. ¼ SW. ¼ sec. 25, T. 1 S., R. 2 E., both being opened on the Viola limestone. The most northwesterly of these pits is hardly more than a prospect hole but considerable tonnage has been removed from the other. The lithology is similar to that of location number one, though the asphaltic content is greater.

Location number three:—This location is the old Number four quarry of Eldridge. It is situated on the NE. ¼ SW. ¼ sec. 25. T. 1 S., R. 2 E., and is the only important quarry on the segregated land in this district. It has always been the main quarry of the region and is described by Eldridge (page 210-11) as follows:

This is advantageously opened on what promises to be a productive body of rock in the block of No. 4 Ordovician limestone on the northeast side of fault C. The limestone has the same features of composition, texture, and impregnation as those described for it at the No. 4 quarry (location number nine of this paper) of the Buckhorn district. The earthy, granular, and crystalline textures are all repeated; the barren calcite bodies are present, in equal contrast with the general mass of the rock; the calcareous mud is all readily identified in one locality as in the other; and each variety of rock in texture shows the same difference in the degree of impregnation. If there be a difference in the rocks of the two localities it is in an apparently more general distribution of the calcite bodies through the rock of the Brunswick quarry, and a possible slight lowering in consequence, of an otherwise equally maintained average in the bitumen percentage. A feature, too, conspicuous in certain portions of the Brunswick pit, is the filling of fracture cracks with pure bitumen, derived, probably, by infiltration from the main body of the rock.

The same width of limestone is not exposed here as in the No. 4 quarry in the Buckhorn field, but at no point in the present area is the entire thickness of the bed brought to light. The possibilities in an economic way must therefore remain unknown unless the drill be resorted to.

The No. 4 Brunswick quarry is located about a mile north of the plant, to which the product is hauled, over an easy road, for conversion into mastic or other manufactured product, or is carried beyond to the railway at Dougherty, a total distance of between 4 and 5 miles.

The quarries of the Brunswick district have been idle the greater part of the time since the descriptions by Eldridge were written, though location number three has been operated from time to time by the Downard Asphalt Company of Ardmore to supply lime asphalt for paving purposes.

THE WASHITA CANYON DISTRICT.

The rock asphalt of the Washita canyon region consists of a few scattered occurrences along the bluffs of that river between Davis and Dougherty, stations on the Gulf, Colorado and Santa Fe Railway. None of these deposits have thus far been proved to be of commercial importance. They are mentioned in order that the discussion of the subject may be more nearly complete. Then, too, there is no evidence that they have ever been carefully examined, but as one of them is advantageously located it may repay investigation.

The geology of the canyon is, in many respects, similar to that of the Buckhorn and Brunswick districts.

The principal limetsone is the Viola, from 350 to 400 feet thick. The Hunton limestone is also present. The Simpson formation and Sylvan shale are the less resistant rocks of lower Paleozoic age in the region, though the Caney shale, Franks Conglomerate and Sycamore limestone, all of Carboniferous age, are locally present. The most prominent structural feature is a great arch, the Dougherty anticline, which affords an excellent section of the stratigraphy of the east side of the canyon where the Gulf, Colorado and Santa Fe Railway has cut across its northwestern extremity.

The most prominent prospect is located near the center of sec. 21, T. 1 S., R. 2 E., about four and one-half miles northwest of Dougherty, and a quarter of a mile east of the Gulf, Colorado and Santa Fe Railway. The opening is in the Viola limestone, on the northeast slope of the anticline mentioned above; the outcrop of the limestone is prominent and continuous, and the zone of impregnation embraces a very considerable area in the vicinity of the prospect, in fact extends northwestward nearly to the river. The asphaltic content is variable. No data as to the per cent of saturation has been obtained, though that is the questionable feature of the occurrence. The limestone of the region is of a mottled color, the mottling being due to the uneven distribution of asphaltic matter. The texture is fine grained to crystalline, the crystalline character being caused by the presence of calcite. The rock is hard, but brittle. The limestone was crushed into innumerable angular fragments at the time of folding and has since been recemented to a marked degree, though numerous joints have remained, and now form the open spaces into which the asphaltic bitumn has penetrated.

The location of this prospect is the most convenient to transportation of any known deposits in Murray County, lying as it does within a quarter of a mile of the railroad, at an elevation above it, and without intervening hills or streams, thus offering an easy means of overland transportataion to a commercial siding on the railroad. The rock seems to be in almost unlimited quantities, but the quality is yet to be proved.

Eldridge reported (p. 312 report often referred to) two occurrences on the west side of the Washita River about seven or eight miles southwest of Davis and above the canyon proper. One is a thin limestone carrying only a trace of asphaltic bitumen and including a half inch vein of the same material which had seeped from the surrounding rock.

The second occurrence is about a quarter of a mile southwest of the one just mentioned. It is a slightly impregnated sandstone in shales.

Neither of these occurrences seems to be of commercial promise. Both occur in limestones, sandstones and shales of Ordovician age, and are of interest chiefly because they help to show how widely petroleum of an asphaltic base, was distributed through the older rocks of the Arbuckle region prior to their deformation and wearing down to the oil bearing levels, so that the more volatile portions of the enormous petroleum deposits stored in the sandstones and porous limestone could escape into the air.

OUTLYING DEPOSITS.

Besides the rock asphalt deposits occurring within the districts above described there are two occurrences so far removed from those districts that they are treated as individual deposits. Both of these

consist of occurrences of sand asphalt. One is situated on the SW. ¼ sec. 20, and the NE. ¼ sec. 29, T. 1 N., R. 4 E., while the other is reported as being located on sec. 11, T. 1 S., R. 2 E. Only the first one of these has been visited and examined by a member of the Survey staff. It is described as the Hickory deposit.

Hickory deposit:—As just stated this occurrence consists of sand asphalt in secs. 20 and 28, T. 1 N., R. 4 E. The rock is rich in asphaltic matter but has never been thoroughly investigated so that neither the thickness of the deposit nor the extent of the area over which it occurs are known. The formation in this locality lies, apparently, level. Eldridge mentions this deposit on page 305 of the report so often quoted in this paper and tentatively correlates the horizon with the Dixon sandstone of the Buckhorn district. This, it will be remembered, is the member on which the Moss and Kerby quarries have been opened and is a portion of the Simpson formation. The sandstone is composed of medium sized rounded quartz grains, and it is believed that the bituminous matter forms the cementing material in this locality. The exact per cent of the bituminous content is not known, but it is estimated to be between ten and fifteen. The occurrence is about one and one-half miles south and two miles west of the station at Hickory on the Frisco Railroad. Quarries operated on the occurrence could be drained by gravity to a depth of ten or fifteen feet by opening a small ditch to a branch of Mill Creek a few hundred feet distant. This occurrence has been prospected by stripping an area about twenty by thirty feet in the section line, but has never been exploited on a commercial basis. So far as could be learned the thickness of the deposit has never been determined but it is believed to be at least ten or fifteen feet.

Deposit near Davis:—As previously stated this deposit is reported to occur in sec. 11, T. 1 S., R. 2 E., and is therefore a few miles southeast of Davis. The probable value and extent of this deposit are unknown, though it is reported to be of considerable promise.

ROCK ASPHALT OF LOVE COUNTY.

Love County, of which Marietta is the county seat, is situated in the south central portion of the State. The topography of the northern part is broken by deep stream valleys and differential erosion due to alternating hard and soft formations; the southern portion, along Red River is characterized by rounded sand dunes. The drainage is by small creeks, southward into Red River. The main line of the Santa Fe is the only railroad which enters the county.

The geology of the county is comparatively simple. A small area of Permian Redbeds is found in the extreme western part and a few square miles of lower Paleozoics occur in the vicinity of Overbrook in the northern portion. The rest of the county is composed of sandstones, limestones, and shales of Comanche Cretaceous age which unconformably overlie the older rocks. The structure of the Cretaceous and Permian rocks is monoclinal. The former usually dip southeastward at low angles, though the Red River fault, which extends from near Overbrook southeastward toward the Alabama Landing fault, has effected the structure to some extent throughout its course in Love County. The latter, that is the Permian Redbeds, usually dip northwestward at very low angles. Their structure, however, is very difficult to determine, owing to the great irregularity of deposition. The Pennsylvanian rocks consist of sandstones, shales, and occasional thin limestone ledges which have been called the Glenn formation by Taff. These rocks suffered great deformation at the time of the Arbuckle uplift and are usually nearly vertical and often faulted. The prevailing strike of the Pennsylvanian formation in the county is northwest and southeast.

The rock asphalt of Love County sometimes occurs in the Glenn formation and sometimes in rocks of Cretaceous age. The peculiarities of each occurrence studied will be noted.

Location number one:—This occurrence is found on the SW. ¼ sec. 6, T. 6 S., R. 2 E., about three quarters of a mile southeast of Overbrook. The material is a sand asphalt which occurs in a thick, continuous Pennsylvanian sandstone member of irregular sedimentation, and with a dip of 65° S. 37° W. The asphaltic material, which is thought to be the residium of an old petroleum deposit, occurs along the bedding plane of the sandstone. The outcrop as exposed is approximately forty yards wide by fifty yards long.

A few years ago the rock asphalt was quarried but for some reason operations have been suspended, though the deposit does not appear to be exhausted. The quarry was operated in a hill side so that drainage was accomplished by gravity. Steam power was employed for hoisting the product from the pit and loading it on the cars which were brought in over a spur from the railroad, a short distance west of the mine.

Location number two:—Location number two consists of two occurrences in sec. 27, T. 6 S., R. 2 E. One of these is a sand asphalt deposit on the hill north of Hickory Creek in the north half of the section, probably in the northwest corner of the northeast quarter. The other is found south of Hickory Creek and consists of a small amount of petroleum issuing from a spring surrounded by sand asphalt. The latter occurrence was reported by Larkin and no data given other than that it occurred in the Trinity formation, probably near the base. The occurrence in the north half of the section is on land owned by H. C. Drawn of Marietta. This has been prospected but never exploited on a commercial scale. There are at present two prospect pits, about 100 feet apart, that are from ten to twenty feet deep. This deposit parallels the outcrop of the members of the Glenn formation which appear at the Cretaceous contact a few miles to the northwest, and are in strike with the sandstone which bears the asphaltic material at Overbrook and in sec. 26, T. 5 S., R. 1 E. This occurrence, however, is found near the base of the Trinity formation. As a rule the Trinity formation bears little evidence that asphaltic matter could have originated in it, and it is therefore thought that the asphalt of these occurrences is the result of petroleum seepage from the Pennsylvanian rocks below.

The cover above the rock asphalt is thin and friable. The outcrop is on an elevation so that mines could be operated by hillside or open cut methods and drained by gravity. The pits would be only about two miles from the G. C. & S. F. R. R. With comparatively little labor a road could be opened to the right-of-way where a commercial siding could doubtless be constructed. If, however, this plan were inadvisable the station of Overbrook is only five miles distant and the roads are tolerable.

Location number three:—This location consists of three exposures in sec. 35, T. 6 S., R. 2 E. As reported by Larkin they consist of oil springs with deposits of viscous asphaltic material surrounding the seepages. The one which occurs in the northeast corner of the southeast quarter is accompanied by considerable sulphur water. The material is all found in an indurated member of the Trinity formation.

Location number four:—Location number four, also reported by Larkin, consists of two occurrences in the S. ½ sec. 1, T. 7 S., R. 2 E. Both of these occurrences are oil springs with deposits of asphaltic material surrounding them. The oil collects on the surface in considerable quantities so that the inhabitants of the community skim it off for medicinal purposes. Like the occurrences just described this is also in an indurated member of the Trinity sandstone. The dip is southeastward at low angles.

Location number five:—These occurrences, reported by Larkin, are found in secs. 4 and 5, T. 7 S., R. 3 E. and consist of one natural and two artificial exposures. The natural exposure is an oil spring on Powder Creek in the NW. ¼ SE. ¼ sec. 4. There is little or no asphalt present and the oil seems to be of paraffin base. The other two occurrences consist of an oil, similar to that found in the spring on Powder Creek, on the water in wells, dug for domestic purposes, in the SW. ¼ NE. ¼ sec. 4, and the SE. ¼ SE. ¼ sec. 5. So far as could be told the deposits are both in the lower portion of the Trinity formation. Little or no asphaltic material occurs at any point in that neighborhood.

Location number six:—This is a reported occurrence of asphaltic material in SE. ¼ sec. 32, T. 6 S., R. 3 E. Nothing definite could be learned concerning the character and amount of the material. It is reported that the exposure occurs about a mile north of the mouth of Pumpkin Creek in upturned rock, therefore it is doubtless in the Glenn formation of Pennsylvanian age.

Location number seven:—Location number seven consists of a portion of the S. ½ sec. 9 and N. ½ sec. 16, T. 6 S., R. 3 E. At different places over the area described deposits of what seems to be impure paraffin or mineral wax occur. At present the land is leased by the American Paraffin Company. The material is found in the Trinity formation but the exact horizon was not determined.

ROCK ASPHALT OF MARSHALL COUNTY.

Marshall County, of which Madill is the county seat, is situated in the south-central portion of the State. The topography is considerably broken by stream dissection. The northern part along the breaks of the Washita and throughout almost all that part of R. 7 S., which is in this county, is what might be termed a hilly country; while the central portion is a gently rolling prairie with fringes of timber along the streams.

The rocks composing the surface of Marshall County are sandstones, limestones and shales of the Comanche Cretaceous series. In this region these formations have a maximum thickness of perhaps 900 feet, and lie unconformably upon the upturned edges of the Glenn formation of Pennsylvanian age. The structure is monoclinal. The general dip is southeastward at low angels away from the Arbuckle uplift. The normal dip is, however, interrupted in the southern townships by the Red River Fault, which has caused a differential movement in T. 7 S., R. 5 E. of approximately 400 feet. The faulting has accelerated erosion so that in many places the Trinity formation, which is the basal member of the Cretaceous in this vicinity, is exposed for perhaps one half of its thickness.

The existence of asphaltic materials in what is now Marshall County, Oklahoma, has been known ever since the early settlement of northern Texas. The first occurrence which attracted attention was the oil spring near the source of what is known as Oil Creek, a few miles north of Madill. The Indians frequently camped around this spring and drank the crude oil as a medicine, while the settlers in northern Texas made long pilgrimages to this point to collect the crude petroleum, which was then known as "Seneca Oil," and was considered a panacea for rheumatism, burns, indigestion and in fact nearly all human ailments. The deposits of rock asphalt in the county did not attract attention until later.

Rock asphalt is found in various parts of Marshall County, from the breaks along the Washita River almost to Red River. The various occurrences studied will be described under the respective field numbers and such details of stratigraphy and structure given as were noted in a hurried study. No tests of the per cent of asphaltic saturation have been made of the samples collected; the statements, therefore, as to amount of bituminous matter are based on comparative studies.

Location number one:—This occurrence is found in the SE. ¼ sec. 34, T. 4 S., R. 5 E., and is what is known as the oil spring mentioned above. Heavy asphaltic petroleum seeps from a lentil shaped sandstone near the top of the Trinity formation. This does not seem

to differ materially in character from the Trinity sandstone in which it is imbedded, other than it contains more cementing material and is therefore harder. The flow of petroleum is very slight; in fact, it consists of only a few drops per minute,, which are washed from the rocks by sulphur water (the sulphur being due to the generation of hydrogen sulphide by the decomposition of pyrite) that really forms the spring. The oil seeps from the formation about ten feet below the base of the Goodland limestone that lies conformably above the Trinity sandstone. The lentil from which the oil comes is approximately fifteen feet in thickness and is exposed for a distance of about fifty yards along the bank of the ravine. The petroleum seems to come from the lower portion of this member, the productive zone varying from three to five feet in thickness along the exposure. What seems very peculiar is the fact that though the oil seems to come from the sandstone, yet the outcrop of the rock is not saturated with petroleum. In times past three small pits, into which the water and oil collect, have been dug at the foot of the bluff.

The flow of petroleum is scant and it is not likely that the pits will ever produce an economic yield. The structure of the region is monoclinal, with a dip of about 1° S. 40° E.

Location number two:—Location number two is found in the SW. ¼, sec. 32, T. 4 S., R. 5 E. The stratigraphic position of this occurrence is approximately the same as that of number one, but the material is a low grade sand asphalt, instead of heavy petroleum. The asphaltic material impregnates a lentil, less friable than the surrounding rock, near the top of the Trinity sandstone. It appears to contain a greater per cent of bituminous matter near the top than at the base, though a few seepages of heavy oil occur near the bottom of the lentil. The asphaltic sandstone rests upon a friable sandy shale which grades downward into an unconsolidated, thin-bedded sandstone. The exposure examined is about 300 feet long and could be easily drained by gravity if quarrying should be undertaken. The material, which may be found of value, has an overburden of about twenty-five feet of Goodland limestone. From what was seen it is not believed that it could be economically worked under present conditions. The asphaltic content is not believed to exceed two per cent and this is not always uniform.

Location number three:—This occurrence is found in the SW. ¼, sec. 26, T. 5 S., R. 5 E. The material is a rock asphalt which outcrops along the east bank of Glasses Creek about a half mile north of the northeast corner of the Madill townsite. The deposit has never been worked, though some prospecting has been done. The outcrop shows a thickness of about four feet of sand asphalt, which is exposed for several hundred feet along a small ravine. At some places where it was examined the sandstone carries sufficient asphaltic material to make it plastic when slightly warmed.

Like the other occurrences it is found in a hard lentil near the top of the Trinity sandstone. The over-burden is therefore the Goodland limestone, where it is present. That formation, however, has been worn down very thin near the outcrop so that a large quantity of material could be removed with the handling of but little overlying detritus. The quarries could be drained by gravity. The shipping point is only about one and one-half miles distant and the haul would be over good country roads. It is therefore believed that the rock asphalt could be economically quarried at this place.

The structure is monoclinal, the dip being southeastward at low angles.

Location number four:—Location number four is in the NE. ¼, sec. 29, T. 5 S., R. 5 E., or to be more exact, in the head of a small ravine in the southwest block of the Oakland townsite. The occurrence consists of a sand asphalt lentil in the Trinity formation. At its greatest development the lentil has a thickness of eight or ten feet, but pinches rapidly both east and west from that point. The principal part of the asphaltic material seems to have lost its viscosity so that it is, in the main, what the citizens of that vicinity call a "dead asphalt." There are places, generally quite local, which contain four or five per cent of viscous asphaltic bitumen. It is not likely that this occurrence will repay working unless the per cent increases rapidly upon opening a quarry.

The structure is a monoclinal with low dips to the southeastward. The bituminous matter occurs along the bedding plane of the sandstone.

Location number five:—This occurrence is in the NW. ¼, sec. 17, T. 5 S., R. 5 E. Like the other occurrences this one consists of a lenticular mass of sandstone, which is slightly harder than the surrounding rock, in the Trinity formation, and contains asphaltic bitumen along the bedding plane. At its greatest development the lentil, which is impregnated at two different horizons, is about twelve feet thick. The deposit is exposed for nearly 400 yards along the south side of a small creek, but thins rapidly in both directions, so that nearly its entire east and west extent is exposed.

The deposit has never been prospected so that it is not known how far the zone of impregnation extends southward. The sandstone appears to carry from one to five per cent of asphaltic material at the outcrop. The rich places are usually localized. Often there is nothing left of the bituminous matter except a dark stain and a very slight odor.

From a study of the exposure it seems that there are only a few places where the sandstone carries enough viscous material to make it valuable except as an adulterant for richer rock asphalt, unless the bituminous content increases under the overburden. The deposit, however, appears to be so large that the writer believes it to be worthy of further investigation. Quarries could be drained by gravity. The occurrence is only about two miles from the railroad station at Oakland, and the haul would be down grade the greater part of the distance and over good roads.

Location number six:—The writer did not examine this occurrence, but he saw some of the material which came from the place. It consists of an unconsolidated sandstone, in the upper portion of the Trinity, which is so thoroughly saturated with asphaltic bitumen that it clogged the bit while drilling the well at the Madill cotton seed oil mill. The deposit occurs near the surface but it has never been examined further than the note that was made during the drilling of the well. Its desirability and availability are unknown. Since it is so near the railroad it is thought worthy of investigation by operators.

Location number seven:—This occurrence is found in the NW. ¼, sec. 26, T. 7 S., R. 5 E. It consists of two small lenticular deposits at different levels in a sandstone bluff on the south side of Sand Creek. The zones of impregnation, which occur about 100 feet below the top of the Trinity formation that has been brought up at this place by the Red River Fault, are only about five feet thick. The enriched portions pinch rapidly in both directions so it appears that the deposits are probably small.

CONCLUSION.

So far as investigations have been made, all of the rock asphalt of Marshall County occurs as lenticular masses in the Trinity formation. The impregnation is along the bedding plane and does not seem to be genetically associated with faulting, or other structural phenomena of the Trinity. In several places the sandstone above and below the asphaltic deposit is exposed but it seems to contain no traces of petroleum or other bituminous matter, so no inference concerning the original source of the asphalt could be drawn.

ROCK ASPHALT OF JOHNSTON COUNTY

There are but three known deposits of rock asphalt in Johnston County. They occur under dissimilar conditions and are therefore discussed as locations.

Location number one:—The most important deposit of rock asphalt known is on the segregated asphalt land about three and one-half miles west of Ravia. The segregation consists, approximately, of the NW. ¼, sec. 6, T. 4 S., R. 5 E., the NE. ¼ sec. 1, T. 4 S., R. 4 E., the S. ½ SE. ¼, sec. 36, T. 3 S., R. 4 E. and the S. ½, SW. ¼ sec. 31, T. 3 S., R. 5 E. Some of the sections, however, are fractional, so that the segregation contains 478.79 acres.

The rock asphalt of this location consists of limestone, sandstone, and conglomerate impregnated with asphaltic bitumen. The first operations were begun about 1902 by the Ravia Asphalt Company, a local firm which held the lease. This company opened a quarry in the sand asphalt in the NE. ¼, sec. 1, T. 4 S., R. 4 E., and operated it for a little more than a year when the lease is reported to have been sold to the Barber Asphalt Company. The quarry is now idle and is reported to have been so since the transfer.

During the operations of the Ravia Asphalt Company the raw material was hauled in wagons to Ravia from where it was shipped to St. Louis for paving purposes. The pit opened up is near the base of the Trinity sand of Cretaceous age and is about 75 feet by 100 feet in extent. The valuable material is in a massive sandstone about six feet thick. The overburden is a calcareous shale which ranges from nothing to nearly twenty feet in thickness. Drainage was by gravity.

The rocks of the region consist of limestones, sandstones, and shales, chiefly of the middle and upper Paleozoic age, though there is an unconformable overlap of Cretaceous age across the southwestern half of the area. The structure of the older rocks is monoclinal with high dips to the southwest, but that of the Cretaceous overlap is tilted southeastward at an angle of about 3°. There seems to be no evidence of faulting in the region through crumpling and local slipping has occurred in some of the softer members.

Location number two:—This occurrence of rock asphalt is along the bank of a small creek in the NE. ¼, sec. 14, T. 4 S., R. 5 E. The deposit consists of a fine grained quartzose conglomerate member of the lower Trinity sand of Cretaceous age. It is about six feet thick and contains perhaps as much as 4 or 5 per cent of asphaltic bitumen. The deposit has never been prospected and its character, under cover, is not known. The rock seems very hard and would likely be difficult to crush.

Cross bedding prevails and the outcrops are short, so it was impossible to determine the exact dip of the formation, but it seems to dip northwestward at low angles. The deposit is overlaid by from from 3 to 6 feet of soil and stream wash, and is located only about 1,000 feet from the railroad. The quarries could be drained by gravity. The location is excellent if the deposit is of the right character and in sufficient quantities to pay.

Location number three:—This location is the occurrence described by Eldridge[48] as the A. C. Harkness Prospect. This is the only report extant on the deposit, and is as follows:

> This deposit of bitumen, in practically horizontal Trinity (Lower Cretaceous) sandstone, occurs on the A. C. Harkness farm, 3 miles southeast of Emet, within a short distance of the line between the Choctaw and Chickasaw nations. The locality is between 15 and 20 miles from railroad, and has received little attention. One or two small prospect pits within an area of a half mile have been sunk into the sandstone that here lies immediately beneath the surface, but the extent, continuity, and thickness of the impregnated rock are unknown. The rock consists of sharp quartz grains of medium size with occasional bodies of small, subangular to angular pebbles of this and other material scattered in layers through the mass of the bed. The pebbles are not impregnated either in their material or in cracks across them. The color of the rock is brown, weathering brownish gray. Bitumen, although in varying quantity, is probably the chief cementing substance, but a small amount of oxide of iron is visible in the unimpregnated portions of the bed. The richer portions of the rock are soft and gummy. Six per cent of bitumen is perhaps the maximum.

48 Eldridge, Geo. H., Asphalt and bituminous rock deposits, 22d Ann. Rept. U. S. Geol. Survey, pt. I., 1901, p. 318.

Location number four:—This occurrence is found in the SE. ¼, sec. 19, T. 4 S., R. 6 E., and consists of a very rich sand asphalt. It has been prospected by an open cut about twenty feet wide by fifty feet long. In many places the heavy asphaltic oil oozes from the bottom of the cut. So far as could be told the deposit has a cover of four to six feet of detrital material over a considerable area. Quarries could be drained by gravity. The impregnated sandstone is exposed to a depth of from six to eight feet and the base is not yet in sight. The occurrence is about two miles from the Frisco Railroad and is the richest the writer examined in Johnston County. It is believed that careful prospecting may prove it worthy of development.

Like the other deposits in this county, occurrence number four is in the Trinity formation. The exposure, however, is poor and the mode of occurrence could not be determined further than that the bituminous matter is found along the bedding plane of the sandstone.

ROCK ASPHALT OF PONTOTOC COUNTY

Pontotoc County is situated on the south bank of the South Canadian River southeast of the geographical center of the State. Its county seat, Ada, is at the junction of the Frisco and M., K. & T. railroads. The topography is comparatively rugged. The stream valleys are usually V-shaped or narrowly U-shaped. The drainage belongs to two systems. The water of the northwestern half of the county finds its way northward to the South Canadian, while that from the southeastern portion flows to Red River through Clear and Muddy Boggy creeks and the tributaries to the Washita.

The geology of the greater part of the county is comparatively simple, but that portion of the southern part lying in the triangle designated as "Lower Paleozoic" on the geological map of the region was involved in the Arbuckle Mountain uplift and relations have been greatly disturbed by faulting, folding and crushing. With the exception of this triangle the rocks of the entire county consist of unclassified conglomerates, sandstones, limestones, and shales, probably of Middle Carboniferous or Pennsylvanian times. The rock asphalt to be described occurs both in the Pennsylvanian and lower Paleozoic formations.

The rock asphalt deposits of Pontotoc County are grouped naturally into two general groups which have little or nothing in common and which may, with propriety, be called districts. One of these groups is found near Ada and is called the Ada district, while the other is in the vicinity of Roff and is termed the Roff district.

ADA DISTRICT.

The occurrence of sand asphalt at Ada is one of the largest deposits of the kind in the State. The outcrop of the asphaltic sandstone can be traced along both banks of Sandy Creek for more than four miles. The sandstone is more or less asphaltic throughout the entire outcrop, but the paying deposits are local. A very peculiar paradox exists in this vicinity in that it often happens that those locations which produce the greatest amount of asphaltic oil are poorest in viscous asphalt, which will form a cementing mixture. That is to say that those places where liquid asphalt is running from the outcrop, or the rocks from which it runs when exposed to the sun, are usually so poor in bituminous matter that it is unfit for paving purposes. A marked example of this kind is found in the NW. ¼, NW. ¼, sec. 31, T. 4 N., R. 6 E., where the first pit was opened several years ago. A considerable quantity of heavy asphaltic oil was running from the outcrop and the place was looked upon with favor. An open cut was driven thirty or forty feet into the bluff but the source was not found; in fact the flow was not increased nor did the sandstone itself carry more asphaltic material at a depth than near the outcrop, except very locally. Other occurrences of like nature have been found to behave similarly so that the prospectors of the district now pass as unpromising those places where the viscous asphalt is seeping from the rock.

Perhaps a dozen quarries and more than a score of prospects have been opened in the district. No attempt will be made to describe each of these. It is sufficient to say that more than two hundred carloads were shipped from a single quarry during the first half of 1909, and arrangements were about complete in July to open another pit on even a greater scale. The average price received was $2.20 per ton on board the cars.

The exact horizon of the deposit was not determined but it seems to occur in a sandstone varying from fine-grained and even-textured, to a fine conglomerate or pebble stone, which is thought to be near the base of what Taff[49] has described as the Franks conglomerate. The deposition of this formation is irregular and cross bedding is frequent, so that even had there been time for careful study, it is quite probable the minute structure could not have been determined. An observation taken along Spring Creek showed the dip west of Sandy Creek to be N. 70° W., at low angles, while a low dip in the opposite direction was recorded in NW. ¼, NW. ¼, sec. 6, T. 3 N., R. 6 E. This last observation was not carefully checked by others, so it was not certain whether Sandy Creek is cutting its way downward along the axis of an anticline or not, but the general topography of the immediate region suggests that such is the case. It appears that the vast deposit of

49 Prof. Paper U. S. Geol. Survey No. 31, p. 34.

sand asphalt is an old oil sand which has been laid bare by the agencies of erosion, and partly carried away, while the lighter oils and gases of the petroleum deposit have escaped into the air.

Besides the deposits in the immediate vicinity of Ada there is one about two miles northwest of Fitzhugh which, owing to the occurrence in the same geological formation, really belongs to the Ada district. This occurrence consists of sand asphalt in the NE. ¼, sec. 5, T. 2 N., A. 5 E. Two exposures were examined; one in the NE. ¼, and the other in the SW. ¼ of the land just described. Of these the former contained three or four seepages of heavy oil, but at no place did the sandstone appear to be uniformly and sufficiently saturated with bituminous matter to be of value though nearly fifteen feet of the formation was asphaltic. There were small oil seeps along the bedding plain at the latter exposure which was of a fine-grained sandstone that carries a large per cent of asphaltic bitumen. The seeping of the heavy oil seems to be due to supersaturation, as the material was exposed for over forty feet and it showed no tendancy to yield up so much of the asphatlic material that it would be left "dead." These occurrences have not been developed commercially but they seem to be of promise. Fitzhugh is the nearest shipping point.

A deposit of sand asphalt is reported from near Ahloso but it was not examined. Nothing definite is known of its character and quality, though it is said to be of high grade and easily accessible.

ROFF DISTRICT.

The rock asphalt deposits of the Roff district are different from those of the Ada, in that they consist of a number of seemingly independent occurrences often at probably different horizons of greatly deformed strata, instead of one large exposure of a single member in a strata which have suffered but little or no deformation. On account of their isolated and independent character it is necessary to treat each occurrence separately.

Location number one:—This occurrence, at the outcrop, is little more than a bituminous stain in the Simpson formation about 300 feet south of the Frisco bridge in the NE. ¼, sec. 24, T. 2 N., R. 4 E. It has never been prospected and seems to be of little promise.

Location number two:—Location number two is situated in sec. 15, T. 2 N., R. 4 E., and consists of a very richly impregnated sand asphalt in the Simpson series near a fault line between the Simpson and Viola formations. A quarry was opened during the present year and fifteen or twenty carloads of rock asphalt shipped from Fitzhugh, when operations were suspended though the pit was only well opened. The sandstone which contains the asphalt is about ten feet thick where it has been quarried and dips 15°, S. 50° W. The overburden is a friable, ferruginous shale which breaks down readily and conceals the outcrop so that it was not easily traceable. The workings as developed were drained by gravity and it is believed that a large mine could be opened up if proper methods were used.

Location number three:—This occurrence was noted in the road at the SW. cor. NW. ¼, NW. ¼, sec. 27, T. 2 N., R. 4 E. It is a slightly impregnated sand asphalt in which the asphaltic material at the outcrop has lost its viscosity. The deposit has never been prospected. Observations made do not warrant exploitation unless it is found to be much richer beneath the surface.

Location number four:—This location is situated in the SE. ¼, SE. ¼, sec. 15, T. 2 N., R. 4 E., and consists of a slightly sulphurous spring which brings a very viscous asphaltic oil from the crevices of a quartzitic sandstone. The daily production of oil is reported to be about ten gallons. It has not been tested, however, and this seems a little excessive. The formation yielding the oil is a member of the unclassified Carboniferous series, but it is thought to be below the Franks conglomerate. Several cubic yards of stone have been removed in an attempt to discover the source of the oil, but the output has not been increased, nor is the country rock sufficiently impregnated to be valuable as rock asphalt. These facts suggest that the oil is probably from another horizon through which the water of the spring comes, and that the water rinses the oil out in passing.

Another occurrence similar to number four was reported in the NW. ¼, sec. 11, T. 2 N., R. 4 E., but it had been covered by the debris of recent freshets and could not be examined.

Location number five:—This occurrence seems to be of little importance, owing to the fact that the sandstone is only slightly bituminous. The material is found in a cross-bedded sandstone in the head of a ravine in the SE. ¼, sec. 15, T. 2 N., R. 4 E. It has never been prospected, so its character or depth is unknown.

Location number six:—Location number six consists of 480 acres of segregated asphalt land which belongs to the Choctaw and Chickasaw Indian tribes in common. It is situated in secs. 28 and 29, T. 2 N., R. 6 E. It is at present leased to the Farmer Asphalt Company which opened quarries there a number of years ago, but operations have been suspended for several years. The mineral, which consists of limestone, sandstone, conglomerate, and shale asphalts, occurs along two fault lines which bring the Hunton limestone in contact with Carboniferous formations, probably the Caney shale, on the north and the Viola limestone on the south. The deposit is usually high in bituminous content but the distance, about nine miles, to a shipping point makes the cost of operating prohibitive under present conditions.

1 ASPHALT MINE, TUSKAHOMA.
2 ASPHALT MINE NEAR ATOKA.
3 DUMP OF ASPHALT MINE.

ROCK ASPHALT OF ATOKA COUNTY

The rock asphalt deposits of Atoka County have never attracted public attention, though several occurrences are known to exist.

There is a deposit of shale asphalt, with which a small amount of petroleum is associated, near the center of sec. 35, T. 2 S., R. 13 E. This has been prospected by two pits, one fifteen feet deep and the other not more than ten. So far nothing of value has been discovered. The shale in which the asphalt is found is underlaid by a massive sandstone which exudes a small amount of bituminous matter. An occurrence of sand asphalt was noted in the N. ½ of sec. 26 of the same township and range. This deposit has never been prospected and so far as could be determined is of little consequence. Sand asphalt associated with a small vein of asphaltite, probably grahamite or impsonite, occurs on the S. ½, sec. 13, T. 2 S., R. 13 E. A prospect pit was opened on the deposit several years ago, but no extensive development was undertaken. The exposure was so obscured by detrital matter from bluffs of the ravine in which it is found that the extent of the occurrence could not be determined. The presence of the asphaltite suggests possibilities.

An occurrence of sand asphalt is reported from the SW. ¼, sec. 8, T. 1 S., R. 13 E., but neither have been examined and no idea of their value and extent can be given.

Another deposit of sand asphalt was examined on land belonging to E. P. Miller of Redden. It is located in the NE. ¼, sec. 13, T. 1 S., R. 14 E., and consists of a massive sandstone ledge, only the top portion of which is exposed. No idea of the probable extent of the deposit could be gained, because of the inadequate exposure. At the surface the deposit contains, perhaps, about six or eight per cent of asphaltic bitumen in a fine-grained sandstone, but for some reason the viscosity of the bitumen seemed to be almost destroyed. What the character of the deposit is at greater depths is unknown.

All the occurrences above mentioned occur within the limits of the Pennsylvanian series of rocks as at present understood. The exact horizon is not certain, but those occurrences in Potato Creek bottom are, perhaps, in the Standley shale, while the others are probably in the Jackfork sandstone formation.

The entire region has suffered much disturbance which resulted in mashing, folding and faulting, but owing to the present unimportance of the deposits no detailed study of the structural conditions was made.

There is a reported occurrence of sand asphalt and malthea in the southwestern part of the county, but it has never been examined by a member of the Survey and little or nothing is known of its value. It is said to be in the Trinity sand of Cretaceous age, and to occur about five miles northwest of Caddo.

ROCK ASPHALT OF McCURTAIN COUNTY

McCurtain County, of which Idabel is the county seat, is the southeastern county of the State. The northern part is topographically young, while the southern portion is nearing maturity. The surface features of the north end consist of deep, V-shaped valleys, high ridges, and narrow flood plains, while that portion south of range five south is characterized by long gentle slopes, low rounded hills, and broad flood plains. The drainage is southward into Red River.

The geology of the north half of the county consists, in the main, of very much involved strata of probably Pennsylvanian age and a basic intrusion which came into place at the time the Kiamichi Mountains were formed. The contact metamorphism of this county is unique in that this is the only region in the State where profound metamorphism is known to have taken place. The rocks of the southern half consist of unaltered sandstones, shales and limestones of the Comanche Cretaceous series which form an unconformable overlap upon the mountain-making formations of the Kiamichi uplift.

Rock asphalt:—A number of rock asphalt deposits have been reported from McCurtain County, but on examination all proved to be either a small amount of carbonized wood or a black shale formation, except the one near Idabel. This occurrence is found in sec. 20, T. 7 S., R. 24 E., on the south bank of Little River, and consists of sand asphalt in the middle or lower Trinity formation. The asphalt-bearing horizon is exposed along the stream for about one-half of a mile, where the current bears against the south bank. Up and down streaam from this point, the level at which the mineral is found is covered by river wash. As far as exposed the sandstone appeared to be rich enough in asphaltic matter to be valuable, and in the writer's opinion, there is no doubt but that it is present in merchantable quantities; for faces of the rock asphalt twenty-five feet high were noted and the bottom was not in sight, while the saturated zone doubtless extends southward into the bank for ten rods and more. In fact, larger and richer deposits of rock asphalt are seldom seen in the State.

The city of Idabel is located, in part, in section thirty-one, T. 7 S., R. 24 E., but the railway yards are, I believe, in section six of township eight south. Thus, then, the asphalt deposit is about three miles from the loading point on the railroad. The haul would be over good country roads with only a few short pulls from the Little River bottom.

Other locations:—There were rumors of rock asphalt near Garvin, Goodwater and Bokhoma, but when followed all seemed to point toward the occurrence at Idabel. It is to be borne in mind, however, that the Trinity formation, which is the chief rock asphalt-bearing

horizon of Love, Marshall and McCurtain counties, extends eastward a few miles north of these places and it is not unlikely that even casual outlook would soon be rewarded by the discovery of new deposits of asphaltic sandstone.

ROCK ASPHALT OF LEFLORE COUNTY

The rock asphalt of Le Flore County so far as at present known is confined to a single deposit of sand asphalt about a mile east of Page on the southwest slope of Black Fork Mountain, on land belonging to the John H. McClure estate. The occurrence is about 300 yards north of the Kansas City Southern Railway and perhaps 100 feet above the track, so that loading could be accomplished by gravity.

The deposit has never been prospected nor has the outcrop been studied in detail, so no idea as to its probable extent can be given. Where exposed the rock is a fine, angular grained quartz sandstone and carries, perhaps, 6 per cent of asphaltic bitumen.

ROCK ASPHALT OF BRYAN COUNTY

Several good samples of sand asphalt have been sent to the office from Durant, but none of them were accompanied by a description of the land on which they were found. It has, therefore, been impossible to visit the occurrences and give them the notice they seem to deserve. Under the circumstances nothing more ca nbe done than to mention the fact that owing to the geology of the county its possiblities for large deposits of high grade rock asphalt seem good.

ROCK ASPHALT IN OTTAWA AND CRAIG CO.

No deposits of rock asphalt have yet been worked on a commercial scale in Ottawa and Craig counties. Heavy petroleum, however, is known to occur near the surface in several places and asphaltic bitumen impregnated some of the sandstones west of Afton. Rock asphalt was encountered in a cellar and a well on sec. 1, T. 25 N., R. 22 E. The probable value of this deposit is unknown. Its accessibility to transportation and nearness to large cities of Kansas and Missouri seem to make it worthy of investigation by those interested in the asphalt and paving industries.

CHAPTER IV.

ASPHALTITE DEPOSITS

INTRODUCTION

The term asphaltite is used to designate the pure, solid minerals of asphaltum, such as albertite, grahamite, gilsonite, etc., which are sometimes locally called coal asphalt.

The development of the asphaltite deposits of the State is only well begun and it is, therefore, difficult to define the limits of their occurrence. At present, however, it appears that the region where these materials are most abundant is the northwestern part of the Ouachita Mountains extending from Page in southeastern Le Flore County to Atoka, the county seat of Atoka County. Deposits have been exploited to a greater or less extent at Page, near Tuskahoma, at Jumbo, in the McGee Valley and near Atoka. Besides these there are several reported and known occurrences within this region which have not been developed, and two isolated known deposits farther west—one near Dougherty in Murray County and one west of Alma in Stephens County, known as the Loco Mine. The mine at Jumbo is the only one on segregated land. The other deposits are either owned in fee or belong to the allottee.

The total output of pure asphalt within the State for the year 1909 is reported to have been 4,413 tons, consisting of asphaltic material won from the sand asphalt at Woodford and from the grahamite mines at Tuskahoma and Jumbo. Of these, the Tuskahoma mine was the greatest producer.

PAGE DEPOSIT

The asphaltite deposit near Page, in Le Flore County, consists of a deposit of grahamite situated on the southern slope of Black Fork Mountain, about two miles east of Page, a station on the Kansas City Southern Railroad. To be more exact it is on the S. ½, sec. 24, T. 3 N., R. 26 E. on land belonging to the estate of John H. McClure.

This occurrence was first brought to notice in 1895 when a hunter by the name of Upchurch reported that he had found coal in Black Fork Mountain. It is reported to have been exposed over an area about twelve by sixteen feet, but the detritus from prospecting now covers the greater part of the exposure. When he learned of the occurrence Mr. McClure entered the land according to the laws and customs of the Choctaw Indians and when allottment was made he secured a title. The land was once under lease to the Mena Coke and Coal Company of Mena, Arkansas, but was never developed on a commercial scale. The deposit was first described by Taff.[50]

Black Fork Mountain is composed of the Jackfork sandstone which is made up of massive sandstones separated by thin shale members. The exact structure of the mountain was not determined during the hasty reconnaissance of the past season. It has the appearance, however, of being a steeply dipping monocline, but it may be an overthrust-fault from the south, or an overturned closed fold, the axial plane of which dips toward the south. Taff concurs in this opinion, though he, too, has not, it seems, determined the structure in detail. In many parts of the mountain the sandstone has been shattered and faulted to a high degree, so much in fact that it is often difficult to determine the dominant lines of fracture.

The grahamite occurs as a vein-filling material along a fault fissure, which trends south by southwest, cuts the strata at an acute angle and pitches steeply toward the southeast. There has been faulting, subsequent to the filling of the fissure, which has cut the deposit short to the eastward. About fifty feet from the east end of the deposit the grahamite is again cut by a cross fault and the strike changed frm about S. 45° W. to S. 20° W., a direction which it maintains throughout its exposed extent. There has been a shaft sunk along the vein, near the south end of the exposure, to a depth of perhaps thirty or forty feet and then an entry driven to the shaft from the south face of the mountain. At the outcrop the vein is about ten feet thick, and is reported to have been found to be twelve or fifteen feet in the workings, but conditions were such at the time examination was made that this could not be verified. It is readily seen that this is a very highly disturbed vein deposit, variable in its extension, and that its dimensions can only be determined by actual exploration.

Samples of the asphaltite at Page were taken with considerable care during the past season, but it has been impossible to make as complete laboratory examination as desired. However, a few of the physical characteristics have been determined. In general the material resembles the grahamite at Jumbo in the Impson valley, of the Atoka occurrence, and of the upper portion of the deposit near Tuskahoma. It is quite black and friable, and has a hackly fracture. In masses the luster is not brilliant, but the small facets exposed by fracture are brilliant. In some parts the vein shows a banded structure, probably due to movement after solidification, as small slickensided surfaces are in evidence. The planes of fracture in an individual band are all parallel, but at varying angles with those of adjacent bands. So far as examined this deposit seems to have suffered more extensive metamorphism than have the deposits farther west in the Ouachita Moun-

50 Taff, J. A., Grahamite deposits of southeastern Oklahoma: Bull. U. S. Geol. Survey No. 380, pt. I., 1909, p. 294-295.

tains. By reason of the metamorphic action a greater amount of the volatile constituents have been removed and the mineral is more resistant, both to solvents and heat, than are those from other regions of the state, except, perhaps, that northeast of Dougherty. On heating in a candle it crackles but does not ignite as does the grahamite from Jumbo; in fact it seems quite probable that this material belongs to a class of asphaltites different from those in other parts of the State. In the following table, after Taff the per cent of fixed carbon represents the degree to which the material has been metamorphosed.

Proximate analyses of bitummens from Impson Valley and Black Fork Mountain, Oklahoma, and Fourche Mountain, Arkansas.

	Impson Valley grahamite.	Black Fork Mountain. solid bitumen.	Fourche Mountain, solid bitumen.
Moisture	0.25	0.09	2.51
Volatile bitumen	43.33	23.06	17.78
Fixed carbon	55.97	75.90	79.15
Ash	1.45	0.95	0.55
Sulphur	1.47	1.69	1.38

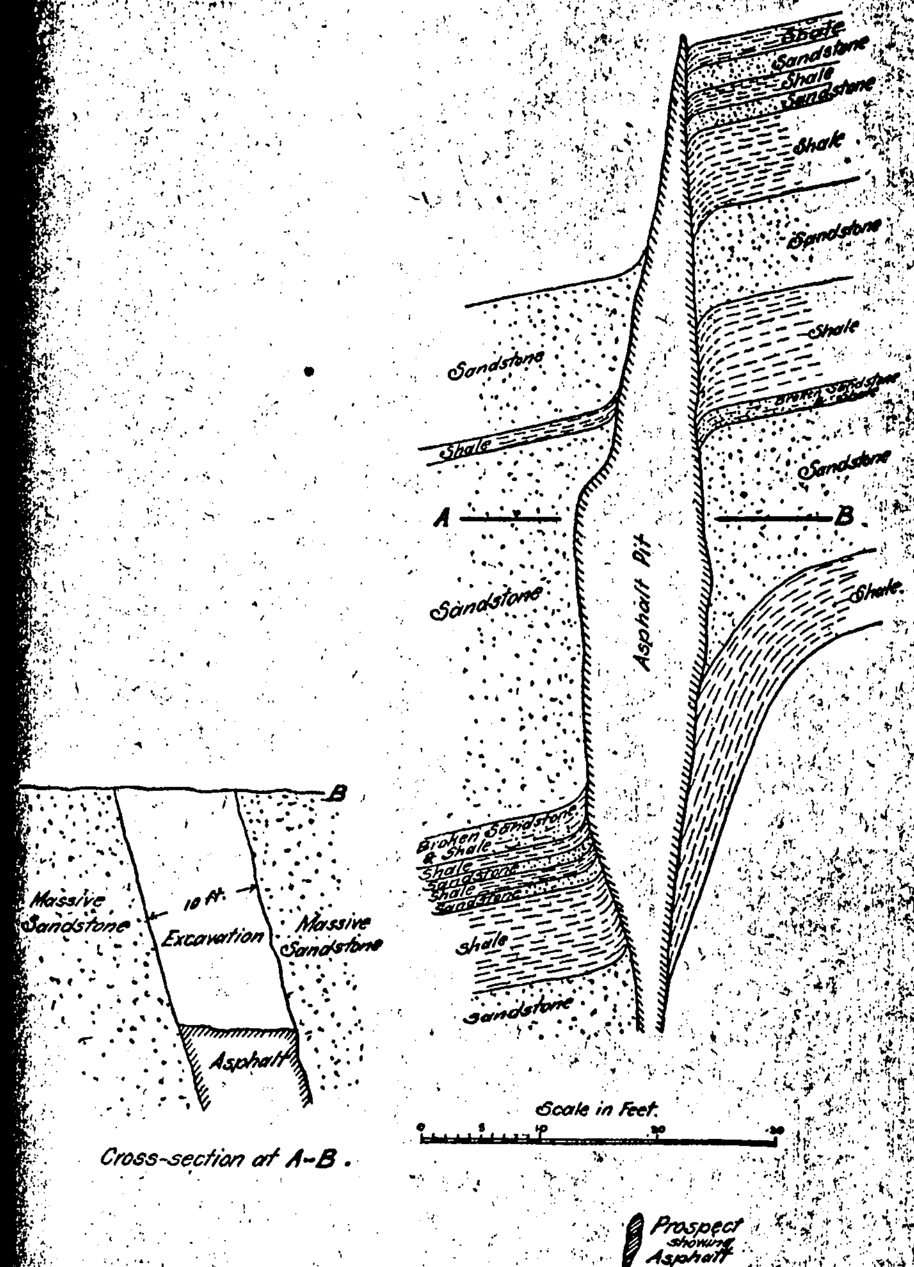
DEPOSITS NEAR TUSKAHOMA

INTRODUCTION.

Tuskahoma is located on the north bank of the Kiamichi River, in a broad valley formed upon the friable Standley shale formation. The valley is interrupted to the north by the Potato Hills composed of Talihina chert. Eastward it extends nearly to the headwaters of the Kiamichi River, while to the westward it is connected with McGee valley. The main deposit of asphaltite near Tuskahoma is in the valley of Jackfork Creek about ten miles northwest of the village, though there are some occurrences of minor importance in the Potato Hills about four miles north of the town.

POTATO HILLS OCCURRENCES.

There are two small occurrences of asphaltite noted in the Potato Hills. These deposits consist only of small amounts of what seems to be grahamite along the bedding planes and in joints and solution cavities of the Talihina chert. The country rock of the occurrence, on the SE. ¼, sec. 1, T. 2 N., R. 19 E., is a highly silicious limestone exposed at the crest of a small broken fold trending east and west. The other occurrence is in the NE. ¼, sec. 2 of the same township and range, where the rocks dip 85° S. 7° W. The formation consists of thin strata of highly silicified limestone and slaty shale. The asphaltites and occasional showings of viscous bitumen, also occur along bedding and joint planes and in solution cavities. Neither deposit is though to be of economic importance.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Massive Sandstone
10 ft.
Excavation
Massive Sandstone
Asphalt
Cross-section at A-B.
Scale in Feet.
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Prospect showing Asphalt

PUMROY MINE.

JACKFORK VALLEY OCCURRENCE.

This occurrence, situated partly on the NE. ¼, sec. 9, T. 2 N., R. 18 E., and partly on adjacent land, is one of the largest known asphaltite deposits of the State. In point of production during the past year it is the largest, though it is not so extensively explored as is the Jumbo vein to be described later. The deposit was first brought to public notice during the winter of 1906 and shipments were made the following fall, however, it is said that a citizen found it in a well prior to allotment, and supposing it to be coal, kept it secret to avoid segregation. The first report of the occurrence was by Taff. The land known to contain the asphaltite is under lease to the Ft. Smith Asphalt Company, of Ft. Smith, Arkansas, which has opened up a mine on the SE. ¼, NE. ¼, sec. 9, as described. The operators report that they have traced the vein by prospect pits, for a distance of three-fourths of a mile west of the mine location and about one-fourth of a mile east of it, thus making the known occurrence one mile long.

The country rock consists of sandstones and shales near the center of the Standley formation, of Carboniferous age. The rocks here dip south at an angle of 37° at the outcrop, and the vein which is reported to average four feet at the surface, lies parallel to the bedding plane of sandy shales below, and a slightly shaley sandstone above, to a depth of more than 125 feet, where the dip of the deposit changes to about 47° and so continues to the bottom of the mine, but the dip of the formation does not change. The opening occupied by the asphaltite seems to have been formed by a bedding fault probably overthrust from the south. Slickensided surfaces in the wall rock are comparatively few, and none were noted in the vein material, thus indicating that there was very little movement along the fault plane prior to filling and none at all after the bituminous matter had solidified. The mine was opened at the point where the asphaltite was the thickest, about 19 feet. Development has shown a maximum thickness of about 25 feet. Drifts east and west from the main opening have shown that large pieces of the hanging wall fell into the deposit before it had become solid. At other places the vein is parted near the middle apparently by the branching of the fault, though exploration has not gone far enough to determine whether the zone of fracture had really parted or whether the parting is only due to a gigantic cave from the hanging wall.

Taff, in the report cited above, calls the vein filling material grahamite, though he records no laboratory identifications. There are two distinct types of the material throughout nearly the entire occurrence as exploited. The lower zone, which ranges from a few inches to more than nine feet, consists of irregular pentagonal prisms, black in color, of bright luster and distinctly subconchoidal to conchoidal fracture. The upper done is of irregular structure, hackly fracture and dull luster, except on small facets. Where the lower zone is of sufficient importance the material is separated from that of the upper portion of the vein and sold as gilsonite, while the remainder is marketed as grahamite. Whether there is any real difference in the material or not has not been determined, but if there is none the striking difference in structure and fracture presents a very interesting phase.

THE IMPSON VALLEY OR JUMBO DEPOSITS

This occurrence of asphaltite, located on the W. ½, sec. 28, 2 1 S., R. 15 E., was first discovered in 1891 by C. E. Wilson and was thought to be coal until 1899 when Taff's[51] paper describing it as asphaltite was published. A small mine was opened soon after the discovery in 1891 and operated by Dr. H. C. Nash et al., of Antlers, the product being chiefly marketed as coal for use at Antlers. The Choctaw Asphalt Company came into possession of the mine in 1902, but has made no attempt at exhaustive exploitation. This company has maintained only sufficient crew at the mine to continue prospecting and keep the plant in repair.

In Taff's first paper, above mentioned, he compared the Nova Scotia albertite with the specimens collected in the Impson Valley and decided that there was sufficient difference for them to belong to different species and suggested the name impsonite for the Impson Valley mineral, but in a later paper (Bull, U. S. Geol. Survey, 380) he calls the Impson Valley asphaltite grahamite.

The grahamite deposit occurs along a zone of faulting and fracture near the top of the Standley shale and extends for one-half mile along the west side of the valley in a north and south course, near the base of the hills of Jackfork sandstone, which form the western barrier of that portion of the drainage basin of Ten-mile Creek, known as Impson Valley. The structure of the region is graphically described by Taff in Bulletin No. 380, above referred to, and is as follows:

> The formation has been strongly folded upward and thrust over slightly toward the west. The strata have been fractured and probably faulted along a belt parallel with the axis of the fold and near the west side of the valley. The beds of shale and sandstone contiguous to the veins have suffered crushing and shearing to such an extent that they are retained in the walls of the mines with great difficulty after the grahamite has been extracted. Strong pressure has been exerted on the rocks since the bitumen became solid, tehreby causing it to be fractured and intimately jointed. The grahamite veins are lenticular and variable in form both laterally and vertically. The strike of the veins has a general north-south direction, parallel with the general trend of the rocks, but not necessarily parallel with the individual beds. The pitch of the veins is steep toward the east, in the direction of the dips of the rocks, but usually at a greater angle.

The cross sections of the Jumbo mine given in this report are compiled from maps and plans, furnished by A. W. Thomas, Superintendent of the mines and mill, show the extent and character of the deposit better than description.

51 Taff, J. A., An albertite-like asphalt in the Choctaw Nation: Am. Jour. Sci. 4th series, vol. VIII., Sept., 1899, New Haven, Conn.

1 AND 2 ASPHALT PITS.
3 PILE OF GYPSONITE.

McGEE VALLEY DEPOSITS

There are two known occurrences of grahamite in the McGee valley in eastern Atoka County, neither of which has been previously described. One is located on the SE. ¼, sec. 28, T. 1 N., R. 14 E. The other occurrence, known as the Pumroy mines, is located on the NE. ¼, sec. 25, T. 1 S., R. 13 E., about twelve miles southeast of Stringtown on the Missouri, Kansas and Texas Railroad. Both occurrences are in the Standley shale, probably near the top. The general strike of the formation is northeast-southwest, though local irregularities are frequent. There is evidence of mashing and faulting at the first location, while the structure at the Pumroy pits is shown by a "figure" in this report. Between these two occurrences there were several places noted where mashing and breaking were in evidence. In each instance the structure had a trend of north about 30° east. While it was not determined whether there is a continuous line of fracture extending from one occurrence to the other, it seems highly probable that they are both in the same zone of mashing, though the faults in which the grahamite occurs may be of local extent.

The grahamite of the most northerly occurrence is exposed at two places in the bank of a branch of McGee Creek where the line of outcrop has been cut by an abrupt bend. The vein, which is one inch thick at the north end and two inches at the south end, occurs in a greenish sandy shale that is very much distorted and mashed and has been displaced by faulting. Several years ago a shaft was sunk on the vein to a depth of fifteen or twenty feet, but as it had only slightly increased in thickness, the site was abandoned. It is impossible to predict the probable value of the vein as all asphalts of this character are very irregular in their occurrence.

THE PUMROY MINE.

The Pumroy mine consists of three openings on a vein of grahamite in NE. ¼, sec. 25, T. 1 S., T. 13 E. The exact date of the opening is not known, but a citizen says that theoccurrence has been known for forty years; its exploitation, however, did not begin until within the last few years. The first shaft sunk is on the bank of a branch of McGee Creek. Several carloads of the material were shipped from Stringtown, but the mine became so badly flooded that a second shaft was opened about a quarter of a mile southwest of shaft number one, which was abandoned. At the time the property was examined the north shaft was filled with water so no examination was possible. The other, however, was only partially filled and examination showed that the grahamite is contained in a fissure caused by the faulting of the formations, at an angle to their outcrop, after they had been steeply upturned.

It is reported that in all more than a hundred cars of the material were shipped from Stringtown. Operations are suspended at present, though the original operators say that the grahamite was present in paying quantities as far as it was prospected. At present the long haul to a shipping point mitigates greatly against profitable working of the deposit at this location.

There is a small vein of grahamite on the S. ½, sec. 13, T. 2 S., R. 13 E., which trends nearly north and south, besides other reported occurrences. None of these have been sufficiently prospected to detetrmine their possibilities.

DEPOSIT NEAR ATOKA

This deposit, also consisting of grahamite, is located on the SW. ¼, sec. 29, T. 1 S., R. 12 E., on the south bank of North Boggy Creek, about six miles northeast of Atoka and only a few hundred feet from the Missouri, Kansas and Texas Railroad. The date of its discovery is unknown to the members of the Survey, but the first mention on record is Taff's short account on page 296 of United States Geological Survey Bulletin No. 380, where he describes it as the Boggy Creek deposit.

The material occurs as a vein filling substance in a greenish clay shale with large amounts of associated chert in the Talihina chert of Ordovician age. The vein, so far as exploited, which is only about eighty feet, lies along the bedding plane of the formation. The mine was worked by a slope which has a dip of 32° S. 80° E. at the mouth of the slope, but owing to the presence of water it could not be examined for more than a few feet. The vein is reported to have been only about two inches thick at the outcrop, but it is said to have gradually thickened with depth until it was several feet thick at the bottom of the slope. The grahamite is exposed in the bank of a small ravine thirty feet north of the shaft. At the top it is only two inches thick; two feet lower it has increased to three and one-half inches so the reported increase with depth does not seem extravagant. Local faulting at an angle to the dip is common, and the joints and seams of the rock in the vicinity are often filled with grahamite.

The material is commercially classed as grahamite, and as a rule exhibits the hackly fracture, dull luster, except on small surfaces, and other general characteristics of the Jumbo grahamite and the upper portion of the vein near Tuskahoma. Some of the material, however, has a distinctly sub-conchoidal to conchoidal fracture, bright luster, and is irregularly pentagonal in cross section. Whether this difference is due to the presence of different varieties of mineral in the same vein or to greater pressure and slight movement and crushing in some portions of the vein, is unknown. It seems, however, that the latter explanation is the more probable. It takes fire and swells in the flame of a candle and burns with a short red flame for a brief time when removed from the fire.

WILLIAMS PROSPECT

The Williams prospect consists of an opening on a vein of asphaltite-like material located on sec. 33, T. 1 S., R. 3 E., about five miles northeast of Dougherty, on land belonging to W. J. Williams of Sulphur. The prospect consists of a shaft, seventy-six feet deep, sunk on the vein which is nearly vertical. The vein occurs in what is thought to be the Woodford chert, and seems to be near the top, only ten or twelve feet below the Sycamore limestone, but the horizon was not carefully determined. The vein is reported to be eighteen inches thick at the top and seven feet at the bottom of the shaft. The opening, however, was filled with water at the time of examination and these thicknesses could, therefore, not be verified, but the vein material is eighteen inches thick in a shallow pit about 100 yards southeast of the mine, hence the reported figures are doubtless correct. The structure was not determined because of the mantle of detritus which covers the region, but the deposit appears to be along the bedding plane of the chert which is composed of the characteristic chert lentils and silicious shales of the Woodford formation.

The material mined has not been tested in the laboratories of the Survey, but the owners sent some to a commercial assayer who reported it to be a "fuel asphalt." The physical properties of this deposit differ greatly from those of the grahamites already described as the one near Loco to be discussed later. It is a dull lusterless, waxy black, requires a sharp blow to break it, sub-conchoidal to conchoidal fracture, hard to crush with the teeth, is fully as hard to kindle as the average bituminous coal, cokes readily, but burns to an ash, if in open air or a stove, without melting. Its solubility in crude petroleum or other ordinary solvents for the asphalts is not known.

LOCO DEPOSIT

This deposit of grahamite occurs in the NW. ¼ sec. 6, T. 2 S., R. 4 W., as a vein filling material in sandstones and shales of Permian age. The occurrence is not segregated and was first described by W. R. Crane as "Asphaltic Coal" in the Janaury, 1906, issue of Mines and Minerals. Since then Taff wrote a short sketch of the occurrence for the Federal Survey. The field occurrence was studied for the present report by Ben C. Belt whose notes are quite complete in many respects, but owing to the fact that work has been suspended for several years he could not procure underground data such as Crane[52] gives, hence that author's report is drawn upon. His report, in part, is as follows:

52 Crane, W. R., Asphaltic coals in the Indian Territory: Mines and Minerals, vol XXVI., No. 6, January, 1906, p. 252-254.

The formations associated with asphaltic coal of this locality are gravels, sandstones, shales, and clays (both red and blue) which beds have been cut by a series of parallel fissures ranging from a few inches to several hundred feet apart........Three well-defined veins have been discivered and opened on this property, known as the Sanner Claim, which is 80 acres in extent. The main vein has been traced for fully half a mile by shafts and test pits, and has a strike of 47 degrees east of north and a pitch of 80 degrees to nearly 90 degrees to the northwest. Running exactly parallel with it at a distance of about 300 feet to the south is a second vein, which has been traced for about one-fourth mile, beginning with the extreme western extension of the former vein. These two parallel veins are also cut by another, which has a strike of 45 degrees west of north, thus lacking but 2 degrees of forming a right angle. The pitch of this vein is also 80 degrees to 90 degrees, but in this case to the west. It has been traced for a distance not to exceed 350 feet—the contents pinching out both to the north and south, although the fissure is known to continue for some distance further. Development work on the cross-vein showed the existence of still another vein running parallel with the first two mentioned and at a distance of about 250 feet north of the middle or main vein........

The pitch of all the veins so far developed averages probably 85 degrees: i. e., a shaft sunk upon the vein and maintaining a straight line would have such a pitch, although the pitch of the individual portions, or enlargements, of the vein may range from the vertical to as low as 45 degrees........

The greater portion of the longest vein, thus far designated as the main vein, is barren, or has at most only a few inches (1 to 3) of asphaltic coal. The extreme eastern extension of this vein has proven to be most productive, and the vein as a whole more productive than any other in the vicinity.

Four shafts have been sunk at about half a mile from the cross-vein, mentioned above, at which point the vein has been pinched out quite abruptly—its continuation is then uncertain from this point on eastward. Just west of the squeeze or pinch-out occurs the most extensive part of the deposit, which extends for a distance of 800 to 1,000 feet along the vein, and it is in this portion of the vein that theshafts are located. The first shaft is sunk at a point 85 feet from the termination of the vein, while the others are located at intervals of 150 to 300 feet apart. The shafts vary in depth from 60 to 100 feet, some of which still continue in the deposit, while others have passed below what appears to be the workable limit........A careful examination of the vertical sections of the deposit, rendered possible by the open stopes, shows a peculiar arrangement of the parts of the vein and gives a decided impression of vertical folding along the line of the vein. So pronounced is this effect that in several cases observed the enlargements of pockets, in the deposit, were connected by only a few inches of vein filling, or necks, the adjacent ends of the pockets slightly overlapping as though having been acted upon by vertical compression. The condition of the associated formations on both hanging and foot-walls does not, however, bear out the idea of folding, but rather seems to point to the squeezing effect of lateral compression. The condition of the associated formations on both hanging and foot-walls does not, however, bear out the idea of folding, but rather seems to point to the squeezing effect of lateral compression as the agency which acting upon a viscous non-compressible material has produced the marked irregularities of vein content noted. The softness and weakness of the country material have rendered the irregularities more striking. The brooming of the shales and the broken condition of the harder sandstone and limestone portions of the walls also corroborate the lateral compression theory........

Fissuring rather than faulting seems to be the condition prevalent in this district. Displacements of only a few inches at the most show the extent of faulting in the veins in question.

The pockets are roughly lenticular in shape and vary in thickness from a few inches up to 10 and 12 feet, average probably 4, and range from 25 to 100 feet in both horizontal and vertical extent. At several points on the vein, at a depth of 100 feet or thereabouts, the deposit has pinched out entirely, as shown by shafts and other workings, this closing of the vein may be more or less abrupt, while at other points the deposit has maintained its thickness; in still other cases, although the main body of the deposit has pinched out, yet it continues as stringers, of which there may be quite a number, even as large as 1 inch in thickness. These stringers usually run out in the course of 10 to 20 feet........

The formations, containing the veins, have a dip of about 2 degrees to the east of south, which accounts for a still further distribution of asphalt through the surrounding strata. On the up, or north side of the main vein, the dissemination of the liquid asphalt does not extend more than several feet, except in rare instances, while it may reach to a distance of one-half mile or more on the south side or in the direction of the dip........

CONCLUSION

The commercial asphaltites of Oklahoma all occur as vein filling deposits either in fissures occasioned by faulting or along the bedding planes of formations which have evidently suffered great distortion or extensive movement. All known deposits are associated with sandstones and shales, or near-shales, as we might call the cherty shales of the Talihina and Woodford formations. The rocks containing the grahamite are of Ordovician age near Atoka; of Devonian age at the Williams prospect; and Permian at the Loco occurrence, while the others are at different Carboniferous horizons below the Permian. The physical properties of the deposits at Atoka, Jumbo, in the McGee and Jackfork valleys and near Loco are alike in all essential respects unless the variable luster and fracture of portions of the product from Jackfork Valley and near Atoka should prove a part of the vein to be of some asphaltite other than grahamite. The deposits in Black Fork Mountain and near Dougherty differ from the others and from each other. This difference seems to be due to a greater loss of volatile constituents and may prove them not to be true grahamites. Throughout the region the veins have been found to be of variable extent both as to thickness and length, a condition which characterizes all vein filling deposits. Little can be conjectured of the amount of available material beyond the limits of actual prospecting. There are numerous rumors of outcrops of "coal" east of Antlers, in the vicinity of Hochatown and in the Kiamichi Mountains southeast of Tuskahoma. It is believed that these rumors are likely occasioned by the presence of outcrops of asphaltite, as the rocks of that region are geologically below the coal bearing horizon, but are of the same age as those which contain asphaltites at Page, and Jumbo, and in the Jackfork and McGee valleys.

CHAPTER V.

ON ASPHALT PAVING.

Many cities and towns either have asphalt pavements already laid or are preparing to construct them in the near future, hence there are constant inquiries about street paving processes. It is with the hope of assisting many of those interested in such work that these few pages are inserted.

The best treatise on the subject which I have consulted is the *Modern Asphalt Pavement* by C. Richardson, published by Wiley and Sons of New York. That writer discusses the building of pavements at length, and the various materials and tools used in their construction, and also gives standard tests for various asphalts used, such as Bermudez, Trinidad Lake, and California oil asphalt, etc., of which more will be said later. The processes of testing were, it appears, developed with especial reference to the use of Bermudez, and Trinidad Lake asphalts, which are mainly owned and controlled by the Barber Asphalt Company for which Mr. Richardson is reported to be chief chemist.

In general an asphalt pavement consists of three courses, the foundation, intermediate, or binder course, and the surface course.

The preliminary steps in paving are three in number: (1) Construct a subsoil base by excavating the street to such a depth that, after being thoroughly rolled, the surface of the pavement when finished will be at the desired grade: (2) Good substantial curbs should then be constructed of poured concrete: (3) Concrete gutters should be built with the joint between the gutter and the curb watertight.

In preparing the sub-soil all soft places and water seeps should be thoroughly remedied by drainage and the introduction of such foreign material as will insure a stable base for the foundation to rest upon, and the drainage system of the streets established. In cities with storm sewers the gutters should drain toward the sewer openings while the center of the street should be high enough to insure ready drainage toward the gutters. Curbs of flagging stone or brick laid in cement mortar are sometimes substituted for poured concrete curbs but these are seldom satisfactory, for the stone must necessarily be set on "edge" so that frost and heat soon burst it to pieces, while brick will be found expensive, when properly laid, and if one is torn out, or disintegrated by freezing or other cause, those adjacent are loosened.

The gutter is often omitted in actual practice, but as a rule it is not best, for horses or wagons left standing by the curb during warm weather will cause depressions in the surface in which water will collect and rapidly disintegrate the pavement. Then, too, the street dirt always gravitates to the gutters, and will collect more abundantly along the curb than anywhere else, and the organic matter contained therein will generate compounds which are injurious to asphalts. Running water also has a tendency to destroy the average surfacing where exposed to its action. All things being considered a concrete gutter is an economy rather than an expense, though the initial cost may be more.

When the drainage and proper grade have been established and the curbs and gutters are in, the street is ready to receive the foundation course which is to carry the weight of the other two courses and also that of the traffic, and should therefore be without defect. It should consist of from four to six inches of poured concrete, the thickness depending on the base and probable weight of traffic. The concrete should be composed of crushed stone, or clean gravel, and sand of assorted sizes so that each portion of smaller aggregates will fill the voids left by the next larger, thus forming a mechanical bonding and lessening the strain on the cement. Extreme care should be used to insure perfect contact where new work abutts against old; otherwise the finished pavement is liable to crack due to give in the foundation.

The second, or binder course, should consist of assorted crushed stone from one inch or one and one-fourth inches in diameter down, and of such amounts that a mechanical bond will be formed. In common practice this mineral aggregate is heated and coated with enough asphaltic bitumen to envelope every particle, then spread the desired thickness, usually three inches or so, over the foundation and rolled smooth with a steam roller.

The third or surfacing course is similar to the binder, except that the mineral aggregates are much finer, usually clean sand and fine mineral dust, heated and coated with asphalt and rolled down. The object of this course is to prevent dust and mud, deaden sound, resist wear, and break jars; it must, therefore, be tough and elastic, and be rigidly supported, laterally by the curbs and from beneath by the concrete foundation.

Richardson makes his work, referred to in the beginning of this chapter, appear fair by applying the so-called "standard" tests for the Trinidad and other artificial asphalts to the natural rock asphalts of the United States and finding them wanting in many respects. He, therefore, concludes that because the natural product does not satisfy the artificial demands made to suit an artificial product, the former is of no value for paving purposes. To determine the relative merits of the artificial material and Oklahoma natural rock asphalt, one only needs to compare the pavements of Oklahoma City, which are made from artificial mixtures, with those of Ardmore, Sulphur, Paris, Texas, and some in St. Louis, Kansas City, and other cities of the Southwest, constructed of Oklahoma rock asphalt. In every instance the natural product is out-wearing the artificial one, *but it is not prepared and applied exactly as specified for the artificial mixture.* The preliminary steps of grading, curbing and guttering should be the same for either material.

In preparing the artificial material mineral aggregates free from all asphaltic bitumen is used in the binding and surfacing courses. After sizing, the aggregates are mixed with enough asphalt, while hot —three to six per cent—to coat each particle. At first thought it appears that this should form an ideal asphaltic concrete, but it does not, because of what might be called "self consumption." The asphaltic cement contains a large amount of volatile matter, otherwise it would not liquify at the temperatures demanded and be as easily penetrated as specifications require. The mineral aggregates are free from asphalt and are honey-combed with capillary pores and cracks, due to crushing and natural causes. When each particle of the aggregate is heated and encased in a film of the semi-liquid asphalt, capillary attraction immediately sets to work to draw as much of the liquid within the stone as is possible, that is to satuurate the aggregates, while solar heat evaporates the volatile matter at the surface. Thus two forces are continually at work destroying the elasticity and viscosity of the asphalt, making it more brittle than cement, and rendering the surface capable of being powdered to dust.

Since the elastic and viscous qualities of asphalt are all it has to recommend it as a cementing material, it is very obvious that the more forces that are at work destroying those properties the less desirable it will be as a paving cement.

In the case of natural rock asphalt the deteriorating factor of "self consumption" is removed. The rock, limestone, sandstone, or shale, as quarried is thoroughly saturated with asphaltic bitumen. Paving with this natural product is about as follows: The desired kind of rock asphalt is quarried and crushed to various sizes. The limestone and sandstone varieties from the constituents of the binder course and are so sized,after crushing, that the voids are filled in order to form a mechanical bond. If the per cent of asphalt is too great, it is then diluted by adding some less bituminous rock, heated and rolled down. The surface mixture is composed of finely crushed sandstone mixed with the finest material from the limestone crushings. This is heated and rolled down in the same manner as the artificial mixture. As the sun's heat drives off the volatile constituents of the asphaltic cement of a natural rock asphalt pavement, the reserve

contained within the individual pieces of the mineral aggregate will yield up a sufficient amount of volatile matter to maintain the necessary elasticity and viscosity of the cement for a long time after the artificial mixtures would be impoverished and worn out.

Thus it is apparent that a pavement properly built of natural asphalt must needs be far superior to any artificial mixture in which the mineral aggregates are not thoroughly saturated with the cementing material—asphalt.

PART II.

PETROLEUM AND NATURAL GAS.

BY L. L. HUTCHISON.

CHAPTER VI.

ON THE HISTORY OF PETROLEUM AND NATURAL GAS.

INTRODUCTION.

"In the History of Human Error an extensive chapter is requisite in connection with petroleum."—Redwood.

It is not the purpose of the writer to try to correct the errors which have arisen in connection with attempts to account for the origin of petroleum and natural gas, and their accumulation into limited areas; nor is it intended to introduce new theories, but rather to make a careful review of all obtainable literature on the subject, which seems worthy of consideration—because of the author's prominence as a scientist, or on account of the apparent care used in making the observations recorded—then summarize the data gathered and point out what seems to be the most plausible theories and show why, in the writer's mind, they are so.

In the study of the subject several questions have arisen which, it appears, are new to the literature. These have been stated as clearly as possible and tentative suggestions made as to a possible answer. It is intended to use these suggestions as a basis for further investigation, for, in the light of present data, a satisfactory solution is impossible.

The published papers and reports on petroleum and natural gas have been used as texts of general information. Under such circumstances it is impossible to give complete credit, but in all cases where the direct thought or words of another have been used, it has been the purpose to give reference to the author and article from which it was obtained.

In this connection, the writer wishes to acknowledge the assistance of Prof. J. D. Irving, and the valuable data furnishe dby Prof. Charles Schuchert, on which the generalizations under the sub-head of "Distribution in Time and Space" are based. It is also desired to express appreciation for the kindly interest shown by Messrs. F. B. Laney and H. L. Ward, in bringing to attention several valuable articles which would otherwise not have been had. Acknowledgment is also due Prof. I. C. White, of West Virginia, for valuable

references on foreign fields; Prof. J. C. Banner, of California, for bibliography of California petroleum and some suggestions; to Prof. H. Hoefer, of Austria, for like assistance relative to petroleum fields of his country; to Dr. Koohibe, Director of the Imperial Geological Survey of Japan, for a full report, the latest maps, etc., of the oil fields of that nation; to Mr. Frank Barnes, of Bristow, Oklahoma, who so kindly loaned the author many of his father's old papers relative to the earliest attempts to discover oil or gas in eastern Oklahoma; to Dr. Skelton, of Okmulgee; Dr. Clinton and Hon. E. R. Perry, of Tulsa; Mr. Russell H. Johnson, of Bartlesville; Mr. Mitchell, of the Gulf Pipe Line Co.; Mr. Moran, of the Texas Pipe Line Co., and many others who either furnished valuable data or lent personal assistance to the writer in his attempts to collect trustworthy information. Special mention is due Mr. Kelsey, of the Cudahy Oil Co., of Cleveland, Ohio, who supplied the office with nearly 300 accurate well records and other data; and to C. H. McReady, Oglesby, Oklahoma, with the Low Oil & Gas Co., who not only furnished valuable records, but also exact elevations of the mouths of all their wells, as compared with a nearby bench mark. Owing, however, to unfortunate circumstances, it is impossible to use much of these data in this report. They have been filed and will be of great assistance in future detailed work which the Survey proposes to undertake in the future, when it is hoped that all Oklahoma operators will be as willing to assist as these gentlemen have been.

HISTORICAL SKETCH

INTRODUCTION.

Because the manufactured products of petroleum have been known and used in a commercial way only for half a century or so, it is commonly thought that the crude product is a recently discovered mineral, but both biblical and classical history record its presence as far back as human records have been kept, and it seems that a few of these references may be of interest.

BIBLICAL REFERENCES.

In the Scriptures, reference is frequently made to salt and slime. It appears that these words were translated from a term which, in the original manuscript, was used indiscriminately to mean common salt, niter and bitumen. Accepting this interpretation it would seem in the building of the Tower of Babel, Genesis ix, 3, where it is said

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[53] For fuller discussions of the history of petroleum see:
Redwood, Sir Boverton, Petroleum and its Products, 1906.
Henry, J. D., Baku, an eventful History.
Thompson and Redwood, Handbook on Petroleum.
Thompson, A. Beeby, The Oil Fields of Russia.
White, Dr. I. C., West Virginia Geological Survey Report, Vol. 1 (a), 1904.

"slime had they for mortar," that the mortar was some form of bituminous subtsance, an assumption which receives confirmation in the writings of Herodotus, who, about 450 B. C., spoke of the use of bitumen, brought down by the river Is, as mortar in the building of the walls of Babylon (Hist. 1,179). In Genesis xiv, 10, we are told that "The vale of Siddim was full of slime pits," and the word here translated "slime" appears as bitumen in the Latin Bible. Also in Job xxix, 6, "and the rock poured me out rivers of oil," and Deuteronomy xxxii, 13, "oil out of flinty rock" perhaps referred to "natural oil," but it may be that these expressions are merely oriental hyperbolae for an abundance of olive oil so essential in the domestic economy of those days. Then, too, may not the pitch with which Noah "pitched the ark within and without with pitch," Genesis vi, 14, have been one of the solid or semi-solid bitumens?

CLASSICAL REFERENCES.

Among the classical writers, Herodotus, Vitruvius, Strabo and others refer to the working of bituminous deposits for both oil and asphalt. Strabo and Pliny tell of the use of "Sicilian Oil" from Agriegentum for illuminating purposes. According to ancient Japanese and Chinese records it appears that these nations were using petroleum and natural gas as fuel, even before Abraham was called from Ur of Chaldea," but China, in keeping with her ultra-conservative policy, is not even yet one of the world's petroleum producing nations. The Pythian shrine to Apollo was situated over a natural gas emanation, the mystery of which gave rise to the rites and ceremonies of a religious cult of ancient Greece, while the eternal fire of the Zoroastrians was the burning of escaping natural gas.

To cite more of the early history would be beyond the purpose of this paper and only add unnecessary detail to the established fact that petroleum and natural gas have been known to man and used or worshipped by him ever since before history began.

HISTORY OF MODERN DEVELOPMENT.

INTRODUCTION.

In 1908 the United States, Russia, Eastern Archipelago (Sumatra, Java and Borneo), Galicia, Roumania and India produced 95.35 per cent of the world's petroleum, while Japan, Mexico, Canada, Germany, Peru and Italy combined produced only 4.62 per cent. Of these the United States and Russia are the greatest producers. In 1908 the former yielded 63.09 per cent of the whole, while the latter produced 21.85 per cent. So it seems, owing to their importance, that brief mention of the early beginnings and present development of petroleum production in these countries would be of interest.

PETROLEUM IN UNITED STATES.

The earliest mention of petroleum within the present bounds of the United States was made in a letter written, by a Franciscan monk, dated in 1629, and published in Sagard's "Histoire du Canada" in 1632. This letter describes some of the oil springs of what is now the State of New York. It is also recorded that Peter Kalm, a Russian naturalist who visited America in 1748, discovered petroleum. On returning home Mr. Kalm published an account of his travels, together with a map on which he located the springs of Oil Creek Pennsylvania. Mr. Gesner says, in a Practical Treatise on Coal, Petroleum, etc., (1865), that petroleum and soft bitumen have been known in California since 1792. There is no record of early discoveries of petroleum in the Mid-Continent field, but it appears that as early as the middle of the nineteenth century petroleum was known to occur, as springs, in eastern Kansas.

EARLY USES OF PETROLEUM.

Whether the Indians used petroleum as a medicine or not is not certainly known, but such was the use to which white men first put it in America. "Seneca Oil" as it was called, (for Lake Seneca, New York, near which the first source of supply was located), was considered a panacea for all burns, bruises, sprains, rheumatism, etc., and was so much in demand that a small phial full would sell for forty or fifty cents as late as 1833.

APPALACHIAN FIELD.

The excessive prices just mentioned did not obtain for long. Salt manufacturers drilling for brine in the Appalachian regions of Pennsylvania, West Virginia, Kentucky and southeastern Ohio often encountered petroleum and the supply soon outgrew the demand. The manufacture of coal and shale oil by distillation of coal and bituminous shale, whence the name coal oil, had grown to considerable magnitude by the middle of the nineteenth century and there was a great demand for these products. It took only a few tests to discover that the "rock oil," which was looked upon with disfavor in the brine wells, was of nearly or quite the same quality as the crude distillates from coal and bituminous shale, and the petroleum soon began to displace the oil obtained from coal and shale. The "natural or rock oil" market thus being stimulated by dispensing with coal and shale oil, borings soon began to be made in search of petroleum. The first well drilled in America for oil only was completed at Titusville, Pennsylvania, by E. L. Drake in 1859. From that date until 1905 the Appalachian region held first place among American oil fields; but during that year it fell to third place, yielding first and second to California and Texas, respectively, but due to a great slump in Texas production, it rose to second in 1906. Since 1906 the Appalachian field has been outstripped and was fourth among the nation's producing fields in 1908.

LIMA-INDIANA FIELDS.

For twenty-five years the Appalachian fields produced all the petroleum of the United States, but during the fall of 1884 gas was discovered in the Trenton limestone at Findley, Ohio. Trial borings were made in all directions from Findley and by the close of 1887 the Lima-Indiana oil field was fairly well defined. In 1908 this region ranked sixth among the American oil fields.[54]

ILLINOIS FIELD.

During the early excitement in the Appalachian region several attempts were made to procure oil in Illinois, but none were especially successful. There were some gas wells drilled near Litchfield in 1884. In 1889 the same wells began to yield petroleum. Development was slow and was carried on mainly by local companies of inexperienced men until within the last twelve years or so, when experienced oil operators were attracted thither and development began on a larger scale. This region has proved very prolific and in 1908 was third in importance in this country.[55]

MID-CONTINENT FIELDS.

The Mid-Continent oil and gas field as defined by the United States Geological Survey, is composed of the petroleum producing regions of Kansas, Oklahoma and north Texas. From the data at hand it appears that the earliest settlers of Kansas discovered petroleum springs in the eastern part of the State and used such local supplies for lubricating purposes, etc. G. W. Brown[59] began prospecting for petroleum near Paola, Kansas, as early as 1860; but the political unrest of those times demanded the attention of every one and nothing further was done until after the war. Considerable quantities of gas had been found near Iola as early as 1873, and Paola was heated and lighted by natural gas in 1882. The real development of the region, however, did not begin until 1890, when Pennsylvania operators entered the field. From that date productiion has steadily grown, until the Mid-Continent field now ranks first among the producing regions of the United States.[60]

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54 Mineral Industry for 1908, New York, 1909.
55 Op. cit.
59 Report Kansas Univ. Geol. Survey, Vol. 1, 1895.
60 Mineral Industry for 1908, New York, 1909.

TEXAS FIELDS.

Petroleum was first discovered in Texas about 1860[61] when a few flowing wells were brought in near Nacogdoches at a depth of only 100 feet. A few storage tanks were built, but production was light and the industry dormant for more than a quarter of a century, as is shown by the fact that the total yield of that place was only fifty barrels. The Sour Lake strike of 1893 was worth while, and the Corsicana field (first discovered in 1894) yielded 546,000 barrels in 1898; but the importance of Texas as an oil producer was not known until the bringing in of the Lucas well at Beaumont in January, 1901. This well had an estimated initial flow of over 75,000 barrels per day. The area of the field, however, was small and the wells were numerous, so production soon declined. Other small but very prolific pools were soon discovered near Beaumont, so that Texas ranked second among the oil producing states in 1905, fell to sixth in 1906,[62] and ranked fourth in 1908.[63]

LOUISIANA FIELDS.

Petroleum was known in Louisiana as early as 1820,[64] but was only used locally for lubricating purposes and to prevent rust on implements. There was no development worthy of mention until 1904, when, doubtless stimulated by the Beaumont strike in January of that year, a well was undertaken near Jennings, Louisiana, (about ninety miles east of Beaumont, Texas) and completed as a gusher in August of the same year. From this beginning development went on rapidly until in 1908 Louisiana produced nearly seven million barrels of crude oil,[65] and promises greater things for 1909.

CALIFORNIA FIELDS.

As stated earlier in this paper the presence of petroleum in California has been known for more than a century, but there was little done toward development as is seen from the fact that though the first well was drilled in 1869, the total production in 1880 was only 40,552 barrels. From this latter date, however, California's production moved steadily forward until in 1905 it was the greatest producer among the states of the Union. Its claim to this distinction was short lived, for Oklahoma exceeded it in 1907 and 1908.

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61 Bulls. 212 and 282, U. S. Geol. Survey.
62 Mineral Industry for 1906, New York.
63 Through Story Land to Sunset Sea, H. S. Kneedler, 1898.
64. Mineral Industry for 1908, New York.
65 Through Story Land to Sunset Sea, H. S. Kneedler, 1908.

LESSER FIELDS.

Besides the states mentioned above there are known occurrences of oil or gas, generally both, in fourteen other states which had a combined production of nearly a half million barrels in 1908. Of these Tennessee, Colorado and Wyoming promise best, but there are others of the fourteen which will doubtless prove productive in the near future.

PETROLEUM IN RUSSIA

To go back to the beginning of the history of Russia petroleum and natural gas it seems would be to go back to the very beginning of history itself for the earliest record of man's doings in the Caucasian regions of what is now Russia contain accounts of the use of petroleum as ointments and medicines, and we find the Zoroastrian cult of fire worshippers bowing before "eternal fires" (burning gas emanations) at Baku as early as the sixth century B. C. To even enumerate the early writers who have described the "natural wonders" of the Russian field would make a long and interesting list, but the purpose of this paper forbids its insertion.

EARLY DEVELOPMENT.

Though Baku petroleum has been known and worked from the earliest times it seems that there is no direct evidence of its exportation from the Apsheron Peninsula, on which Baku is built, before the tenth century. Marco Polo[67] about the close of the thirteenth century wrote of a "fountain on the confines toward Georgine, from which oil springs in great abundance." He says that this "oil was used to burn and to anoint mangy camels" and that "people came from great distances to obtain it, for it was the only oil in the country round about."

Thus it appears that Caucasian petroleum was of commercial importance even that early. The industry, however, was carried on in a desultory, oriental fashion until the final wresting of Baku from Persia in 1806. At that time the Russian government granted a merchant named Merzoff a monopoly of the operation of the Baku oil fields. This monopoly was not abolished until 1872, when it was replaced by a government tax which held for five years, after which that, too, was discontinued. The effects of the monopoly and the tax were to limit production and restrain development so that the total production in 1872 was only 1,500,000 poods, roughly 150,000 barrels.

66 For a fuller discussion, see:
Redwood, Petroleum and its Products, Vol. 1, 1906.
Thompson and Redwood, Handbook on Petroleum, 1906.
Henry, J. D., Baku, the Land of Eternal Fire.
Thompson, A. Beeby, The Oil Fields of Russia.

67 The book of Sir Marco Polo, the Venetian, Ed. by Col. Yule, London, 1871.

MODERN DEVELOPMENT OF RUSSIAN FIELDS.

Prior to 1871 the oil in Russia was collected from hand-dug wells and pits, which rarely exceeded fifty feet in depth. During that year, however, a well was drilled on the Balakhany plateau with the result that it was the first of a large number of gushers—pre-eminently the greatest that the world has ever known—and marked the beginning of modern development in the oldest oil field of Caucasian history. The introduction of drilling, followed as it was by the dissolution of the monopoly in 1872, and the removal of the excise tax in 1877, gave great impetus to the modernization of the Russian petroleum industry.

CHAPTER VII.

DISTRIBUTION OF PETROLEUM AND NATURAL GAS.

INTRODUCTION

In order to later serve the purposes of the discussion on the origin of petroleum and natural gas, the subject of distribution is treated from three view points, viz., geographical, as related to physical features and in time and space.

GEOGRAPHICAL DISTRIBUTION[68]

Bitumen in the form of solids, liquids and gases is one of the most widely distributed substances known. There is scarcely any part of the earth where it is not known to be present. Hence petroleum, which seems to be the ultimate source of all natural hydrocarbons,[69] except coal, is necessarily very frequently met with. The occurrence of petroleum and natural gas is not limited by land or sea. They are found equally abundant in the interior of the great continents, along the coasts, and on the islands of the sea. Mariners often report having seen petroleum floating on the surface in mid-ocean, while the burning of escaping gas off the coasts of Texas and Baku is a common spectacle.

PRODUCING COUNTRIES

From the above, it is obvious that the discovery of petroleum or natural gas is by no means always of commercial importance. Though petroleum has been reported from every large island and nearly every country south of the equator there are, at present, only two of those regions (the Eastern Archipelago and Peru) where commercially valuable deposits are being exploited.

Of the grand divisions, North America leads in production with all of its countries producing, except the West Indies and Central America. Europe is second, and procures her yield from Russia, Galicia, Germany, Roumania, Italy and Hungary. The Eastern Archipelago ranks third among the world's producers. All of the commercial petroleum from those islands comes from Borneo, Sumatra, and Java. Asia is fourth with merchantable yields from Japan, India and the Caspian province of Asiatic Russia; while South America was represented among the world's producers in 1908 by Peru only. There are, however, very promising deposits of heavy petroleum in Venezuela, Colombia, Brazil and on the Trinidad Islands. So far, African petroleum deposits are not adding to the world production, but it is believed that the petroliferous strata of the Lake Nyanza region, Gasa Land, Mozambique, Guinea, the Transvaal and the Barbary States may be found productive.

MINOR OCCURRENCES

Besides the productive occurrences mentioned above, there are trustworthy reports of the presence of petroleum or natural gas, or both, in nearly every country of the world. To attempt to describe these ever so briefly would require more time and space than are now available.

DISTRIBUTION AS RELATED TO PHYSICAL FEATURES

In the preceding pages geographical distribution of petroleum and natural gas has been discussed. But since there is a theory concerning the origin of these hydrocarbons based on volcanic activity, and others claiming that they are due to inorganic chemical reactions brought about within the earth at high temperature and pressure, the relation of the great oil fields of the world to regions of vulcanism and former orogenic activities should be noted.

According to the best authority[70] at hand the line of volcanic activity in the Japanese Empire follows near the southeastern coast of the middle island (Yesso) and a little east of the central line of the southern island (Nippon). Saghalien, the northern island, has no volcanoes. Numerous active volcanoes are also found along the southern coast of Nippon. From Japan the line of activity extends southward through the Philippine Islands and the Celebes, and then swings in a broad curve through Java and Sumatra to the northern end of the Malay Peninsula. Borneo is included within the loop, but has no volcanoes and is several hundred miles from any volcanic activity. Mill locates an old volcano at the south end of the Caspian Sea and one at the southeastern extremity of the Black Sea. Dryer shows a line of ancient activity extending from the Sea of Azov in Russia northwestward to the Baltic coast of Germany, thence curving near, and with the trend of the coast, it passes across France into Spain.

In the Western Hemisphere the general trend of the volcanic zone with the western coast is too generally known to need more than passing mention. Dryer shows a line of extinct volcanoes along the eastern slope of the Allegheny Mountains of North America from the Gulf of St. Lawrence to Northern Georgia.

68 For a fuller discussion see, Thompson and Redwood, Handbook of Petroleum, Chap. II., 1906.
69 Orton, Edward, Sr., Ohio Geol. Survey Reports.

70 Mill, the Realm of Nature, p. 90.
Dryer, Lessons in Physical Geography, p. 208.

In Japan, Java and Sumatra the main mountain axes coincide with the lines of greatest vulcanism, and the Himalayas north of India form the great system of Asia. In Europe orogenic forces were most profound in the region of the Swiss Alps and western Austria-Hungary, while the Carpathian and low Caucasian ranges are the eastern expression of the same general movement. On the American continent the coincidence of the line of volcanic activity with the trend of the great mountain ranges of the west is quite noticeable, and the Appalachian Mountains of the eastern United States pass from New York across central Pennsylvania, eastern West Virginia and Tennessee, closely paralleling the chain of extinct volcanoes farther east.

With the above data in mind let us now study the location of the principal petroleum fields of the world and their relation to the regions of volcanic activity and previous orogenic movements.

The oil fields of Japan are found along the west coast of Nippon, the western and southern coast of Yesso and the eastern shores of Saghalien, usually as far removed from the line of volcanic activity as possible.

Of the Eastern Archipelago, Borneo has no volcanoes but has a small mountain system consisting of a chain running northeast-southwest, north of the center of the island, while the petroleum fields lie near the coast along both sides. The principal field of Java extends out to some adjacent islets and is found along the north side of the east end of the main island, and Sir Boverton Redwood[71] after discussing the occurrence of petroleum in Java and the deteriorating effects of volcanic heat on the petroleum in the contiguous oil bearing strata says, "It is scarcely necessary to add that the richest fields are those far remote from volcanic foci." The oil fields of Sumatra are in two widely separated regions; one is along the northeast coast in the plains drained by the Lanksa River; the other is near Palambang in the southeastern end of the island. The former field lies between the low range of mountains which extend about half the length, and near the center, of the island. The latter occupies a comparatively level country drained by the Lalang River.

So far as the authority cited above shows there have never been any active volcanoes in Burma, the oil production of which comes from two general regions. One of these regions is along the west coast, and the other, which is the more prolific, is situated in the valley of the Irawaddy River between two mountain ranges, Pagu Yoma on the east and Arakan Yoma on the west. The Assam fields are near the Brahmaputra River far down the slope of the Himalayan uplift.

The Baku region on the Apsheron Peninsula produces by far the greater part of the Russian oil. This field is removed from any volcanoes, either ancient or recent, but it appears to be near the axis of the Caucasus deformation, which has not resulted in profound crumpling or folding in the petroleum districts.

71 Petroleum and its Products, p. 155.

The Galician fields extend for several hundred miles along the northeastern slope of the Carpathian Mountains. The producing areas have the northwest-southeast trend of the mountains and a few occurrences are known near the crest of the range; but with these few exceptions the entire field is well removed from the region of the greatest mountain making disturbances. The Roumanian and Transylvanian fields occupy the southeastern and southern slopes of the same range of mountains but are generally at considerable distance from the zone of greatest tectonic disturbance.

The German fields are far to the north of the great center of orogenic activity of the Alps, but the petroleum is in strata which have been disturbed by folding.

Turning now to America we find that the Appalachian petroleum field (Pennsylvania, New York, West Virginia, etc.) is well out upon the western slope of the Appalachian uplift. The Lima-Indiana[72] field is far removed from the Appalachian uplift and is little disturbed.[73] The same is true of the Illinois region and none of these fields are in any way connected with regions of recent or ancient vulcanism. In the Mid-Continent field, so far as it is yet developed, the strata all dip uniformly to the west and northwest, away from the Ozark Mountains, at low angles except where they are interrupted by gentle anticlinal folds. Oil has, in no instance, been found in the regions of profound disturbance which begins east of Grand River and extends east into Arkansas. The best production of the field is more than forty miles from the region of faulting and over one hundred miles from the focus of the Ozark Mountains, while volcanic activity, ancient or modern, is unknown to that part of the United States. The petroleum of Texas and Louisiana is found under small quaquaversal domes along the coastal plain of the Gulf of Mexico far removed from either volcanic or great tectonic movements; and the Mexican fields occupy a similar province along the eastern coast of that country.

The California petroleum fields have been divided into ten districts.[74] The entire region extends, roughly, for a distance of two hundred miles northwest-southeast at an acute angle with the coast ranges, and has a maximum width of perhaps one hundred miles.[75] Being thus at an acute angle with the trend of the mountains some of the producing districts are on the coastward slope while others are in the basin around Tulare Lake. From data at hand it appears that the Santa Clara, Los Angeles and Puente Hills are the most highly dis-

72 Includes Ontario for present discussion.
73 Orton, E. Sr., Eighth Annual Report, U. S. Geol. Survey, Part II.
74 See Bull. No. 309, U. S. Geol. Survey.
75 This estimate is of course regardless of barren or undeveloped territory.

turbed of the more important districts of the coastward regions. These fields consist of faulted, over-turned and distorted sedimentaries of Miocene and later ages, besides some Jurassic granites in the Santa Clara district, and a post-Miocene diabase dike less than three quarters of a mile from producing wells in the Puente field. These conditions, however, do not seem to have influenced the accumulation of petroleum.[76]

76 Eldridge and Arnold. Bull. 309, U. S. Geol. Survey, p. 109.

The Peruvian field, it appears, extends from the Gulf of Guayaquil southward nearly two hundred and fifty miles to Point Aguja, and is about one hundred and fifty miles wide, lying between the Andes and the coast. According to Mill's map, already cited, there appears to be a cessation of volcanic activity from latitude fifteen degrees south, north to the vicinity of Quito. It is thus readily seen that Peru procures her oil from an area remote from severe volcanic activity and at a maximum distance from the mountains.

DISTRIBUTION IN TIME AND SPACE[77]

Petroleum and its derivatives, gas and solid bitumen, are among the most widely distributed of known substances. In one form or another members of the petroleum series are reported from every geological age from the Laurentian to the most recent members of the Quaternary formations. If, however, the solid bitumens are omitted the range is narrowed for the oldest reported occurrence of petroleum or natural gas is from the Archean of France where gas is said to emanate in small quantities.

The occurrence of petroleum or natural gas in economic quantities in rocks older than the Potsdam (Cambrian) sandstone is unknown. In fact, the gas from that horizon in the western part of New York is the only known deposit of liquid or gaseous bitumen of commercial importance in rocks older than the Ordovician. Petroleum from Cambrian beds has been reported in Alberta, but its value is not yet known. All the petroleum from rocks older than the Carboniferous is produced in the eastern part of the United States and Canada. The Trenton limestone is the most prolific horizon of Ordovician age as it is the reservoir rock in southern Ontario, Lima-Indiana, and part of the Kentucky and Tennessee fields. The production from the Silurian rocks is much less than from the Trenton. The only regions where valuable deposits of petroleum are reported from Silurian sediments are in the Appalachian fields, the principal occurrence being in New York, Pennsylvania, Kentucky and Tennessee. The data, however, are not as clear on that point as could be wished, and it is

77 See:
Redwood, Petroleum and its Products, 1906.
Thompson and Redwood, Handbook on Petroleum.
Thompson, A. Beeby, Oil Fields of Russia.
Orton, Petroleum, Natural Gas, etc., Kentucky Geol. Survey.

not always possible to determine the exact horizon of production. The amount of oil being obtained from Devonian[78] rocks is much more than from those of Silurian age, but the Devonian production is still far below the yield from Ordovician sediments.

The production of West Virginia is almost, if not quite, wholly from Carboniferous and Upper Devonian rocks. Illinois obtains her supply from beds of Pennsylvanian age as also does the Mid-Continent field. The three fields just enumerated are the only ones where the Carboniferous formations are heavy producers. The Permian rocks are barren in the Mid-Continent regions except some minor deposits at Arkansas City, Kansas; Petrolia, Texas; Ponca City, Blackwell, Lawton, Wheeler and Gotebo, Oklahoma. There is also a qualified statement to the effect that some oil comes from members of that age in Europe, but the Permian, so far as is at present known, is by no means an important petroleum and natural gas horizon.

There are nearly a score and a half of reported occurrences, of bituminous matter of one sort or another in rocks of Triassic or Jurassic age but so far as the writer is able to learn notable amounts of petroleum are not secured from either of these horizons, though some of the oil of Colorado and Wyoming is found in members of one or both of these ages.

The Cretaceous formations on the American continent are productive in Texas, southern Oklahoma, Colorado, Wyoming, Alberta, and probably in a few instances in California; while a portion of the petroleum of Germany, Galicia, Roumania and the Trans-Caspian provinces of Russia, comes from rocks of that age.

The petroleum of the great fields of Russia, California, the Gulf coast, the Eastern Archipelago, Japan, Galicia, Roumania and some of the minor fields, as those of Mexico, Peru, Germany, India, Colorado and Trinidad is being produced from Tertiary rocks. These countries and states are accredited with 58.74 per cent of the world's production in 1908.

Deposits of petroleum and natural gas in the Quaternary and recent sediments are reported but none are of economic importance. Redwood in his work, Petroleum and its Products, reports that collections of organic matter adjacent to the Red Sea are giving rise to oil along the shore, while the occurrence of marsh gas in the swamp regions is a matter of common knowledge.

Thus it is seen that the greater portion of the world's petroleum is being produced from rocks of three geological ages, namely: Tertiary, Carboniferous, and Ordovician, though considerable quantities are obtained from Devonian, Cretaceous, and Silurian rocks,

78 Statistics of 1908.

and in one instance gas is found in the Potsdam of Cambrian age, but in spite of the wide time range of petroliferous strata, the Tertiary rocks are by far the greatest oil and gas producing formations in the world.

This "trio" of principal producing ages gives rise to several very interesting questions, some of which are:

(1) Do those ages in which the greatest deposits of petroleum and natural gas have been found bear evidence of more abundant life?

(2) Do those ages contain a relatively greater per cent of marine strata ?

(3) What are the comparative areal extents of exposed, and therefore explorable, strata of the different ages?

(4) Are the formations of those ages in which petroleum is the less aboundant more highly oxidized than those of the producing strata or not, or is there any perceptible difference?

To make complete answers to the above questions would, it seems, be of value in determining the reasons for the occurrence or non-occurrence of oil and gas in rocks of different ages, but at present such answers are impossible because of the scarcity of data. It appears, however, that an examination of procurable data would not be without profit.

There seems to be no reason to believe that there has been any general diminution of the total aggregate of life during any period since Cambrian times.[79] That is to say, there is evidence of abundant life during Cambrian times and that since then the total amount of organic life perishing during various periods of rock formation has been, comparatively speaking, constant rather than fluctuating rapidly from age to age, or period to period, though there has been a difference in the kind of life. During some stages when terrestrial animal and plant remains only were preserved, the formations are considered subaerial deposits; while during other stages sea weeds and marine animals supplied the organic matter contained in the rocks, and the strata are classed as of marine origin. It seems that it matters little, if the organic theory of origin is correct, whether the deposits were formed on land or under sea so long as organic matter, eithcer animal or vegetable, was buried in large amounts during sedimentation.

According to the best data[80] available it appears that the sediments from the beginning of Cambrian times until the close of the Pennsylvanian period were, in the main, marine. The deposits of the Permian were generally sub-aerial with the exception of one inundation in western North America and probably the northern extension of the Mid-Continental region. The rocks of Triassic age are, as a rule,

79 The writer wishes to again acknowledge the personal assistance of Prof. Schuchert, of Yale, in making these generalizations.
80 Idem.

non-marine, and those of the Jurassic are perhaps more predominately so. The Cretaceous beds were to a great extent formed in the sea, but rocks of Tertiary age bear evidence of a greater per cent of sub-aerial deposits than any other of the main geologic periods.

A rough estimate, for at best it is only such in the light of present data, shows that the areal extent of rocks of the various ages stands approximately in the following relations to each other:

First, Carboniferous,
Second, Ordovician,
Third, Devonian,
Third (a)[81], Cretaceous,
Fourth, Silurian,
Fifth, Cambrian,
Sixth, Triassic,
Sixth (a)[82], Jurassic,
Seventh, Tertiary.

Thus it appears that of the Paleozoic eon the Carboniferous and Ordovician rocks are most widely exposed at the surface. It will also be seen that these two ages rank first and second, respectively, in the production of petroleum and natural gas from rocks of pre-Mesozoic age, while the Devonian, Silurian and Cambrian which respectively rank third, fourth, and fifth among the older formations, in the production of oil and gas, also hold those serial positions in the table of comparative areal exposures. The Cretaceous formations, which are nearly equal in extent to those of Devonian age, were, in 1908 far greater producers of liquid and gaseous hydrocarbons than the Devonian rocks.

The Triassic and Jurassic beds, which rank sixth in area, yielded little petroleum in 1908; while the Tertiary rocks which have a less superficial exposure than those of any other age, yielded the major part (58.74 per cent) of the world's oil in that year.

A high degree of oxidation of a formation is indicated by the red color due to the presence of ferric oxide in the rocks. Oxidation of rock formations may occur in two ways: first, by an absence of organic matter at the time of deposition; second, by superficial weathering. Thus if a series of beds is red throughout, the fact points to a dearth of organic remains entombed in the rocks, but not necessarily to a scarcity of life; for the conditions necessary to mix the organic matter with the sediments and preserve it—thus preventing oxidation—may have been poor. There was, therefore, no organic matter deposited in red rocks from which petroleum could be formed*; and "red beds" are necessarily non-petroliferous unless petroleum has been introduced from adjacent strata.

81 That is are equal to Devonian in extent.
82 That is are equal to Triassic.

* The question of origin is unavoidably anticipated here. For complete discussion see Chapter IX., of this report.

Superficial oxidation due to weathering and rock decomposition can occur only after a region has been elevated above sea and is effective only to limited depths, so that it can have no influence whatever on the deep seated petroleum making processes.

So far as data at hand show, "red beds," except an occasional stratum, are not found from Cambrian to upper Carboniferous, Permian, times. The Catskill formation of Devonian age in Pennsylvania and West Virginia is sometimes called "red beds" but the conditions there are vastly different from those which obtain in the Permian and often in Triassic and Jurassic. White[83] describes the contrast as follows:

I note what you say with reference to the barren (of oil and gas) condition of the Redbeds of Oklahoma. As I understand the matter, these strata are all red—sandstones, shales, and everything—which is a condition quite different from that occurring in the Catskill Redbeds. Here only the shales are red and some even of them are dark or gray, while the conglomerates and sandstones are almost invariably white and always contain more or less organic reamins when they crop to the surface. One of these conglomerates I have studied in detail where it is a surface rock and even yet contains much oil in the vicinity of LeBoeff Station, Erie County, Pa. This is fully described in my Report Q4 of the Pennsylvania Geological Survey, to which you doubtless have access. I recognized in it there not only abundant animal remains, but also land plants as well as marine plants. The same sandstone or conglomerate is frequently filled with great numbers of fish remains. Hence, I have always held to the organic origin of oil and gas and I think that most of it is indigenous to the sands themselves where it is now found instead of having ascended into it from shales or other strata below.

The Permian of Oklahoma and Texas is uniformly red, non-fossiliferous, non-petroliferous. These conditions also obtain in the Permian in parts of Europe and often the Triassic and occasionally the Jurassic occur in a highly oxidized state, but the Cretaceous and Tertiary are seldom if ever so. The presence of so much red color in Permian, Triassic and Jurassic rocks is positive proof that little or no organic matter was deposited in them, and it therefore appears that there must be some genetic relation between the absence of organic remains and the non-presence of petroleum in these highly oxidized beds.

Since petroleum and natural gas are very volatile substances it is quite obvious that even though the rocks of early geologic times, which have been exposed to weathering for ages, had been highly petroliferous at the time of their elevation the opportunity for escape afforded by exposure would have been so great that the available supply would be nearly or quite exhausted by the present time. The chances for the preservation of petroleum until the present are, therefore, very poor in old, weathered and altered rocks, or in regions of a later age where unconformities are frequent.

Finally, then, we may say that the abundance of petroleum in the rocks of a given geologic age does not appear to depend so much on a more abundant life, on a predominence of marine sediments, or on a wide areal extent of exposed rocks, as it does on favorable conditions for the preserval of organic matter, on the recentness of the disturbance which brought the rocks to or near the surface, and on the continuity of sedimentation.

83 White, I. C., Personal letter to the author dated Jan. 24, 1910.

CHAPTER VIII.

CHEMISTRY OF PETROLEUM AND NATURAL GAS.[84]

INTRODUCTION

It is not the present purpose to enter into a detailed chemical discussion of petroleum and natural gas, but to deal in a general way with those features of the subject which are germane to the treatment of the question of origin as discussed later. So after making brief mention of a few of the properties of these substances, together with their common impurities we shall pass to a study of the members of the hydrocarbon series most commonly found in petroleum and natural gas.

COMPOSITION OF PETROLEUM AND NATURAL GAS

INTRODUCTION.

Petroleum and natural gas are supposed by many laymen to be definite chemical compounds. More exactly, however, they are intimate mechanical mixtures of a great variety of chemical compounds known as hydrocarbons with which impurities of different kinds and in varying amounts are associated. The most common impurities are oxygen, nitrogen and sulphur, often as gases. These elements are usually in a state of combination either with members of the hydrocarbon series, as $C_{12}H_{17}N$, $C_7H_{14}S$ etc., but sometimes occur as independent compounds, as H_2S, SO_2 etc., or even in a free state, as in sulphur in some of the oil at Beaumont, Texas.[85]

THE HYDROCARBONS IN PETROLEUM AND NATURAL GAS.

Primarily hydrocarbons naturally form a number of regular series to each of which a generalized formula has been given according to the following scheme:

1. C_nH_{2n+2}
2. C_nH_{2n}
3. C_nH_{2n-2}
4. C_nH_{2n-4}
5. C_nH_{2n-6}
6. C_nH_{2n-8}
7. C_nH_{2n-10}
8. C_nH_{2n-12}

. . . .

18. C_nH_{2n-32}

84 For fuller discussion, see:
Redwood, Petroleum and its Products, p. 244 et seq.
Clark, F. W., The data of Geochemistry, Bull. U. S. Geol. Survey No. 330.
Peckham, S. F., History of Petroleum, Vol. X., Tenth census, United States.

85 Redwood, Petroleum and its Products.

Members of the first eight series have been discovered and identified in petroleum but those of the first, second and fifth are most often present in appreciable amounts. These are respectively known as the paraffin, the olefine and the benzine series. Clark,[86] in his Data of Geochemistry says, speaking of the first eight members of the hydrocarbon series:

> These expressions, however, have only a preliminary value, although they are often used in the classification of petroleums. Each one represents a group of series—homologous, isomeric, or polymeric, as the case may be—and for precise work these must be taken separately. The first formula, for example, represents what are known as the paraffin hydrocarbons, which begin with marsh gas, or methane, CH_4, and range at least as high as the compound $C_{35}H_{72}$. Even these are again subdivided into a number of isomeric series—the primary, secondary, and tertiary paraffins—which, with equal percentage composition, differ in physical properties by virtue of differences of atomic arrangement within the molecules. Each member of the series differs from the preceding member by the addition of the group CH_2, and also by the physical characteristics of greater condensation. Methane, CH_4, for example, is gaseous; the middle members of the series are liquids, with regularly increasing boiling points; the higher members are solids, like ordinary paraffin.

PARAFINS IN PETROLEUM AND NATURAL GAS

The paraffin series of hydrocarbons is especially characteristic of Pennsylvania petroleum, from which many members of the series have been separated and identified.

Paraffins from Pennsylvania Petroleum.

Name.	Formula.	Melting point. °C	Boiling point. °C
1. Gaseous:			
Methane	CH_4	-186	-164
Ethane	C_2H_6	-172.1	- 84.1
Propane	C_3H_8	......	- 37
Butane	C_4H_{10}	......	+ 1
2. Liquid:			
Pentane	C_5H_{12}	......	37
Hexane	C_6H_{14}	......	69
Heptane	C_7H_{16}	......	98
Octane	C_8H_{18}	......	125
Nonane	C_9H_{20}	- 51	150
Decane	$C_{10}H_{22}$	- 31	173
Endecane	$C_{11}H_{24}$	- 26	195
Dodecane	$C_{12}H_{26}$	- 12	214
Tridecane	$C_{13}H_{28}$	......	......
Tetradecane	$C_{14}H_{30}$	+ 4	252
Pentadecane	$C_{15}H_{32}$	......	......
Hexadecane	$C_{16}H_{34}$	18	......
3. Solid:			
Octodecane	$C_{18}H_{38}$	......	......
Eisosane	$C_{20}H_{42}$	37	......
Tricosane	$C_{23}H_{48}$	48	......
Tetracosane	$C_{24}H_{50}$	50- 51	......
Pentacosane	$C_{25}H_{52}$	53- 54	......
Hexacosane	$C_{26}H_{54}$	55- 56	......
Octocosane	$C_{28}H_{58}$	60	......
Nonocosane	$C_{29}H_{60}$	62- 63	......
Hentriacontane	$C_{31}H_{64}$	66	......
Dotriacontane	$C_{32}H_{66}$	67- 68	......
Tetratriacontane	$C_{34}H_{70}$	71- 72	......
Pentatriacontane	$C_{35}H_{72}$	76	......

To the above Redwood[87] adds the isomeric secondary paraffins: isobutane, isopentane, isohexane, isoheptane, isooctane, and the solid paraffins, $C_{27}H_{56}$ and $C_{30}H_{52}$.

86 Clark, F. W., Data of Geochemistry, Bull. U. S. Geol. Survey, No. 330, 1908, p. 619.
87 Redwood, Petroleum and its Products, p. 229.

Natural gas is composed almost entirely of the gaseous paraffins, but usually contains very subordinate amounts of impurities, such as olefine gases, carbon-dioxide, oxygen, nitrogen, helium and often hydrogen sulphide. In six samples of West Virginia gas, analyzed by C. D. Howard[88] in 1904, there was an average of 95.02 per cent of paraffin gas of which 81.75 per cent was methane while the gases of the heavier hydrocarbons (olefine etc.) averaged only 0.25 per cent.

The following table compiled by F. W. Clark[89] gives a more general notion of the composition of natural gas. (The parentheses are the author's.)

Analyses of Natural Gas.

A. From Creighton, Pennsylvania.
B. From Pittsburg, Pennsylvania.
C. From Baden, Pennsylvania.
D. From Vancouver, British Columbia.
E. Mean of four Indiana and three Ohio gases.
F. From Osawatomie, Kansas.

	A.	B.	C.	D.	E.	F.
CH_4 (methane)	....	....	....	....	93.36	97.63
Parafins[1] (C_nH_{2n+2})	96.36	98.90	87.27	93.66	....	....
C_2H_4, etc. (olefine gases)	....	....	....	....	.28	.22
CO	....	....	....	....	.53	1.32
CO_2	3.64	.40	.41	.14	.25	.22
H_2	none	none	none	none	1.75	none
N_2	none	.70	12.32	6.30	3.28	.60
H_2S	none	none	none	none	.18	....
O_2	none	none	none	none	.29	trace
	100.00	100.00	100.00	100.00	99.93	100.00

1 Largely methane.

Besides the constituents of natural gas ordinarily reported Cady and McFarland[90] of Kansas have reported helium from a large number of gases from various parts of the United States. The following table represents the average composition of thirty-seven gases from Kansas, Oklahoma and Missouri, and seven from other parts of the country.

88 West Virginia Geol. Survey Report, Vol. 1 (a), p. 556.
89 Clark, F. W., Data of Geochemistry, Bull. U. S. Geol. Survey No. 330, p. 621.
90 Cady and McFarland, University Geol. Survey of Kansas, Vol. IX., 1909, p. 271.

Abstract of Analyses by Cady and McFarland.

	Oxygen	Carbon dioxide	Olefine	Carbon-monoxide.	Methane.	Ethane.	Total Paraffins CH_4+	Hydrogen	Helium	Nitrogen
Formula	O_2	CO_2	C_2H_4 etc.	CO	CH_4	C_2H_4	C_2H_4	H_2	He	N_2
No. of samples tested for	37.00	33.00	37.00	37.00	37.00	37.00	37.00	37.00	36.00	37.00
No. of traces[91] only	8.00	.00	.00	.00	.00	.00	.00	3.00	1.002	.00
No. absent from	5.00	11.00	15.00	32.00	.00	21.00	....	27.00	.00	.00
Maximum per cent	0.05	1.94	1.20	0.30	98.06	11.95	....	0.39	1.84	82.87
Minimum per cent	trace	0.10	0.10	0.10	14.33	0.36	....	trace	0.0093	0.88
Average per cent of in tests made	0.129	0.448	0.219	0.024	83.646	1.920	85.566	0.036	0.367	13.259
Average of all analyses	100.048	per cent.								
Gases from other states.										
Butler, Ohio	0.05	0.00	0.40	0.00	70.00	16.75	86.75	0.27	0.15	12.38
Marion, Ind.	0.00	0.73	0.86	0.00	77.40	14.18	91.58	0.00	0.167	6.66
Morgantown, W. Va.	0.00	0.24	0.65	0.00	88.10	7.37	95.47	0.25	0.09	3.60
Jennings, La., (some air in sample)	1.81	1.80	0.80	0.40	88.40	1.03	89.43	....	trace	5.76
Los Angeles, Cal., (some air in sample)	2.86	6.68	0.20	0.25	83.70	0.00	83.70	....	0.00	6.31
Gas from coal mine, Scranton, Pa.	0.92	1.06	0.39	0.13	94.2	0.00	94.20	0.00	trace	3.31
Pierre, S. Dak.	3.19	1.14	0.25	0.00	73.2	0.00	73.20	....	trace	21.7
Same corrected to air—free gas	0.00	1.35	0.29	0.00	86.50	0.00	86.50	....	trace	11.86

91 A trace of a substance is here counted as 0.005 per cent.

OLEFINES IN PETROLEUM

The hydrocarbons of the general formula, CnH2n, are quite as important in petroleum as the paraffins. Some of the olefines which have been separated from petroleum are given in the following list.[92]

Some Olefines in Petroleum.

Name.	Formula.	Melting point.	Boiling point.
1. Gaseous:			°C
Ethylene	C_2H_4	......	-103
Propylene	C_3H_6	......	- 18
Butylene	C_4H_8	......	- 5
2. Liquids:			
Amylene	C_5H_{10}	......	+ 35
Hexylene	C_6H_{12}	......	68
Heptylene	C_7H_{14}	......	98
Octylene	C_8H_{16}	......	124
Nonylene	C_9H_{18}	......	153
Decylene	$C_{10}H_{20}$	......	172
Undecylene	$C_{11}H_{22}$	......	195
Duodecylene	$C_{12}H_{24}$	......	216
Tridecylene	$C_{13}H_{26}$	......	232
Cetene	$C_{16}H_{32}$	......	275
———	$C_{20}H_{40}$	......	......
Solid:			
Cerotene	$C_{27}H_{54}$	65- 66	......
Melene	$C_{30}H_{60}$	62	......

Besides the above, many other heavy hydrocarbons are reported, as for example Maybery and Palm[93] found four of the higher members, C14H36, C21H40, C22H42 and C24H46, of the CnH2n—2 group. The members of the CnH2n series as high as C17H34 were found, as also were members of the CnH2n—4 series—namely C23H42, C24H44, and C25H46, while some California petroleums have been shown to contain these and members of the CnH2n—8 series.

BENZINE IN PETROLEUM

The "Aromatic" or the benzine series (CnH2n—6) of hydrocarbons, it seems, has been detected in nearly all petroleums[94], but usually in relatively insignificant amounts It is sufficient for the present purpose only to know that they are common constituents of rock oil. Their empirical formulae, neglecting the isomeric compounds, are as follows:

Benzine	C_6H_6
Toluene	C_7H_8
Xylene	C_8H_{10}
Cumene	C_9H_{12}
Cymene	$C_{10}H_{14}$
etc.	

92 Hoefer, H., Das Erdol, p. 65.
93 American Chemical Journal, Vol. 33, 1905, p. 251.
94 Clark, F. W., Data of Geochemistry, Bull. U. S. Geol. Survey No. 330, 1908, p. 628.

CHAPTER IX.

THEORIES OF ORIGIN.[95]

INTRODUCTION

As a consequence of the great economic importance which petroleum and natural gas attained a little more than a quarter of a century ago, and have held ever since, the question of their origin[96] is an ever recurring one. It seems therefore that a review of the most important theories of origin would be interesting.

Even as early as 1804 Humboldt propounded the hypothesis that oil was distilled by volcanic action from the strata at great depths; but whether he considered that it was distilled from organic remains, or that it was the result of inorganic reaction, is not stated. Reichenbach writing thirty years later advanced the theory that it is formed by the action of subterranean heat on the turpentine of the pine trees. These theories, it seems, received little or no support.

In 1886, Berthelot, the noted French chemist, advanced a theory to account for the origin of petroleum and natural gas by means of inorganic chemical reactions. About the same time, T. Sterry Hunt, of Canada, and J. S. Newberry, advanced the theory that the natural hydrocarbons were formed from organic matter stored in the rocks at the time of their deposition. This gave two theories of origin, namely: the organic and the inorganic which, with some modifications, still obtain.

INORGANIC THEORIES

The inorganic theories have been divided to two classes: the chemical and volcanic. The volcanic theory is only one phase of the chemical theories, but since its author, Eugene Coste, proposes it as an independent mode of origin it will be stated as such, but discussed with the other inorganic theories.

Let us now make a brief study of the laboratory observations on which the inorganic theories are based.

95 Quite a complete discussion of the theories of origin are to be found in:
Orton, E. Sr., Occurrence of Petroleum, natural gas and asphalt rock in west Kentucky, Kentucky Geol. Survey, 1901, pp. 27-61.
Orton, E. Sr., Eighth Ann. Rept. U. S. Geol. Survey, pt. 2, pp. 488-506.
Redwod, Sir Boverton, Petroleum and its Products, 1904, pp. 251-261.
Peckham, F. S., Tenth Census U. S., Vol. X., pp. 59-74.
Moissan, The electric furnace, 1904, pp. 260-264.
Clark, F. W., Data of Geochemistry, Bull. U. S. Geol. Survey, No. 330, 1908.

96 Prof. Orton, in Petroleum, Natural Gas and Asphalt Rock in West Kentucky, Ky. Geol. Survey, has shown that petroleum is, beyond reasonable doubt the original source of natural gas and solid bitumens; so in this discussion the origin of petroleum will include gas and solid bitumen.

CHEMICAL THEORIES.

DATA FOR CHEMICAL THEORIES

It has been shown that when cast iron is dissolved in acid hydrogen is evolved. There are present, however, impurities which were early recognized as being akin to hydrocarbons, and H. Hahn, in 1864, attempted their identification. He separated them by fractional distillation and collected the gas in bromine. In this way he found organic bromides of the general formula, $C_nH_{2n}Br_2$, in which the olefine hydrocarbons were present from C_2H_4 to C_7H_{14}. By treating spiegeleisen in the same manner Hahn obtained olefines up to $C_{16}H_{32}$. S. Closz[1] conducted a series of experiments from 1874 to 1878 by allowing either hydrochloric or sulphuric acid to act on large quantities of spiegleisen: be collected the hydrogen vapor by direct condensation and as bromides, then separated them by fractional distillation and identified the distillates. In this way Closz, obtained the olefine, C_8H_{16} and the bromo-olefines, $C_7H_{13}Br_2$ and seven paraffins, $C_{10}H_{22}$ up to $C_{16}H_{34}$.

Moissan, in his experiments with the electric furnace has made and investigated nearly or quite a score of carbides,[97] together with hydrocarbons obtained by treating the carbides obtained with different reagents. For the purposes of this paper it is necessary to consider only those hydrocarbons produced by the action of water on the carbides, because water is the reagent most likely to come into contact with metallic carbides if they exist within the earth.

By inspection of Moissan's results we find that:

(1) The carbides of lithium, sodium, potassium, calcium, strontium and barium, treated with water, yield acetylene, C_2H_2.

(2) The carbides of aluminium and glucinum yield principally methane, CH_4.

(3) The carbide of manganese yields a mixture of methane and hydrogen.

(4) The carbides of yttrium, lanthanum, cerium, thorium and uranium yield mixtures of acetylene, methane, ethylene, and hydrogen. The cerium, lanthanum and uranium compounds also yield some liquid and solid hydrocarbons. From four kilograms of uranium carbide Moissan obtained one hundred grams of liquid hydrocarbons, consisting largely of olefines, with some members of the acetylene series and some saturated, that is paraffin, compounds.

The above proves beyond any doubt that hydrocarbon compounds, such as are found in the petroleum series, can be produced by the reaction of water on carbides of both metals and alkalies. If LaPlace's nebular hypothesis of earth origin is the correct one, then carbides, silicides, nitrides, etc., would be among the first compounds

97 Closz, S., Compt. Rend. Vol. LXXVIII., p. 1003, 1877: Vol. LXXXVI., 1878, p. 288.

2 Moissan, The electric furnace, Lehner's trans. p. 200 et seq.

formed, and oxidation could not take place until later. If these compounds were formed, some of them may have existed in the rocks for long geologic times and may still exist at great depths and if encountered by water, hydrocarbons would inevitably result. The theories are possible, but can they be proved, or can it be shown that any considerable amount of the world's petroleum has beyond reasonable doubt, been formed in that manner?

VOLCANIC THEORY.

STATEMENT OF THE VOLCANIC THEORY

The volcanic theoy, as stated by Coste assumes that all petroleum and natural gas, except escaping marsh gas, are formed by the entrapping of volcanic or magmatic emanations from abysal igneous masses. It seems that he assumes that these masses are continually exerting a great upward pressure on the overlying sediments and that the emanating gases possess the power to penetrate the earth crust for an indefinite distance, through all kinds of strata, and with sufficient force to dome up areas, as at Beaumont, Texas, and Sour Lake and Jennings, Louisiana, and make for themselves reservoirs. It appears that he believes volcanic activity to be due to the beaking out of gaseous emanations, which if held in, would have formed petroleum and natural gas fields. He also attributes the impurities, as sulphur, nitrogen, carbon dioxide, etc., to volcanic origin, as well as much of the saltiness of the waters encountered, and the gypsiferous character of the calcareous rocks occasionally met with in these fields.

STATEMENT OF THE CHEMICAL THEORIES

There have been a large number of theories proposed to account for the inorganic origin of petroleum and natural gas, but those which have received the greatest support were suggested by Berthelot, Mendeljieff, Moissan, and Sakoloff: while a hypothesis proposed by O. C. . Ross in 1891 deserves mention, because of its uniqueness.

BERTHELOT'S THEORY.

As was stated in the beginning of the chapter, the first of the chemical theories was proposed by the eminent French chemist, Berthelot, in 1866. Many writers have, at different times ,made brief statements of this theory but the best discussion at hand is that by Edward Orton,[98] which is as follows:

He (Berthelot) supposed the alkali metals, namely: potassium and sodium, to exist in the interior of the earth in a free uncombined state, and, necessarily at high temperatures. If, now, water, carrying in solution carbonic acid—and the crust of the earth abounds in both—should find access to these metals he pointed out the steps of the chemical action that must take place, and that would result in a series of hyrocarbon compounds. In this case the process of oil and gas formation would be deep seated and continuous, the reactions that give birth to them being constantly renewed in the recesses of the earth.

98 Orton, Edward, Petroleum, natural gas and asphalt rock, Ky. Geol. Survey, 1891.

MENDELJIEFF'S THEORY.

The next in importance among the chemical theories is the one proposed by D. Mendeljieff, a Russian chemist of high repute. The theory is substantially as follows: He assumes that since the center of the earth is much more dense than the outer shell, it must consist of metals. And the facts that iron carbide is found in meteorites and iron is known to exist in the solar system (the latter as shown by the spectroscope) and that basalts and some other eruptive rocks contain relatively high per cents of iron, were, in his opinion, powerful arguments in favor of his theory that the interior of the earth contains large amounts of iron—necessarily at high temperature and under great pressure—either free or as carbides. It seems, however, that Mendeljieff was of the opinion that much of the iron, as well as many other metals, are present in the carbide state.[99]

MOISSAN'S THEORY.

Due to his experiments with the electric furnace,[100] Henry Moissan, a French chemist, came to the conclusion that petroleum is, in the main, of purely chemical origin in certain places. To put it clearly, Moissan is quoted as follows:

There are probably petroleums of different origins. At Autun, for example, the bituminous schists appear to have been produced by the decomposition of organic matter........

We have shown with calcium carbide, under what conditions this compound can be burned and give carbon dioxide. It is probable that in the first geological periods of the earth, nearly all the carbon existed as metallic carbides. When water intervened the metallic carbides gave hydrocarbons and the latter by oxidation, carbon dioxide. An example of this reaction can be found in the neighborhood of Saint-Nectaire. The granites, which form in this place the border of a Tertiary basin, continually give off large quantities of carbon dioxide gas.

We believe also that certain volcanic phenomena can be attributed to the action of water on the easily decomposable metallic carbides. Geologists know that the last manifestation of a volcanic center consists of the emanations of the various hydrocarbons becoming asphalt and petroleum and finally, as a complete oxidation product, carbon dioxide.

A movement of the crust produced by the action of water on the metallic carbides can produce a violent evolution of gases; at the time the temperature is raised the phenomenon of polymerization of the carbides intervenes to furnish an entire series of complex products.

Hydrocarbons can then be produced at first. The phenomenon of oxidation appears and complicates the reatcions. In certain places a volcanic fissure acts as a powerful vent. It is known that the nature of the gas collected from fumaroles varies if the volcano is submerged in the ocean or sunrrounded by atmospheric air. At Santorin, for example, Fouque' collected free hydrogen in the mouths of submarine volcanoes; while only water vapor is formed in aerial fissures.

These carbides exist at high temperatures and probably exist in the depths of the earth, in which case their decomposition would explain the formation of solid, liquid, and gaseous hydrocarbons, and possibly the cause of some volcanic eruptions.

99 Orton, Edward, Petroleum, natural gas and asphalt rock, Ky. Geol. Survey, 1891, p. 32.

100 Moissan, The electric furnace, Lehners translation, pp. 260-264 in part.

SOKOLOFF'S THEORY.

N. V. Sokoloff, a Russian geologist, in 1890 argued that all bitumens are of cosmic origin: that is that they were formed initially during the consolidation of the earth, and enclosed within the primal magma, from which they have since been transferred to the outer layers where they appear as petroleum, natural gas, etc.

ROSS' THEORY.

The inorganic theory proposed by O. C. D. Ross,[101] as stated by Redwood,[102] is as follows:

At the meeting of the British Association in 1891 O. C. D. Ross advanced a theory that petroleum is a product of the action of volcanic gases upon limestones. He partly founded his theory on the observation of Bischoff, that sulphur has been obtained in laboratory experiments by the action of chalk on hot volcanic gases (sulphurous acid and sulphuretted hydrogen) and assumes that such action would further produce both olefines and paraffins, with a separation of sulphur and a conversion of the calcium carbonate of chalk into gypsum.

This hypothesis will receive no further mention, because it was not proven even experimentally.

Such are the statements of the various inorganic theories which have received recognition and comment. Of the authors of these theories, Berthelot, Medelhieff, and Maoissan attempt to prove the formation of hydrocarbons in the deep interior, and base their conclusions on laboratory experiments; while Sokoloff and Coste assume the presence of hydrocarbons within the earth, and attempt to account for their transmission to, or near to the surface. Obviously then, these so-called theories are only different phases of the same theory, and in many respects have similar objections, which will be advanced later.

DISCUSSION OF INORGANIC THEORIES

If petroleum is of inorganic origin as proposed by any of the above theories, then it seems to follow:

(1) That the great oil fields of the world should be located in or very near regions of great magmatic intrusions and vulcanism.

(2) That the decadent stages of volcanoes should be marked by a great production of petroleum and solid bitumens.

(3) That all volcanic pipes and craters should be notable sources of supply of the solid hydrocarbons.

(4) That all great fault lines should be notable sources of supply of hydrocarbons regardless of whether the fault is through bituminous strata or pure crystallines.

(5) That the gases escaping from active volcanoes should contain a relatively high per cent of the natural hydrocarbons.

(6) That all limestones subjacent to oil fields should be gypsiferous, at least in the immediate region of the petroleum field.

(7) That pegmatite dikes should always contain appreciable amounts of bitumen.

101 Report of British Association, 1891, p. 639.
102 Redwood, Sir Boverton, Petroleum and its Products, Vol. I., p. 253.

(8) That the passage of water to the depths of intense heat, at least 300° C., should be a common phenomenon.

It has already been shown in this report under "Distribution as Related to Physical Features," that the world's great oil fields are well removed from regions of plutonic activity. Even on the island of Java the producing regions are as far removed from volcanoes as possible, and the petroleum in the strata near the center of atcivity has been destroyed by—rather than formed by—the proximity of magmatic rocks and internal heat.

In past years the famous "pitch lake" of Trinidad has been cited as an example of bitumen formed in the decadent stages of volcanic activity and has doubtless lent great strength to the inorganic theories in the minds of many of their supporters. Clifford Richardson,[103] however, has shown that the lake occupies the crater of an old mud volcano, and none of the true volcanoes of the world are reported as having at any time presented such a phenomenon.

Clark[104] in his Data of Geochemistry, states that the "pitch" at Trinidad is an emulsion of water, gas and bitumen with some other organic substances and mineral matter; thus he seems to think that the bitumen is organic in its origin. According to Redwood[105] it has been shown that the raw Trinidad bitumen consists of 33 per cent fine clay and vegetable matter, and 33 per cent water, but he does not say of what the remainder is composed. He further states that Wall[106] has reported that strata, which were originally shales rich in vegetable matter, contain bitumen in situ at some distance from the lake. Wall also states that the plant remains have undergone "a special mineralization, producing a bituminous matter instead of coal or lignite." This operation he says, is not attributable to heat, and also mentions that pieces of partly bituminized wood come from the same region. The island is composed of sedimentary rocks rich in oil and gas, as is seen from the following extract from a writer in that region:

Deposits of asphaltic pitch, and strong discharges of gas and oil occur in the southeast corner of the island, where the upper Miocene rocks occupy most of the surface, the lower part of the series, which is the richer in these hydrocarbons, being visible only on parts of the anticlinal axes.

However, in 1897 Peckham[107] studied the occurrence of plant remains within the Trinidad "pitch" and determined it to be exactly the same as that in the lignite bed near the lake, thus making it seem that Wall was mistaken in his former conclusions. The fact, however, remains that there are no indications that Trinidad is a true volcanic island and from all obtainable data it seems that the rocks of the region are all fossiliferous sediments which are uniformly rich in

103 Richardson, Clifford, Jour. Sci. Chem. Ind., Vol. 17, 1898, p. 13; and Rept. Inspector of Cement, Washington, D. C., 1892.
104 Clark, F. W., Data of Geochemistry, etc., Bull. U. S. Geol. Survey No. 330, 1908, p. 626.
105 Redwood, Sir Boverton, Petroleum and its Products, Vol. I., pp. 97 and 254-255.
106 Redwood, Sir Boverton, Petroleum and its Products, p. 186.
107 Peckham, Proceedings American Philosophical Society, Vol. 36, 1897, p. 105.

bituminous matter. Because the bitumen is associated with saline thermal waters and solfaturic gases, does not imply a genetic relation. Since the strata in other parts of the island are also rich in heavy petroleum, it seems rather to point to the fact that the hot waters, which may be heated by a deep seated mass of magma, or by chemical reaction, act as agents of transportation by rinsing the petroleum and asphalt from the strata in which they were formed and bringing them to the surface in quantities.

So far as data at hand shows, asphalt and other solid bitumens are not found in merchantable quantities around old volcanic pipes and craters, but more often occur along limited fault planes[108] which have cut through petroleum deposits. The best examples of these phenomena the writer has examined are the rock asphalt deposits of Oklahoma, where the wall rocks are saturated with bitumen for several feet on either side of some of the faults while other occurrences are plainly the result of exposure, by erosion, of oil bearing strata. The same conditions obtain in the rock asphalt deposits of other states.[109] The asphaltites invariably occur as vein filling deposits in sedimentary rocks and so situated that the vein material is easily referable either to the petroliferous country rock or to a nearby known petroleum bearing horizon. No commercial supply is known to occur in igneous or metamorphic rocks. The faults along which rock asphalt and asphaltites occur are few when compared with the total number in the world, and are therefore the exceptions. Whereas if the natural hydrocarbons originated by either the volcanic or carbide process, or the two combined, all of the older extensible faults should be caches for asphaltites, later ones should contain some asphaltite and have an abundance of associated rock asphalt, while the youngest large faults should be notable vents for limitless amounts of liquid and gaseous hydrocarbons (still in the process of forming within the sub-sedimentary igneous laboratory) regardless of whether they cut crystalline or sedimentary rocks. The facts are, however, that large amounts of asphalt, petroleum or natural gas *do not occur save in sedimentary rocks.* Then too, when petroliferous strata adjacent to asphaltite veins have been explored by the drill their petroleum and gas content is found to have been depleted for hundreds of feet on either side of the vein,[110] whereas if the strata had received their petroleum through the fissure vein the petroliferous content should increase on approaching the vein.

If the natural hydrocarbons are of volcanic origin the gases escaping from active volcanoes and their fumaroles should, beyond

108 See Part I. of this report.

109 Eldridge, Geo. H., Asphalt and bituminous rock deposits of the U. S.; Twenty-second Ann. Rept. U. S. Geol. Survey pt. 1, 1901, pp. 219 et seq.

110 Eldridge, Geo. H., West Virginia grahamite: Twenty-second Ann. Rept. pt. 1, 1901, p. 237.

doubt, contain such high per cents of those gases that there could be no possibility of their arising from destructive distillation of bituminous strata adjacent to the pipe.

Many careful analyses of volcanic emanations have been made from time to time. These are, however, as a rule poor in hydrocarbon gases as is shown from the following analyses taken from Clark's Data of Geochemistry.[111]

Analyses of Gases from Vulcano.

A. Gas from the crater issuing at a temperature above the melting point of lead. This fumarole deposits boric acid. The gas was collected from a vent which emitted flame.

B. A gas similar to the foregoing, but not accompanied by boric acid.

C. Sulphurous fumarole from the north flank of Vulcano.

D. Gas from a cavity filled with hot water, known as "Aqua-Bollente,' and situated near the seashore.

E. Gas from depressions still farther from the crater, collected over water having a temperature of 25° C.

	A.	B.	C.	D.	E.
CO_2	none	none	none	6.4	86.0
SO_2	39.13	27.50	69.6	....	....
H_2S	....	....	....	83.1	....
O_2	10.10	14.02	5.5	.7	none
N_2	50.77	58.48	24.9	9.8	14.0
	100.00	100.00	100.00	100.00	100.00

Analyses of Volcanic Gas from Santorin.

A. Gas taken May 4, 1886, from bottom of a fissure on Nea Kameni. Collected over sulphurous water, at temperature 56°.

B. Collected May 12, 1866, at the foot of the cone Giorgios, from a small fumarole surrounded by crystals of sulphur. Temperature 87°.

C. Like B and near it, the sulphur partly crystallized and partly fused. Temperature 122°.

D. Gas from periphery of eruptive field, March, 1867.

E. Gas collected near the port of St. George of Nea Kameni, March 9, 1867.

	A.	B.	C.	D.	E.
H_2S	trace	0.42	0.90	....	....
CO_2	95.37	5.88	12.24	none	56.63
O_2	.49	18.99	16.41	20.62	1.84
N_2	4.14	74.71	70.45	79.38	41.41
CH_4	....	....	....	....	.12
	100.00	100.00	100.00	100.00	100.00

111 Clark, F. W., Data of Geochemistry, etc., Bull. U. S. Geol. Survey No. 330, 1908, p. 214 et seq.

Analyses of Gases from West India Fumaroles.

A. From fumarole on Mont Pelee, Martinique. Gas collected by Lecroix after the great eruption of May, 1902. Temperature about 400°. Gas at first saturated with steam. Around this vent, ammonium chloride and sulphur were deposited.

B. From the fumarole du Nord, Guadeloupe.

C. From the fumarole Napolen, Guadeloupe.

Gases A and B, previous to analysis, were both saturated with water.

	A.	B.	C.
CO_2	15.38	52.8	69.5
CO	1.60	none	none
CH_4	5.46	none	none
H_2	8.12	none	none
O_2	13.67	7.5	2.7
N_2	54.94	36.07	22.32
A	.71	.73	.68
HCl	trace	trace	none
H_2S	....	2.7	4.5
S, vapor	trace	trace	trace
	99.88	99.80	99.70

Analyses of Volcanic Gases from Santorin.

A. Gas collected on Nea Kameni, March 17, 1866, from the surface of sulphurous water ina fissure between Giorgios and Aphroessa, temperature 78°. Three other similar analyses are tabulated with this.

B. From the same fissure on Nea Kameni, temperature 69°. Collected March 25, 1866.

C. Gas collected March 7, 1867, over sea water, near the end of a still incandescent lava stream.

D. Occurrence similar to C, but from a different stream. Taken March 5, 1867.

	A.	B.	C.	D.
H_2S	trace	trace	....	....
CO_2	36.42	50.41	0.22	none
H_2	29.43	16.12	56.70	1.94
CH_4	.86	2.95	.07	1.00
O_2	.32	.20	21.11	a24.94
N_2	32.97	30.32	21.90	72.12
	100.00	100.00	100.00	100.00

Of the above tables several were chosen because of the presence of small amounts of methane (CH_4) gas. Clark gives nine tables of analyses of volcanic emanations, representing thirty two samples: of these but six samples showed the presence of hydrocarbon gases—methane in every instance. According to Coste, the author of the volcanic theory, marsh gas (methane) does not belong to the petroleum series. The thirty odd analyses of true volcanic gases cited by Clark do not show the presence of any hydrocarbon gas other than methane and therefore, according to the champion of the volcanic theory, do not contain even a trace of hydrocarbons of the petroleum series.

Coste says that the gypsum in the Spindle Top field is "obviously" due to the action of solfataric vapors on limestone. If petroleum is universally formed from rising volcanic or magmatic vapors it seems that the heavy Trenton limestone, which contains the petroleum in the Ontario-Lime-Indiana fields and is often conspiciously saturated with bitumens in other parts of its known occurrence, should be gypsiferous at least at the base. And that the Boone limestone

which occurs only a few hundred feet, at most, below the entire Kansas-Oklahoma field should be more or less gypsiferous throughout; but such is not the case in either instance. According to my own observations in the Mid-Continent fields, it is not true of the Boone and the reports of others who have studied regions where the Boone formation and Trenton limestones are well exposed make no mention of associated gypsum.

These are examples from fields where oil usually contains some sulphur; others might be cited, but it is unnecessary. It seems therefore that all evidence of the metamorphic action of sulphureted gases from subterranean igneous or volcanic emanation is negative in the large fields, and it appears that the gypsum of Spindle Top is more apt to have been formed in the regular process of sedimentation than to have been metamorphosed by invading gases from below.

The absence of appreciable amounts of bituminous matter of any sort in pegmatite dikes need only be mentioned. It is to be remarked, however, that the hydrocarbon gases are much more volatile than those of the other substances found in such places, but, even though such is the case, it is not unreasonable to suppose that in rare instances the gases would be entrapped and form some of the commercial deposits of solid hydrocarbons, if they had their origin in abysal magmas.

The Carbide theory of origin postulates water at great depths and at high temperatures, but makes no attempt to explain the process of its getting there. The earth has been divided into three zones, namely: of fracture, of fracture and flowage and of flowage. It has been shown beyond reasonable doubt by the authors of that division that crevices cannot exist below the intermediate zone, nor even deep into it, for the rocks yield to the intense pressure by flowage rather than by fracture. Thus meteoric water carrying the necessary elements could not descend deep enough to come in contact with the carbides which, in many instances, require the heat of an electric furnace for their free formation and to assure stability.

SUMMARY

We find:

(1) That the great oil fields of the world are not located in or near regions of great volcanic activity;

(2) That the decadent stages of volcanoes are not marked by the formation of petroleum and solid hydrocarbons;

(3) That old volcanic pipes and craters are not repositories of the solid hydrocarbons in merchantable quantities;

(4) That the occurrence of bitumen along fault lines is the exception rather than the rule;

(5) That the fumes from active volcanoes, in a majority of cases contain no trace of hydrocarbon gases;

(6) That the limestones subjacent to the great oil fields have not in any probability been *changed* to gypsum;

(7) That pegmatite dikes do not, in any reported instances, contain notable amounts of hydrocarbon in any form;

(8) That the presence of meteoric water at depths where heat is sufficient for the production and preservation of any considerable amounts of the carbides is extremely doubtful.

It therefore seems beyond doubt, that commercial deposits at least, of petroleum and natural gas are not formed from the gases which emanate from the volcanic intrusions of abysal magmas.

ORGANIC THEORIES

We now have to deal with a set of theories of an altogether different nature from those previously discussed. The chemical theories, as we have shown, do not attempt to account for petroleum within the kind of formations where it is actually found, that is, in of supply, thus calling forth some of the most mooted questions of sedimentary rocks, but go down to the deep interior for their source cosmology as well as putting the ultimate origin of petroleum so deep into the earth that it is unreasonable to expect it to come near the surface except in regions which have suffered profound distortion or vulcanism.

The organic theories, on the other hand, without exception assign the ultimate source of petroleum to materials imbedded within or near the present containing formations during their deposition thus putting the very beginnings of that substance at least approximately within the region where it is now found. Obviously, then, the champions of the organic theories have the vantage from the beginning, for they are not called upon to account for the transportation of petroleum through thousands of feet of unmetamorphosed sediments to its present reservoir, nor are they confronted by the questions of earth origin or the present or past conditions of its interior mass and outer shell, all of which are of great importance to the inorganic theorist. The organic theorists have, so to speak, taken the "shortest cut from raw material to finished product." They have attempted to account for the presence of petroleum by the easiest possible process, and this, it will be remembered, is nature's invariable habit; she always works along lines of least resistance and performs her task in the simplest way.

While the advocates of organic origin are at one as to the ultimate source of supply of petroleum, that is, that it is organic, there is a difference of opinion concerning the processes by which the organisms are transformed from organic tissue to oil. This difference has divided the theorists into two schools: (1) those who believe that the hydrocarbons are due to primary decomposition of entombed substances, the oil in consequence being formed substantially where

it is now found; and (2) those who believe that petroleum was distilled from organic matter which had suffered partial transformation into hydrocarbon compounds. After the petroleum was distilled off the latter school maintains that it was forced, by hydrostatic pressure, into overlying porous strata which serve as reservoir rocks and in which it is found.

For convenience in discussion, the two views have been called, the theory of indigenous origin, that is origin in places, and the distillation theory. It must be borne in mind, however, that no one ever has held unreservedly to the idea that petroleum is strictly indigenous, that is, formed entirely within the rocks where it is found.

We will now make a short study of the laboratory experiments relating to organic origin and then examine the theories themselves, together with the field observation for, and against each.

DATA FOR ORGANIC THEORIES.

It has long been known that hydrocarbons and nitrogenous bases, more closely resembling those found in petroleum than the ones produced by inorganic reactions, can be formed by the destructive distillation of organic tissue, either animal or vegetable, under conditions which preclude the free access of air. The first to attempt to produce artificial petroleum in this way were Warren and Storer[1] in 1865. They prepared a lime soap of menhaden (fish) oil and subjected it to destructive distillation and obtained a mixture of hydrocarbons hardly distinguishable from oil produced by the destructive distillation of coal or bituminous shale. From the distillate thus obtained they separated and identified pentane, hexane, heptane, and octane of the paraffin, or C_nH_{2n+2} series; of the olefines, or C_nH_{2n} series, amylene, hexylene, heptylene, octylene, nonylene, decylene, undecylene, and duodecylene; and of the benzine or aromatic, C_nH_{2n-6}, group, tolomene, xylene, and isocumene. Thus they had prepared a true petroleum, a thing which according to the best obtainable data, never has been done by inorganic laboratory processes.

Thirteen years later the researches of C. Engler[112] were published. He subjected unsaponified menhaden oil to destructive distillation, 320° to 400°, under a pressure of ten atmospheres and obtained a distillate, closely resembling petroleum, which was found to contain the paraffins, C_5H_{12}, C_6H_{14}, and C_7H_{16}. Later he reported normal octane and nonane and secondary hexane, heptane, and octane, probably from the same experiment, but the data are not clear. Engler[113] and Lehmann in another experiment, obtained, besides paraffin, the olefines from C_6H_{12} to C_9H_{18} and some derivatives

1 Mem. Amer. Acad. (2) Series, Vol. IX., 1865, p. 177.
112 Ber. Deutsch, Chem. Gesel. Vol. 21, p. 1916.
113 Ber. Deutsch, Chem. Gesel. Vol. 30, 1897, p. 2365.

of the benzine series, thus confirming the work of Warren and Storer. The difference in results may have been due, in part at least, to the fact that the latter used pure oil while the former removed the glyceroids by making the oil into a soap.

In 1899 W. C. Day[114] formed substances resembling gilsonite by distilling a mixture of fresh herring oil and pine wood to carbonization and redistilling the distillate. On subjecting the oil alone to the same treatment a substance more like elaterite was formed. The wood alone under like treatment gave a similar oil and a similar residue. Both of these artificial material contained some nitrogen. Thus artificial asphalts strongly resembling the natural product were formed.

Vegetable oils also yield similar products. Sadtler[115] has proven it for linseed oil; Engler[116] has formed them from colza and olive oils, and J. Marcusson[117] has formed gas and oil that completely resembled lubricating petroleum from oleic acid.

These are a few of an indefinitely long list of similar experiments which have invariably shown the same results. In short, then, it may be said that of those who attempted to form petroleum by artificial means, those who used organic substances have more nearly succeeded than those who have relied on inorganic chemical reactions. None have succeeded as well as is wished, due doubtless, to the fact that an exact reproduction of nature's laboratory and environments is impossible.

INDIGENOUS ORIGIN.

The opinion that petroleum now occupies the rocks in which it was first formed, that is, is of indigenous origin, has been maintained with great vigor by T. Sterry Hunt an early day geologist of Canada and J. P. Lesley, who made pioneer observations in the Kentucky and West Virginia fields. Hunt's observations were, it seems, confined to a region where the oil was most abundant in very fossiliferous limestone, the casts of fossils often being filled with oil; hence he concludes:[118]

> The facts observed in this locality appear to show that petroleum, or the substance which has given rise to it, was deposited in the beds in which it is now found at the formation of the rock. We may suppose in these oil bearing beds an accumulation of organic matters, whose decomposition in the midst of a marine calcareous deposits has resulted in their complete transformation into petroleum, which has found a lodgment in the cavities of shells and corals immediately near. Its absence from the unfilled cells of corals in the adjacent and interstratified beds forbids the idea of the introduction of the oil into these strata either by distillation or infiltration. The same observations apply to the petroleum of the Trenton limestone, and if it shall hereafter be shown that the source of petroleum (as distinguished from asphalt) in other regions is to be found in marine fossiliferous limestones a step will have been made toward a knowledge of the chemical conditions necessary to its formation.

114 Am. Chem. Jour. Vol. 12, p. 478.
115 Proc. Am. Philos. Soc. Vol. 36, p. 93.
116 Engler, C., Congress International du petrole, Paris, 1900, p. 20.
117 Chem. Zeitung. Vol. 30, 1906, p. 789.
118 Am. Jour. Sci. Vol. 39, p. 169.

It is to be remembered that the origin of petroleum has never been distinguished from asphalt;[119] contrarily it has been shown that the latter is a residuum of the former, as was stated earlier in this paper.

About the same date as the article cited above Hunt wrote in support of his opinion:

> That the great orthoceratite fossils of the Trenton limestone are often filled with petroleum; that concretions of the Marcellus and Genesee slates frequently contain it, while petroleum formed, he believes, in the Corniferous limestone below impregnates the overlying Devonian sandstones of New York and Pennsylvania.

And again he writes some years later:[120]

> In opposition to the generally received view, which supposes the oil to originate from a slow destructive distillation of the black pyroschists belonging to the middle and upper divisions of the Devonian, I have maintained it exists, ready formed, in the limestones below.

In these statements Hunt obviously has recognized the possibility of the transfer of petroleum from its place of original formation to other horizons, but still insists that it must come from "marine calcareous deposits" as he believed at the time of writing the earlier paper to which reference was made. Nor does it seem that he ever admitted the possibility of oil coming from any sources other than limestone, as is seen from a paper[121] written on the occurrence of petroleum at Chicago in the middle of the Niagara formation, which contained about 4.25 per cent of oil. He says:

> With such sources existing ready formed in the earth's crust, it seems to me, to say the least, unphilosophical to search elsewhere for the origin of petroleum, and to suppose it to be derived by some unexplained process from rocks which are destitute of the substances.

Stated briefly then, Hunt's theory is that petroleum is formed by the primary decomposition of organic tissues; and because there is generally in limestones more abundant evidence of former life, he urges that these rocks must be the source of the greatest part of petroleum. When the oil is found in the limestone associated with fossils, he maintains that it is still where it was formed, but if it is found in any other kind of rock he thinks it must have originated in the limestones below and has been transported to its present site. It appears, therefore that he must have believed all petroleum to have been produced from animal remains for the limestones are necessarily without notable vegetable content.

Lesley, who also believed in indigenous origin was of the opinion that petroleum was formed from both plant and animal remains. In writing of petroleum in eastern Kentucky he refers it to the great conglomerate at the base of the Coal Measures. He says:[122]

119 Am. Jour. Sci. 2d ser. Vol. 353, p. 157.
120 Am. Jour. Sci. 2d ser. Vol. 46, p. 361.
121 Idem. Vol. 3, p. 420.
122 Proc. Am. Philos. Soc. Vol. X., pp. 43-44.

A conglomerate age, or horizon of petroleum, exists. This is the main point to be stated, and must be kept in view apart from all other ages or horizons of oil, whether later or earlier in order of geological time. The rock itself is full of the remains of coal plants, from the decomposition of which the oil seems to have been made........For hundreds of square miles this vast stratum of ancient sea sand is a thick packed herbarium of Coal-measures plants........We can easily conceive of the wide, flat, sandy shores of the coal islands of the ancient archipelago of the coal era becoming completely charged with the decomposed and decomposable reliquiae of both the plants of the land and the animals of the sea.

In others of his papers, Lesley sets forth his views on the indigenous origin of Pennsylvania petroleum with considerable assurance; but some of his latest writings show that his opinions became somewhat modified but just in what manner it is hard to say. This change of viewpoint is evident from the following:[123]

The origin of petroleum is still an unsolved problem. That it is in some way connected with the vastly abundant accumulations of Paleozoic sea-weeds, the marks of which are so infinitely numerous in the rocks, and with the infinitude of coraloid sea animals, the skeletons of which make up a large part of the limestone formations which lie severa lthousand feet beneath the Venango oil sand group, scarcely admits of dispute, but the exact process of its manufacture, of its transfer, and of its storage in the gravel beds is utterly unknown. That it ascended rather than descended into them seems indicated by the fact that the lowest sands hold oil, when those above it do not, and that upper sands hold oil when they extend beyond or overhead the lower.

Of the more recent writers, White[124] is of the opinion that in some parts of the Pennsylvania field, for example the third oil sand of Venango County, had its origin in the formation where it is found. He bases his opinion on the great abundance of plant remains found in the formation at its outcrop.

Robert T. Hill says that the petroleum so widely disseminated through the shales of the Tertiary of Texas is to be considered, in his opinion, as due to the great abundance of organic matter deposited with them.

H. Hoefer of Europe, considers the petroleum of Shropshire as found in the strata where it originated, and Wall[125] has shown that Trinidad oil and asphalt are indigenous.

Other authors might be cited, for they are a long list. We shall now turn to the distillation theory.

DISTILLATION THEORY.

The second of the main theories noted above, namely: that petroleum and natural gas are the produce of secondary rather than primary decomposition of organic matter in the rocks, or in other words, that they are slowly and continuously distilled from the hydrocarbons contained in the carbonaceous strata, is far more generally accepted than the theory so ardently championed by Hunt. One of the tenets of this doctrine has always been that petroleum and gas are formed simultaneously and forced, by hydrostatic pressure or otherwise, into the strata above or out upon the surface where they

123 Rep. III., 2d. Geol. Survey, Penn. p. 15.
124 White, I. C., 2d. Geol. Survey of Pa. Rept. of Progress, p. 239.
125 Quar. Jour. Geol. Soc. XVI., p. 467.

would become dissipated, if impervious strata were not encountered to prevent them. This idea of the transfer of petroleum doubtless gave greater currency to the theory, but it must be remembered that though the transfer of petroleum from its parent formation was not held as common, yet it was tacitly admitted by the advocates of the former theory.

The first to suggest the distillation theory was J. S. Newberry in 1859, when he proposed it to account for the origin of oil and gas of the Appalachian region. He regarded the process as one of slow spontaneous distillation from the organic remains, both plant and animal it appears, contained in the Devonian and other sub-Carboniferous shales and particularly the black shales which underlie the productive fields. In his noted paper, Rock Oils of Ohio, he says:

The precise process by which petroleum is evolved from carbonaceous matter contained in the rocks which furnish it, is not yet fully known, because we cannot, in ordinary circumstances inspect it. We may fairly infer, however, that it is a distillation, though generally performed at low temperatures.

Again he writes:[126]

The origin of the two hydrocarbons (oil and gas) is the same, and they are evolved simultaneously by the spontaneous distillation of carbonaceous rocks, and then pass upward into the porous strata.

Newberry bases his opinion on the facts, that ten to twenty gallons of petroleum may be distilled from a ton of the Huron shale, by artificial destructive distillation, and that the oil wells of the Oil Creek district penetrate into the porous sediments immediately overlying that formation. This theory of Newberry's is very generally accepted among geologists to account for the origin of oil and gas in those regions at least, and with a few modifications seems equally applicable to fields of other parts of the world.

A more recent statement of the distillation theory to account for the liquid and gaseous hydrocarbons of the Appalachian region was made by S. F. Peckham in his monograph, on petroleum, in the Tenth United States Census Vol. 10, 1880. He says in part:

Bitumens are not the product of the highest temperatures and violent action of volcanoes, but of the slow and gentle changes at low temperature, due to metamorphic action upon strata buried at immense depths. It is not necessary here to discuss the nature or origin of metamorphic action. It is sufficient for our purpose to know that from the upper Silurian to the close of the Carboniferous periods the currents of the primeval ocean were transporting them into gravel, sand, and clay, forming gravel bars and great sand beds beneath the riffles and clay banks in still water, burying vast accumulations of seaweeds and animals far beneath the surface. The alteration due to combined action of heat, steam, and pressure that involved the formations of the Appalachian system from Point Gaspe, Canada, to Lookout Mountain, Tennessee, involving the Carboniferous and earlier strata, distorting and folding them, and converting the coal into anthracite, and the clays into crystalline schists along their eastern border, could not have ceased to act westward along an arbitrary line, but must have gradually died out farther and farther from the surface.

The great beds of shale and limestone, containing fucoids, animal remains and even indigenous petroleum, must have been invaded by this heat-action to a greater or less degree........

Too little is known about petroleum at this time to enable anyone to explain all the phenomena attending its occurrence on any hypothesis, but it seems to me that the different varieties of petroleum........are the products of fractional distillation, and one of the strongest proofs of this hypothesis is found in the large content of paraffin in the Bradford oil under the enormous pressure to which it is subected.

126 Geol. of Ohio, Vol. I., p. 192.

If this hypothesis........really represents the operations of nature, then we must seek the evidences of heat action at a depth far below the unaltered rocks in which the petroleum is now stored.

Such are the two phases of the theory of organic origin of petroleum and natural gas as presented by early American geologists. Briefly summarized they are:

(1) That petroleum is formed in situ by primary decomposition of organic remains (mainly animal) imbedded in the rocks at the time of deposition.

(2) That petroleum is produced by the distillation of organic hydrocarbons in the formations and has generally been transferred to higher porous strata. Newberry holds that the distillation is slow and continuous and is always going on at ordinary temperatures, while Peckham maintains that the distillation was the result of increased temperature and high pressure due to orogenic forces.

Foreign geologists have discussed the question pro and con but in general have only arrived at conclusions which are but slightly different from the American theories.

A short discussion and summary, of Peckham's, Newberry's, and Hunt's theories seems essential.

S. F. Peckham's theory of distillation was devised to account for the origin of oil in the Pennsylvania field which was the only great field in America at that time. He believed the formation of petroleum was due to "slow and gentle changes at low temperature, due to metamorphic action upon strata at great depths," brought about by profound pressure and widely distributed heat which he considers was a necessary accompaniment of the Appalachian uplift. It appears that Peckham appreciated the fact that such a process would change the rocks to a great extent, for he tells us "to seek the source of heat action far below the unaltered rocks in which the petroleum is now found," but he does not attempt to say how far. Borings have been made to a depth of 1800 feet below the Berea grit at Canal Dover, Ohio, but there is no evidence whatever of metamorphic action in the rocks. This is also true of all other deep borings of the field, even down to the Cambrian sandstone of New York, which yields in some places, and lies comparatively near the granitic basement of the continent.

He also states that the temperature was low; but how low? Artificial destructive distillation of Carbonaceous matter in shales can hardly be carried on at less than 350° to 400° F., but such temperatures could not be reached it seems, without metamorphic action, for Bischof and Hunt have shown that the alkaline solutions common to shales, become powerful solvents of silica and silicates at about 212° F., so that if temperatures adequate for the distillation of carbonaceous matter after that fashion should have at any time obtained, profound metamorphism would have inevitably resulted. It seems reasonble, however, to suppose that temperatures below that

necessary for rapid artificial distillation may, in long periods of time, have accomplished what was impossible in a short time at the same temperatures and that too without any change in the rocks of the region.

It has been objected that if Peckham's theory is correct, there should be such residual products of distillation as coke, etc., present in the rocks. This objection, however, is hardly valid because Engler[127] has shown that organic matter, fish oil, may be distilled at 350° to 400° F., with a pressure of two atmospheres without coke or other solid residue remaining, and an oil similar to petroleum in every respect be formed. He also showed that if the oxygen of the oil combined with a part of the hydrogen to form water that the residue would be carbon, 87 per cent and hydrogen 13 per cent of just the average composition of petroleum. While it is of course not probable that Engler anything like re-produced natural conditions in the laboratory yet it proves the possibility of the organic matter of the rocks being so decomposed as to leave no residuum and yet form petroleum and natural gas.

Newberry's writings were, in many respects, obscure. Just what he meant by spontaneous distillation has, it seems, never been determined. He speaks of "constant" distillation at "low temperature;" now distillation is distinguished from decomposition in that the substance is dissociated by temperatures far above normal, without the presence of air. This is destructive distillation by which organic compounds can be dissociated by heat without the presence of air.

The critics of Newberry's theory have therefore, contended that destructive distillation is envolved. If, however, it can be shown that, under the pressure at great depths and with ordinary increase of temperature with descent, the transformation could have been brought about, then the foundation for this phase of the distillation theory will be laid. On the other hand if we substitute decomposition of organic matter at normal temperatures without air, for constant distillation at low temperatures, we have approached very near Hunt's theory. The objections urged against Peckham's hypothesis, seem to apply here with equal force. Distillation, it seems, is not likely to be accomplished at ordinary pressure below 350° F. and there appears to be no evidence that the rocks of any of the world's greatest petroleum fields have been subjected to that temperature save perhaps in a few limited areas.

Hunt's theory of primary distillation is the simplest of all, and seems to have been formulated to meet conditions peculiar to the field where the Niagara and Trenton limestones contain the oil under conditions which were such that the distillation theories were scarcely applicable. His belief that petroleum was produced from limestone only, must of course be entirely ignored. In his essay (p. 169) he

127 Ber. des Deutschem. Chem. Ges. (21) 1816.

denies that the bituminous shales, so called "except in rare instances, contain any petroleum or other forms of bitumen." Just how he could do this does not appear clear, because it is a well known fact that petroleum (shale oil) was distilled from the shales of the Ontario oil field as well as those of Ohio, New York and New Brunswick before the fields of the United States or Canada were developed. The facts in the case are that the exact reverse is true, namely, that all fresh samples of compact shales contain petroleum, not *potentially,* but actually, and in measurable quantities.[128]

On the other hand it must not be assumed that the shales have a monopoly on the oil of the Mississippi basin, for nearly all the important limestones carry petroleum in appreciable quanaities.

So far oil in the sandstones has been neglected. It often appears that the sandstones are merely reservoirs in which the oil has collected, but there are notable exceptions. White[129] thinks that the oil in the third sandstone of Venango County, Pennsylvania, is indigenous to that formation and also to several other sands of the Catskill group in Pennsylvania and West Virginia. A. Beeby Thompson[130] thinks that the Baku petroleum originated in the sandstone formations of that region, and was formed from the remains of marine animals killed by sandstorms, while it is the writer's opinion that a considerable amount of the oil of the Oklahoma fields is produced from plant remains buried in sandstones, though Haworth[131] thinks the Kansas petroleum is formed wholly from remains in the shales.

Hunt's theory of the origin of petroleum in the limestones is that it was formed in them, at the time the rocks were deposited, by a peculiar transformation of the vegetable matter, or, in some cases, of animal tissues analogous to them in composition; "but he is unwilling to admit that similar deposits of like remains in shales would be 'transformed' in the same way," which seems to be an undue precaution as there is no apparent reason why organic matter which would act one way in limestones would not act similarly in adjacent shales.

The essential tenet of Hunt's theory, however, is not that the oil was produced contemporaneously with the rock, nor that it is an especial product of the limestone; but that it results from primary decomposition of organic substances.

There has never been an instance recorded where one could even approximately observe the process of secondary distillation in

128 See Geology of Ohio, Vol. VI., p. 413.
129 White, I. C., Report Q4 Penn. Geol. Survey and personal letter to the author Jan. 24, 1910.
130 Oil Fields of Russia, p. 85 et seq.
131 Haworth, E., Kansas Univ. Geol. Survey, Vol. I., p. 243.

operation, but primary transformation seems to be in progress in several places at present. The one most familiar to all is the Trinidad island bitumens which were examined by Wall and reported in the Quarterly Journal of the Geological Society. He says in part:

When in situ, (the asphalt) is confined to particular strata, which were originally shales, containing a ecrtain portion of vegetable debris, the organic matter has undergone a special mineralization, producing bituminous instead of ordinary anthracitiferous substances. This operation is not attributable to heat nor to the nature of distillation, but is due to chemical reaction at ordinary temperature and under the normal conditions of the climate. The proofs that this is the true mode of the generation of the asphalt repose not only on the partial manner in which it is distributed in the strata, but also on numerous specimens of the vegetable matter in process of transformation, and with the organic structure more or less obliterated. After the removal by solution of the bituminous material under the microscope, a remarkable alteration and corosion of the vegetable cells becomes apparent, which is not presented in any other form of the mineralization of wood........Sometimes the emission is in the form of a dense, oily liquid, from which the volatile elements gradually evaporate, leaving a solid residue.

Occurrences where the bitumen appears to be in the transition stage are reported from various places in Venezuela, Brazil, Mexico, and islands of the Gulf regions. Peckham cites an instance in California where the organic nature of the petroleum predominates to such an extent that a small quantity of petroleum contained in a cavity in the rock "was so filled with maggots that they crawled over each other precisely as they would in a pool of blood."[132]

During the past summer it was the writer's privilege to visit an occurrence where a black viscous substance covered the surface of a small sandy marsh caused by the over loading of a drainage channel. New sand was washed in with every freshet and a cross section of the deposit showed alternating bands of sand and bituminous substances black and semi-viscous, very much resembling the asphaltic residuum of exposed petroleum. The citizens collected some of the material prior to the visit and sent it to a reliable chemist who reported it to be asphalt. The nature of the occurrence, however, was such that it could not be a true asphaltum left by the evaporation of petroleum. The receding pool of water, from the margin of which the material came, swarmed with water beetles, insect larvae and doubtless anamalcules common to stagnant water and was thickly grown with sedges and mosses. Gas, presumably marsh gas or methane, escaped freely when the bottom was agitated. There was an oily scum on the more protected areas of the surface, easily distinguishable by its physical characteristics from the ordinary ferric (iron) oxide so common around seepages. That organic matter, suffering decomposition under water will form methane is a matter of common knowledge and it does not seem possible that when great masses of such matter are deposited that the evolution of hydrocarbons would necesasrily cease when the remains were deeply covered and the escape of gases prvented. In fact, Walthr, cited in another part of this report, has

132 Am. Jour. Sci. 3d series, XLVIII., p. 250.

shown that in process of organic decomposition under water, carbon dioxide is formed, but as soon as the available free oxygen is consumed the decay of the organic matter will decompose some of the water, thus giving rise to carbon dioxide (CO_2) gas and hydrocarbons.

The observations given above are, to be sure, of a rather superficial nature in that no careful tests of the materials studied were made. But if such tests should prove the observations correct, as I believe they would, there could be little doubt that we have in this occurrence an example of the formation, under ordinary conditions, of natural hydrocarbons of the petroleum series.

Finally then, it appears that the theory of primary decomposition finds more in nature to support it than do those of secondary distillation, though this process may be in progress in regions where temperatures sufficient to produce destructive distillation are reached. Such an instance has been noted in Java, where the heat from a volcano caused oil to be formed in a nearby coal bed.[133] It is also to be remembered that ordinary temperatures extended over long periods of time should be competent to produce the same results as intense temperatures of short duration, for the sum total of energy developed in the former case would equal or excel that of the latter.

Such is a brief statement of the various theories of the origin of petroleum and natural gas that have been proposed from time to time and have met with favor, and of some personal observations that have been made on organic origin. Some liberty has been taken in assigning the volcanic theory to a place among the chemical theories, and some new suggestions have been offered as to why the inorganic theories seemed inconsistent, but no new theory has been broached, nor shall it be. It seems best in this paper to examine into the opinions which most deserve respect, even though positive knowledge is generally wanting. It has been the purpose to show how little real knowledge we have on the subject, and it appears more discreet, in the light of present knowledge, to regard all theories of origin of petroleum as merely tentative until our knowledge is more positive and comprehensive.

The fact must not be lost sight of, however, that present day investigators, with a few worthy exceptions, are practically at one as to the fact that petroleum and natural gas, and their kindred solid bitumens, are of organic origin. This phase of the question, therefore, may be considered as partly settled, but as to how the natural hydrocarbons are formed and as to the mechanism and chemistry of the process, there is grave need of far reaching investigation, careful study and scientific correlation of data collected from the world-field, rather than the setting forth of supposedly general laws, based on observations into conditions which obtain only in limited fields.

133 Redwood, Petroleum and Its Products, Vol. I., p. 155.

CHAPTER X.

THEORIES OF ACCUMULATION.

INTRODUCTION

The fact that petroleum and natural gas are not, like water, almost universally distributed throughout the earth's outer strata has given rise to many hypotheses and theories to account for their accumulation into limited areas. The attempted explanations may be divided into three groups, namely: the crevice and line hypotheses—though the notion that "certain lines" control oil deposition does not deserve to be considered even as a hypothesis, it must be given space for the sake of completeness—the anticlinal theory and the hydraulic theory. These will be discussed in the order named.

ACCUMULATION IN CREVICES

One of the earliest hypotheses seems to have been advocated by Professor Evans of Marietta, Ohio.[134] He said that oil is contained in cavities or fissures in the rocks, together with water, and gas, arranged according to their specific gravities. He believed that the cavities were often of great dimensions and sometimes connected in such a manner that when one was tapped it was often possible to drain others from the same well. There are some early reports extant which state that drilling tools sometimes fell several feet into cavities from which oil gushed, and Fenneman[135] records a similar phenomenon in the Florence, Colorado, field. Therefore the idea of accumulation in crevices is not without some foundation, though oil is rarely reported to occur thus.

Many persons, unacquainted with conditions in the oil fields, seem to think that an "oil pool" is where oil has drained from the surrounding strata into a vast cavern from a subterranean drainage basin such as surrounds a pond or lake on the surface. The ordinary way, however, in which oil and gas are present in the rocks is as a saturating substance filling the interstitial pores of the coarser grained rocks.

OIL LINES

Another idea which early gained credence among the oil operators was that of "oil lines." It is not an attempt to explain how oil originates or collects in the rocks, but because of the fact that there is, as a rule, a well defined trend to the oil producing areas of a region, the drillers, and often operators, reasonable in all other matters, assert

134 Bone, J. H. A., Petroleum and Petroleum Wells: 1868, p. 13.
135 Fenneman, N. M., The Florence, Colo., oil field: Contib. Econ. Geology 1904. Bull. U. S. Geol. Survey, No. 260, 1905, p. 438.

that oil will be found along any line extending in a given direction if it is persistently prospected.

The notion became popular in America during the early days of the development of the Pennsylvania fields and is still held, even by oil men of considerable reading and culture. The "oil lines" of the Appalachian region trend about N. 45° E. Careful investigations tend to show that this trend is intimately related to the geologic structure of the country as is also the general north-south trend of the Oklahoma oil pools.

That many oil men disregard these structural relations and depend on the "line" is easily discovered by a short association with them when they are freely discussing development and prospecting.

THE ANTICLINAL THEORY

The fact that by far the greater number of oil wells in the United States and Canada are along anticlinal axes was early noticed. This observation gave rise to the anticlinal or structural theory of oil and gas accumulation. It is impossible to say to whom the whole credit is due for the origin of the structural theory, because a number of geologists proposed it, independently, at about the same time. T. Sterry Hunt, who published a paper setting forth the principles of the theory in the Canadian Naturalist in 1859, was, it appears, the first to publish on the possibility of the relation of oil deposits to structure. E. S. Andrews, of Marietta, Ohio, reached the same conclusions independent of Hunt and published his opinions in the American Journal of Science in 1861, while H. Hoefer, of Austria, records like observations, independent of either Hunt or Andrews, in his "Petroleum Industry of North America," pages 77-80.

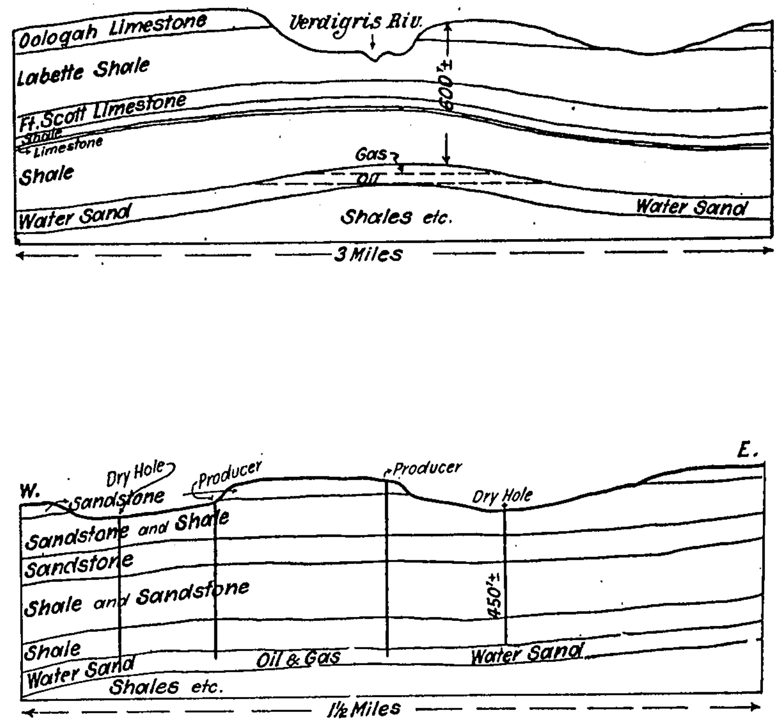
Though it is difficult to determine who was the first geologist to discuss the principles of the theory, the first to put them to tne crucial test was I. C. White,[137] of West Virginia. As a result of these tests White succeeded in locating several of the most prolific gas fields in West Virginia.

The theory, briefly stated is: Since petroleum and natural gas are lighter than water they will rise into the arches of the anticlinal folds in the rock when associated in the strata with it. Assuming the presence of petroleum in the rocks, there are, according to this theory, four prerequisited, before oil and gas can collect in paying quantities. These requirements are:

(1) Water in the formation.
(2) Porous reservoir.
(3) An impervious stratum above the porous reservoir rock.
(4) An anticlinal fold.

136 For further discussion see: Redwood, Petroleum and its Products; White, I. C., Report. W. Va. Geol. Survey Vol. I. (a); 10th Census, U. S. Vol. X.

137 A full account of Prof. White's tests may be found in Science, June 26, 1885, or Vol. I. (a) W. Va. Geol. Survey Report, 1904.



GENERALIZED SECTION OF THE MAIN OIL AND GAS FIELD.

If any one of these conditions is wanting it does not appear that the theory can well hold for the followin greasons: (1) If there is no water present, then the oil is the heaviest liquid in the rocks and will tend to collect in structural troughs, or synclines, instead of in the anticlinal arches. (2) Unless there is a porous reservoir rock, such as sandstone, dolomitized limestone or similarly porous substances, the petroleum will necessarily remain scattered throughout the formation. (3) If the rocks are of an homogenous texture throughout the oil and gas will not collect under the arches, but continue to percolate upward to the top of the ground water level at least, and as much higher as the force of capillarity and the expansion of the gas would carry them. (4) If there are no structural irregularities, such as anticlinal arches or quaquaversal domes, the oil and gas will gradually percolate up the dip of inclined strata, if the strata have a uniform dip, to the point of ingress of the water, or remain widely disseminated throughout the formations.

Experience has often seemed to so thoroughly prove the anticlinal theory that it has come to be considered, by many, as the anticlinal law of accumulation. If the rocks contain both oil and water it often seems to be uniformly true; but if there is no water present it is but reasonable that the oil should seek the lower levels and be found in the synclines.

Ralph Arnold[138] in his recent bulletins of the United States Geological Survey has added much data to the positive side of the question of the structural relations of oil and gas fields. He reports oil from synclines in several localities. In some of the wells, as the Kentucky wells in the Sespo fields, he accounts for this phenomenon by the fact that the syncline is situated between two consequent anticlines on one limb of the great Topatopa anticline; while in some others, it appears, that the strata contain no water and the petroleum, therefore, seeks the synclinal trough.

Many of the most progressive oil operators of the world now begin prospecting a new field along anticlinal axes, though those of the "old school" and many of the speculators prospect in a haphazard way along "oil lines."

With the important provision that the strata must contain water as well as oil the theory is, beyond doubt, worthy of consideration.

"On the continent of Europe, and in Russia, no other theory (than the anticlinal) has any followers whatsoever."[139] White and others have shown its efficiency in the Pennsylvania fields;[1] Blatchley maintains it is true for Illinois;[140] Arnold reports it from California; the writer has found it true for many of the Oklahoma

138 Bulls. Nos. 309, 317, 321, 322.
139 White, I. C., Rept. W. Va. Geol. Survey, Vol. I. (2) p. 53.
140 Blatchley, W. S., Petroleum industry of southern Illinois, and Bull. Illinois Geol. Survey No. 2.

pools, though in some cases one or the other of the modifications, to be discussed later, seems to be applicable, and Fenneman[141] and others have shown that the small fields of the Gulf Coastal Plain are under quaquaversal anticlines.

The modifications of the anticlinal theory referred to above are the arrested anticline or terrace, and the effect of large lentils of sandstone embedded in shale. The former was first observed by Edward Orton Sr., while the latter is mentioned by Gale.[142]

The "arrested anticline" modification as stated by Orton is as follows:

> Though distinct arches are for the most part wanting in Ohio geology, there is another sort of structural deformation found here which is connected in a direct way with the oil and gas of eastern Ohio. The structure referred to is associated with the arrest or suppression of the prevailing dip of the rocks for a given space and the establishment of a terrace or level bench in its place. If the series had been level instead of being inclined at the slight angle which mark most of Eastern Ohio, the movement to which the present terrace is due would have resulted in a low arch, but the uplifting force was too feeble to do more than counteract for a short space the normal dip by which the entire series is affected.

This form of structure obtains in the Coweta field in Oklahoma, and has been noted in other regions not yet prospected, while anticlinal fields are frequent between the Kansas line and Tulsa, and prevail in the Hogshooter and shallow fields.

The petroleum and gas in the Oklahoma fields occur, as a rule, in sandstone interbedded in fossiliferous shales. These sandstones, where drilling has been extensive, have been found to be from a few to one hundred feet in thickness, but usually vary at different places in the same field, sometimes thinning out entirely on one side of the producing area. Where this phenomenon has been observed there is little or no evidence of structural disturbance, but the rocks exposed at the surface usually show a uniform dip, at low angles, toward the west.

The sandstones which have been exposed by erosion are, with a few notable exceptions, narrowly lenticular throughout the Pennsylvanian series in northern Oklahoma. The lentils are usually from five to fifty feet thick and from two or three, to twenty miles or more in latteral extension. Since the exposed sandstones are lenticular it seems that it is not presuming, to assume that many sandstone lentils lie buried in the impervious petroliferous shales. Since these sand lenses were deposited as bars on the shores of the ancient sea, doubtless they are convex upward, so that one, for example, with a maximum thickness of fifty feet and ten miles in diameter, would necessarily cause a gentle arch to be built in the superimposed sediments, thus forming a catchment basin for petroleum or natural gas even in regions of level lying strata. In such a case the oil should be most

141 Fenneman, N. M., Oil fields of Texas-Louisiana Gulf Coastal Plain: Bull. U. S. Geol. Survey, No. 282 1906.
142 Gale, H. S., Geology of the Rangely oil district, Colorado: Bull., U. S. Geol. Survey No. 350, p. 46.

abundant where the sandstone is thickest. If, on the other hand, the rocks form a monocline, and the shales enclosing the sandstone are sufficiently impervious to oil and gas, those hydrocarbons will collect along the highest edge of the lens, provided there is associated water. Drill holes through the producing sand under such conditions would be likely to show that the sand increases in thickness, from the gas territory down the dip of the strata through the oil bearing belt and to persist beyond where oil was present in paying quantities, while the sand would "pinch out" up the dip from the gas pool.

Obviously a deposit caused by either of the phenomena just described would present no surface criteria by which its proximate location could be determined. The only way in which such subterranean conditions can be learned is from a study of the logs and collar levels of the wells. So far it has not been possible to collect sufficient data in any locality in Oklahoma to be certain that the oil does come from sandstone lenses. There are, however, one or two regions where there appears to be no evidence of anticlinal folding, or even an arrest of the normal dip of the rocks, where oil is being produced. A few driller's records show the sand to thin up the dip and the local operators and drillers speak of the oil sand "pinching" out to the east, so it appears that the petroleum is very likely obtained from sandstone lenses.

CONCLUSION

From the foregoing, it appears, that the finding of petroleum and natural gas in large crevices in the rocks is rare and that the idea that there are "oil lines" running in a certain direction the world over, are erroneous, but that in regions where the strata contain both oil and gas, and water the lighter substances tend to collect in arches in the rocks under impervious strata, but in the absence of water the oil seeks the lower levels, and that arches under which the oil and gas may collect in the beds, are due (1) to gentle anticlinal folding; (2) to an arrest of the normal dip of the rocks, and (3) to accidents of sedimentation by which great sandstone lenses were embedded in petroliferous shales.

During the past few seasons M. J. Munn of the United States Geological Survey, has been carrying on detailed investigations in the Appalachian oil fields. As a result of his first summer's work he has written two papers which have appeared in *Economic Geology*, numbers two and six, of Volume IV, 1909. In the first article he sets forth the data collected, while the second is devoted to conclusions reached. In these papers he shows that the oil pools of Sewickley quadrangle, near Pittsburg, are not confined to the anticline folds and that especially those in the "hundred foot sand" occur at various horizons, generally in conglomerate lenses, many of which contain no water. He then hypothecates water currents within the formations during past ages and shows how such currents would have rinsed the petroleum from the surrounding rocks and caused it to collect in those places where the water currents were least, and how it may have then been held in suspension in the sand by the capillary and hydraulic pressure of the surrounding water. There are a number of conditions hypothecated, concerning the behavior of petroleum and gas in clay shales during their early stages of genesis and also after consolidation of the rocks which he uses to arrive at his conclusions. The whole may, therefore, be considered as hypothetical, however, if he succeeds, by laboratory, or other methods, in proving his initial statements he will have added to the sum of knowledge on accumulation, but will probably cast a doubt upon the anticlinal theory, which, it seemed, was becoming fairly well established. It is hoped, however, that these investigations will ultimately lead to a better knowledge of actual conditions of accumulations.

A paper by George F. Becker, Bulletin No. 401, of the Federal Survey, entitled "Relations between local magnetic disturbances and the genesis of petroleum" should be mentioned, but the lack of space forbids a lengthy review of it at this time.

In his paper Becker points out the fact that it has often been noticed that the needle of the compass is often more greatly disturbed in the oil fields of the United States than in adjacent regions. He therefore argues a genetic relation between the petroleum and the cause of the disturbance. He believes in the theory that natural hydrocarbons are formed from metal carbides and that they are now in the vicinity of their origin. Hence the disturbance is due, he thinks, to the presence of magnetic metals near the oil pools. Some argue from this that oil fields may be located by carefully platting magnetic variations as shown by the compass. It is reported that experiments are now being carried forward in Louisiana on this hypothesis.

CHAPTER XI.

STRATIGRAPHY OF THE MAIN OIL AND GAS FIELD OF OKLAHOMA.

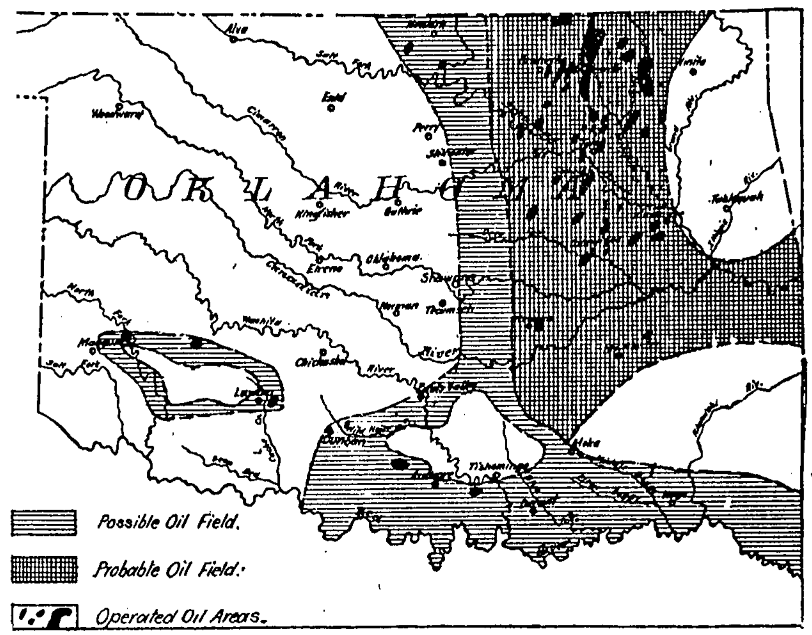
INTRODUCTION

The region covered by the following discussion of stratigraphy is situated in northeastern Oklahoma, north of the township line between townships seven and eight north and east of the range line between ranges three and four west. It comprises all of that part of the Ozark Mountains lying within Oklahoma and, in addition, that portion of the State which has been found to be richest in petroleum and natural gas.

SOURCES OF DATA

The material embodied in this report is derived from many sources. A large part of the region under consideration was first studied by the writer as a member of the Oklahoma Territorial Geological Survey during the seasons of 1905 and 1906. Much information was also obtained while doing "free lance" work in the Oklahoma oil and gas fields during the winter of 1906-'07, and the summer of the latter year, while in 1908, after the present State Survey was organized, I made a reconnaissance survey with complete outfit, through the southern part from Tulsa to Braggs, thence northward to Ft. Gibson and west as far as Porter. The Director of the Survey, C. N. Gould, and D. W. Ohern, Professor in the department of Geology at the State University, have also made extensive investigations in that part of the State and their store of information has been freely drawn upon. Roswell H. Johnson, a geologist at Bartlesville, has aided much by furnishing data concerning field observations and contributing logs. There are many others who aided greatly, appreciation for which is here expressed.

There is no literature extant on the geology of the entire region under consideration and but little has been written on the detailed stratigraphy of any considerable portion of it. With the exception of the Tahlequah and Muskogee Folios[143] and the work of Ohern[144] in the Nowata and Claremore quadrangles all the work that has been done is in the nature of reconnaissance surveys.



GENERAL MAP OF THE OIL AND GAS REGION IN OKLAHOMA.

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143 Tahlequah folio (No. 122) and Muskogee folio (No. 132), Geol. Atlas U. S., U. S. Geol. Survey, 1905 and 1906.

144 Ohern, D. W., A contribution on the stratigraphy of the older Pennsylvanian rocks of northern Oklahoma: Oklahoma University Research Bulletin No. 4, Norman, 1910.

NOMENCLATURE USED

It is the intention in the preparation of this paper to introduce as few names as seems consistent with the stratigraphic conditions found in the region. When formations, which were named and defined in Kansas have been traced south into Oklahoma the Kansas name has been preserved, unless there seems to be a stratigraphic or lithological change in the formation of sufficient importance to render the Kansas definition inapplicable to the Oklahoma section. When it is has seemed advisable to propose new names for the formation or to subdivide them in any way the name proposed is a geographic one, either that of a town or stream near where a typical exposure occurs. There has also been an attempt to preserve those names which have been proposed by different writers on the geology of the region. But if for any reason a remapping and redefining seems necessary the old classification together with the original name has been discarded, not however, without an attempt to make the synonymy clear.

In general it has been the aim to make the nomenclature and definitions used conform to those set forth in the research bulletins of the Oklahoma University, entitled, "Proposed Groups of the Pennsylvanian Rocks of Eastern Oklahoma,"[145] and Ohern's paper referred to above, both of which are now just coming from the press.

TYPOGRAPHY

INTRODUCTION.

The surface of northern Oklahoma slopes to the east at an average rate of about eight feet per mile, while the strata in that portion of the State normally dip west at low angles. This slope of the surface to the east and the gentle dip of the formations to the west gives rise to the "stairstep" relief so often seen in various parts of the State. The forms of relief are due, in general, to two factors—erosion and structure. Broadly speaking the surface of the entire region under consideration is that of an old land surface once worn down nearly to base level, then elevated and again subjected to the agencies of erosion.

In that portion of the region lying west of the main line of the Santa Fe Railroad, the topography is characteristically that of a country composed of nearly homogenous beds while east of that line the folded structure of the rocks, together with the varying resistance of the members, has, in many instances, greatly modified erosion thus producing another type of topography.

TOPOGRAPHIC DIVISIONS.

The topogaphy of northern Oklahoma falls naturally into five distinctive belts or zones each due to erosion modified by the character

145 Gould, Chas. N., Ohern, D. W., Hutchison, L. L., Research Bull. No. 3. State University of Oklahoma, 1910.

and structure of the rocks. The zones, named in the order in which they will be discussed, are: the Ozark Uplift, the Limestone Hills, the Sandstone Hills, Flint Hills, and Low Plains.

THE OZARK UPLIFT

The term Ozark Uplift as here used includes that portion of the Ozark Mountains which lies in Oklahoma. Broadly speaking it is bounded on the northwest, west, and south by Spring, Grand, and Arkansas rivers; more narrowly, it is included almost entirely within the outcrop of the Pitkin limestone.

The general relief of the Ozark region is that of a dome dissected by deep narrow valleys and steep-sided canyons. The valleys may be classed as valleys of corrosion, valleys of solution,[146] and valleys of structure. The line of demarkation between the different types of valleys is not sharply drawn. In many instances at least two of these forces have combined in the process of valley making.

All the streams of the Ozark region in Oklahoma flow from the highest part of the dome outward. This peculiarity of drainage gives a drainage map of the uplift a definite radiate appearance with the common center in the vicinity of T. 21 N., R. 25 E., that is in the southeastern part of Delaware County. The principal streams are: Illinois River, Greenleaf, Sallisaw, Spring, Barren Fork, Lee and Spavinaw creeks.

The entire Ozark Uplift in the State is well wooded. The only open prairies are small glades along the crests of some of the hills or on slopes where the subsoil is a hard clay shale. The timber in the valleys and along the streams consists chiefly of ash, elm, walnut, hackberry, birch, sycamore, burr oak, red oak, black oak, maple and pecan. The clay shale ridges produce little timber except post oak, while the sandy divides grow an abundance of black jack, hickory, white oak, and some pine.

THE LIMESTONE HILLS

The term limestone hills is here used to include that topographic zone which lies west of the Ozark Uplift, north of the Arkansas and Cimarron rivers, and extends west to the line of the Oklahoma Eastern Railway and Buck Creek in Osage County, and north to the State line. Geologically, the region consists of alternating limestones, sandstone and shales with several beds of workable coal interstratified. Many of the sandstone ledges are very prominent, but the greater part of the characteristic forms of relief are due to the outcropping of the resistant ledges of limestone.

146 Taff, J. A., Tahlequah folio (No. 122), Geol. Atlas U. S., U. S. Geol. Survey, 1905, Fig. 1, Col. 4.

The general relief is caused by regularly dipping beds which have been cut by streams running either nearly parallel to the strike or at acute angles to the dip, that is, the topography generally has the characteristic "stair step" appearance previously mentioned. Since the beds normally dip to the west the steep escarpments are usually on the east side of the hills, the west slopes being more gentle. These conditions obtain throughout the limestone hills except in a few cases where the western dip has been interrupted by an anticlinal fold, such as is found in the Shallow and Hogshooter oil and gas fields. In these regions short west-facing escarpments and gentle dip-slopes to the east often occur east of the axis of the fold, while along the axis of the fold the formations are sometimes weathered into bald knobs, flat-topped mesas and buttes, topographic forms characteristic of level-lying strata.

The greater part of the Limestone Hills area is a roughly rolling prairie. Timber occurs mainly along the water courses and on the sandy divides. Hackberry, elm, ash, maple, sycamore, cottonwood, hickory, birch, box elder, and locust abound on the valley lands; the clay shale slopes produce some post oak, and the sandy divides grow black jack and some of the hardier hickories and white oak.

SANDSTONE HILLS

The topographic region for which the name Sandstone Hills is proposed lies south of the Arkansas and Cimarron rivers, extends west from the east line of the State to the vicinity of the main line of the Santa Fe Railroad, and south to the Arbuckle Uplift and Cretaceous overlap, thus extending beyond the limits of the region under present consideration. The transition from the limestone hills region to the sandstone hills is not abrupt, but is, on the contrary, very gradual. The limestones north of the Arkansas and Cimarron rivers are gradually replaced by sandstones. The latter are often less persistent than the limestones thus giving rise to entirely different topographic features.

The structure of the region is very irregular. That of the eastern portion consists of profound folding and sometimes local faulting, so that it can not well be described in a general way, while that of the part lying west of the Missouri, Kansas and Texas Railway usually consists of low dips to the westward. Under normal conditions, the characteristics "stair step" arrangement of outcrops with long dip slopes to the west predominates. If the sandstone members are friable the relief presents a more deeply dissected contour with narrow valleys and rounded buttes, while folding and terracing are locally effective.

That portion of the Sandstone Hills region within the area considered in this paper is drained by the Cimarron, Arkansas and

North Canadian rivers. The tributaries of these master streams are generally short and swift, have steep clay banks, narrow valleys and gravel bottoms.

The timber is found chiefly along the creek and the river bottoms and on the sandy divides. Post oak grows on a few of the clay shale slopes, but as a rule the clay formations are treeless prairies. The timber of the low lands consists principally of walnut, birch, willow, sycamore, cottonwood, hackberry, elm, hickory, and oak. That of the sandstone ridges is chiefly black jack, running oak and certain varieties of hickory.

FLINT HILLS

The term Flint Hills is used for the region occupying the eastern part of Kay County, Osage County west of Beaver Creek, and the extreme northern part of Pawnee County. Geologically, the region consists of alternating beds of shale, cherty limestone, and occasional sandstone lentils, which are the southern extensions of the Flint Hills members of the Kansas region. . This topographic zone is almost co-incident in area with the Chase formation mentioned later.

The drainage is into the Arkansas River by short tributaries. The principal streams, besides the Arkansas River, are Beaver, Little Beaver, and Turkey creeks.

The relief of the region is abruptly rolling or broken due to the resistance of the flinty ledges of limestones alternating with soft shale beds.

The timber occurs almost wholly along the water courses. A few scattered patches of black jack are seen on the divides in the southern part where the sandstones are most prominent.

LOW PLAINS

The topographic province of Oklahoma known as the Low Plains was first described by Gould[147] in 1905. As then defined it comprehended an area greater than is included in this discussion, as the accompanying map covers only the eastern part of the region. That part of the Low Plains included in this report occupies western Kay, Noble, Logan, Oklahoma and Cleveland counties, and the eastern part of Grant and Garfield counties. In general the region is gently rolling, steep bluffs are uncommon, and high hills are unknown. The water sheds are the remnants of the old peneplain to which the region was once reduced, and slopes so gently eastward that one scarcely notices the descent.

The Low Plains may be said to be located in three drainage basins: the North Canadian, Cimarron and Arkansas, although the waters all finally find their way into the latter stream. The general trend of the rivers is to the southeast through broad shallow valleys all of which are sand choked except the North Canadian.

147 Gould, Chas. N., Geology and water resources of Oklahoma: Water-supply Paper U. S. Geol. Survey No. 148, 1905.

The timber of this province consists of black jack and post oak on the sandstone ridges and the Quaternary sand hills area lying north of the principal streams, and of elm, ash, walnut, hackberry, box elder, cottonwood, etc., along the streams.

STRATIGRAPHY

INTRODUCTION.

The geology of the greater part of the region considered in this report is as yet imperfectly understood, and many of the statements made are to be considered as tentative. The grouping of the Pennsylvanian series proposed in Oklahoma University research bulletin No. 3, referred to in the beginning of this chapter, is an attempt to divide the Pennsylvanian series of Oklahoma into major divisions, the detailed stratigraphy of each of which is to be studied later. In the light of present knowledge the discussion of stratigraphy of the various groups can only be of a general character.

The geological range of the formations of this part of the State is wide. Rocks of every period of lower Paleozoic times, except the Cambrian, are represented and Cambrian rocks are doutbless present but not exposed. Nearly all the known outcrops of the various formations are represented on the accompanying map. The following table sets forth their order and age.

Classification of the Rocks in the Main Oil and Gas Fields of Oklahoma.

V. Carboniferous.
- C. Permian series, in part.
  - c. Enid formation.
  - b. Marion and Wellington formations.
  - a. Chase formation.
    - i. Wreford limestone, base (?) of series.
- B. Pennsylvanian series.
  - 4. Ralston group.
    - b. ....undifferentiated.
    - a. Pawhuska formation—base of group.
  - 3. Sapulpa group.

(State line to Ramona.)	(Ramona to Arkansas River.)
c. Wann formation.	c. Ramona formation.
iii. Stanton limestone member.	iii. Avant limestone member.
ii. Copan member.	ii. Ochelata shale member.
ii. Avant limestone lentil.	i. Dewey limestone member.
i. Dewey limestone lentil.	
i. Hogshooter member.	
b. Curl formation.	b. Skiatook formation.
a. Lenapah limestone,—base of group—	a. Lenapah limestone.

  - 2. Tulsa group.

(at the north.)	(at the south.)
d. Nowata formation.	
c. Oolagah formation (Altamont limestone) (Bandera shale) (Pawnee limestone) north of Watova	e. Seminole conglomerate.
	d. Holdenville shale.
	c. Wewdka formation.
b. Labette shale.	b. Wetumka shale.
a. Claremore formation—base of group—	a. Calvin sandstone.

  - 1. Muskogee group.

(at the north)	(at the south.)
Vinita formation, undifferentiated.	

h. Senora formation.
g. Stuart shale.
f. Thurman sandstone.
e. Boggy shale.
d. Savanna sandstone.
c. McAlester shale.
b. Hartshorne sardstone.
a. Atoka formation.

A. Mississippian series.
  c. Pitkin limestone.
  b. Fayetteville formation.
    1. Wedington sandstone member.
  a. Boone formation.

IV. Devonian.
  a. Chattanooga formation.
    Sylamore sandstone lentil.

III. Silurian.
  St. Clair marble.

II. Ordovician.
  b. Tyner formation.
  a. Burgen sandstone.

IGNEOUS ROCKS.

There is but one area in the region under consideration where igneous rocks are exposed. This area is found on Spavinaw Creek, a tributary of Grand River, in the eastern part of Mayes County, and consists of a small granite dike situated about three quarters of a mile west of Spavinaw post office, or six miles above the mouth of Spavinaw Creek.

The first reference to the Spavinaw Dike was made by D. D. Owens in the second report of the Geological Survey of Arkansas, when he mentioned a red granite which occurred near the mouth of Spavinaw Creek some thirty miles west of the Arkansas State line. N. F. Drake[148] visited the region, described the dike, and mapped its surroundings with considerable care in 1896. The writer, in company with R. R. Severin again visited the Spavinaw region in 1906 and made some observations relative to the occurrence of the dike.

The dike rock is exposed along the axis of a gentle anticline which trends approximately north 30° east. As shown at the surface the intrusion is about one-fourth of a mile long and from fifty to seventy-five feet wide. The outcrop is not continuous, but consists of four small exposures each from 100 to 200 feet long, separated by intervals of like distances. The intermittent exposure is due to differential erosion of the overlying strata. The limbs of the fold dip from 5° to 10° east and west from the dike and affect the pitch of the formation for some miles both above and below the intrusion. In color the granite is a light brick red intermixed with black specks or often aggregates of magnetite crystals.

The rocks in the vicinity of the dike are of Silurian age, while those in the surrounding hills are probably Mississippian. The Silurian and Mississippian formations appear to have been folded

148 Drake, N. F., A geological reconnaissance of the coal fields of the Indian Territory, Proc. Am. Philos. Soc. Vol. XXXVI., No. 156, pp. 326-419.

simultaneously. In adjacent regions there are conditions that go to show that the Pennsylvanian series was folded at the same time as the Mississippian. It seems probable, therefore, that the intrusion did not occur earlier than Pennsylvanian times.

ROCKS OF PRE-CARBONIFEROUS AGE.

All the exposures of rocks of pre-Carboniferous age in that portion of Oklahoma to which this paper relates are found in limited areas scattered over what has already been described as the Ozark Uplift. The exposures are either along fault lines or in deep valleys where the streams have cut their way through the superimposed strata. The sediments exposed below the Mississippian are of Ordovician, Silurian and Devonian ages. So far there has been no comprehensive survey made of the entire uplift so it is impossible to give even the location of all the areas where the older rocks are exposed.

Taff[149] describes two formations, the Bergen and the Tyner, of Ordovician age; one, the St. Clair Marble, of Silurian age and one, the Chattanooga formation with its contained sandstone member, the Sylamore, of Devonian age.

N. F. Drake in his paper on the Geology of the Indian Territory Coal Fields[150] mentions three areas, the Spavinaw Creek, Illinois River and Sallisaw Creek areas, where Silurian rocks are exposed, but failed to note the presence of Ordovician and Devonian rocks. It appears, however, from his description of the lithological character of the rocks of these areas, that he observed the other formations mapped by Taff, but, probably on account of a lack of paleontological data, failed to identify them. The Illinois River and Sallisaw Creek areas occur within the Tahlequah quadrangle and the Spavinaw Creek region has already been discussed.

So far as has yet been determined the pre-Carboniferous rocks are economically unimportant except the St. Clair marble, found along Sallisaw Creek, which has been found desirable for structural and monumental purposes.

CARBONIFEROUS SYSTEM.

INTRODUCTION

The geater part of the rocks of Oklahoma belong to the Carboniferous age. The thee main divisions of that age, according to the classification of the United States Geological Survey, are: Mississippian, Pennsylvanian and Permian. Rocks belonging to these different series are well exposed in the State and constitute more than ninety-five per cent of the surface of the region being considered. The grater part of the Mississippian rocks of northeast Oklahoma are

149 Taff, J. A., Tahlequah folio (No. 122) Geol. Atlas U. S., U. S. Geol. Survey, 1905.
150 Proc. Am. Philos Soc. Vol. XXXVI. No. 156m, 1897.

limestones. Among those of Pennsylvanian age, shales and sandstones predominate, though limestone formations are important in the Limestone Hills region. The greater part of the Permian rocks consist of red clay shales and friable sandstone. The various groups or formations which make up the different series will be discussed in regular order.

MISSISSIPPIAN SERIES

The rocks of Mississippian, or Lower Carboniferous, age in northeastern Oklahoma are confined to the eastern part of what was formerly the Cherokee Nation. Roughly speaking the area over which they are exposed is bounded on the west by the Grand and Spring rivers and on the south by a curved line extending from Ft. Gibson through Marble City, thence northeastward to the State line. Where the Mississippian series has been carefully studied, notably in the Tahlequah quadrangle, it has been divided into three distinct formations: the Boone formation, the Fayetteville formation and the Pitkin limestone.

BOONE FORMATION.

The Boone formation lies immediately above, but unconformably upon, the Chattanooga formation, known as the Eureka shale[1] in Arkansas. It is often called the Boone chert, owing to its locally silicious character and is known to drillers as the "Mississippi lime." It constitutes the principal surface rock over several counties in southwest Missouri, northwest Arkansas and northeastern Oklahoma, and is the great lead and zinc bearing formation of Missouri, Kansas and Oklahoma. This formation varies in thickness from 100 to 300 feet, in the Tahlequah region, is perhaps thicker farther north, for as much as 450 feet of limestone are reported at about horizon of the Boone by some drillers in the Shallow Field.

Lithologically, the Boone formation consists of interstratified chert and cherty limestone, with a thin limestone member free from chert developed locally at the base.

FAYETTEVILLE FORMATION.

The Fayetteville formation lies conformably upon the Boone, and is named from its typical exposure near Fayetteville, Arkansas. As described in the Muskogee Folio, the formation varies from twenty to sixty feet in thickness and consists of shale beds with local limestone lentils. In the Tahlequah and Fayetteville quadrangles a sandstone lentil occurs near the middle of the formation and is sufficiently developed to be mapped and named. It is called the Wedington sandstone. The entire Fayetteville formation is approximately 170 feet thick in the Tahlequah quadrangle, while it has a vertical section of more than 200 feet in the Fayetteville region. The shales of the formation are dark blue to black in Oklahoma but grow much lighter in Arkansas. The texture of the limestones is locally variable, but all are rich in fossils, some of which are rare blastoids. Its northward extension has never been determined.

[1] Taff, J. A., Tahlequah folio (No. 122), Geol. Atlas U. S., U. S. Geol. Survey, 1905, p. 2.

THE PITKIN LIMESTONE.

The Pitkin limestone, the uppermost member of the Mississippian of northeastern Oklahoma, lies immediately above and is conformable upon the Fayetteville formation. Its outcrop is the western and southern limits of the exposures of Mississippian rocks in the Ozark uplift. Roughly speaking the horizon of this formation appears to enter Oklahoma south of Baxter Springs, Kansas, curves to the southwest, passes near Miami, thence bears southward to a point near Fairland, from whence it trends southwest to the Missouri, Kansas and Texas Railroad about five miles southwest of Vinita; thence it extends southward in an irregular line meandering back and forth between Grand River and the Missouri, Kansas and Texas Railway until, at a point about fourteen miles north of Fort Gibson, it turns east and forms a zigzag outcrop to a point a little more than a mile south of Tahlequah; thence it swings southwest past Park Hill, follows far down the Illinois River, Sallisaw and Lee's creeks and finally passes from the State a little north of Evansville, Arkansas.

The Pitkin limestone varies locally, from a few feet to forty or sixty feet in thickness. In the thinner portion, the formation is often a clayey friable limestone. Where it is thicker and more massive it is light blue to brown and often oolitic in texture.

PENNSYLVANIAN SERIES

INTRODUCTION.

The lower members of the Pennsylvanian series are the great coal, oil, and gas bearing hoizons of Oklahoma, though workable coal and some economic deposits of oil and gas occur well up toward the middle of the section.

The discussion of the stratigraphy will follow the general outline in sequence and gouping set forth in Research Bulletin No. 3, Oklahoma State University, 1910, referred to above. The goups there proposed are, Muskogee, Tulsa, Sapulpa, and the Ralston groups, beginning with the base of the Pennsylvanian series.

DEFINITION OF THE GROUPS.

These groups are defined as follows, beginning with the lowest:

1. *The Muskogee Group* includes all the rocks from the base of the Pennsylvanian series to the base of the Claremore formation or its southern extension. The name is taken from Muskogee County near the center of the area occupied by the group.

2. *The Tulsa Group* includes all rocks from the base of the Claremore formation, and its southern stratigraphic equivalent yet to be detemined. The name is from Tulsa County.

3. *The Sapulpa Group* includes all rocks from the base of the Lenapah limestone, mentioned above, to the base of the Pawhuska limestone and its southern straitgraphic equivalent. The group name is from Sapulpa, the county seat of Creek County.

4. *The Ralston Group* is composed of the rocks occupying the interval from the base of the Pawhuska limestone to the base of the Permian series, which has been considered to be the Wreford limestone for a number of years. The horizon is occupied by the Payne sandstone[1] south of Noble County.

STRATIGRAPHY OF THE GROUPS.

The stratigraphy of the main field will be discussed only in a geneal way, the discussion being based on the resarch bulletins of the State University formerly referred to in this chapter, and on the author's pesonal knowledge of the region.

MUSKOGEE GROUP.

The Muskogee group consists of a series of sandstones and shales with occasional limestone lentils, and some coal beds of considerable lateral extent. Vertically the group extends from an unconformity at the top of the Mississippian series to the base of the Claremore formation, or its probable southern equivalent, the Calvin sandstone, on the west. The area included within the outcrop of the rocks of the Muskogee group is included mainly within Craig, Mayes, Wagoner, Muskogee, McIntosh, Sequoyah, Haskell, Le Flore, Latimer Pittsburg, Atoka, and Coal counties though the borders often extend into adjacent counties.

At the State line the approximate thickness of the rocks of the group, known as the Cherokee shale in Kansas, is 450 feet. However the series thickens southward until on passing from Pryor Creek to Claremore, Ohern and Wolf noted the following section:

Section—Pryor Creek to Claremore.

		Feet.
14.	Shale with a few interbedded sandstones	135
13.	Massive, medium-grained sandstone	17
12.	Shaly sandstone	8
11.	Argillaceous heavily bedded fossiliferous limestone	2½
10.	Bluish shale	35
9.	Carbonaceous shale capped by six inches of ferruginous, silicious limestone	3
8.	Gray, fine-grained sandstone	7
7.	Arenaceous shale	70
6.	Alternating shales and sandstones	70
5.	Argillaceous fossiliferous limestone	8
4.	Massive medium-grained sandstone	37
3.	Shaly sandstone	8
2.	Massive, medium-grained sandstone	14
1.	Bluish shale, weathering to a light yellow and a few stratified sandstones	550

1 Kirk, Chas. T., Master's Thesis, University of Oklahoma, 1904.

The series continues to increase in thickness southward until Taff[151] gives the following approximate thickness for the series from the lowest exposure of the Atoka formation of that region to the base of the Calvin sandstone.

	Feet.
Senora formation	500
Stuart shale	250
Thurman sandstone	200
Boggy shale	2,000
Savanna sandstone	1,200
McAlester shales	2,000
Hartshorne sandstone	200
Atoka formation	3,000
Total	9,350

Thus the series of rocks occupying what appears to be the same time-interval as that series which is about 450 feet thick at the Kansas line, has increased to more than 9,000 feet in a distance of about 175 miles.

The Muskogee group is the great coal bearing series of Kansas and Oklahoma, though there are workable beds of coal in the Tulsa group yet to be discussed. There are at least seven beds of coal of commercial importance in the main. fields in the southern extension of the Muskogee group, while there are two known beds north of the Canadian River which seem to be of promise.

It has been assumed by some who have visited the region that the change in thickness from north to south is due to unconformity by overlap, but after having spent parts of several seasons in that region the writer is, as yet unable to discover conditions which seem to warrant that hypothesis as accounting for it in toto, though it appears that that phenomenon has locally contributed to the increase.

The Muskogee group has never been studied in sufficient detail north of the Arkansas River to enable one to separate it into various formations and numbers and it is therefore treated as a single formation in that region, though the Morrow and Winslow formations of Taff[152] are known as far north as Wagoner. At the south, however, the group has been divided into eight formations according to the table given on a previous page.

TULSA GROUP.

The Tulsa group includes all the rocks between the base of the Calvin-Claremore horizon and the base of Adam's Upper Parsons limestone, or the Coffeyville of Haworth of Kansas, but owing to changes in Oklahoma, Ohern, in his University research bulletin now in press, is calling it the Lenapah limestone. It is the same formation which the writer tentatively called, in an unpublished thesis, the Tulsa limestone from Tulsa south, and that is known as the "Checker board limestone" in the region of the Glenn pool. The group outcrops as a

151 Taff, J. A., Coalgate folio (No. 74) Geol. Atlas U. S., U. S. Geol. Survey, 1901.
152 Op. cit.

band about twenty miles wide from Kansas beyond the area under discussion. The Lenapah limestone has not yet been definitely located south of the north Canadian River, but it is believed that future work will prove it to be the equivalent of a limestone exposed near Holdenville.

The series included within the Tulsa group is the southern equivalent of the Fort Scott limestone, Labette shale, Pawnee limestone, Bandera shale, Altamont limestone, and Walnut shale of Kansas geologists.

The Claremore formation was, for many years, considered to be the southern equivalent of the Fort Scott limestone of Kansas, known in the oil field as the "Oswego lime." In Kansas the formation consists, typically, of two limestones and a shale, but in Oklahoma Ohern finds it to be composed of three limestones and two shales, both of which contain coal, so that the Kansas definition is not applicable to the Oklahoma section, and he therefore proposes the name Claremore for the formation because it is typically developed in the hills west of that city. The formation loses its calcareous nature in the vicinity of Weelaka Mission and the Concharty Mountains, and the approximate horizon is taken by the Calvin sandstone which has been traced south past Calvin to the vicinity of Ada.

The Labette shales, a name first used and defined in Kansas, lies conformably upon the Claremore formation and extends upward to the next higher limestone, the Pawnee, in that state. This shale member is about 200 feet thick at the north end of the Shallow field east of Nowata, which is somewhat thicker than it is at the State line. The upper limiting member of the Labette shales, the Pawnee limestone, coalesces with the next higher limestone in the vicinity of Watova and forms the Oolagah limestone of this paper, which has not been definitely identified south of the Arkansas River. The Labette shales therefore coalesce with higher shales south of that stream, making a formation which is not yet named.

In order to better understand conditions the next three higher formations at the Kansas line, the Pawnee limestone, Bandera shale, and Altamont limestone (Lower Parsons) will be discussed together.

The Pawnee limestone is of variable thickness in Kansas—from eight to fifty-two feet—but in Oklahoma it seems to be fairly constant. It is separated from the next higher limestone, the Altamont, of Haworth, by the Bandera shale from 60 to 100 feet in thickness. The Altamont limestone is reported by Haworth[153] to be not more than ten feet thick at any place. The Pawnee limestone[154] is about nineteen feet thick east of Nowata, the Bandera shale thirty-five feet, and Altamont limestone thirty-five feet, giving a total thickness of about eighty feet. The shale continues to thin southward until in the vicinity of Watova it ceases to be mapable and from Talala Creek south it is only a shale parting of about eight feet. From the point where the Bandera shale ceases to be mapable the three members taken together form the Oolagah limestone which has been mapped nearly to the Arkansas River, southeast of Broken Arrow. The total thickness of the Oolagah at the town of Oolagah is reported by some to be nearly 100 feet. It appears, from all available data, that the Oolagah and the northern extension of its lower member, the Pawnee, constitute the "Big lime" of the Oklahoma oil fields.

153 Haworth, E., Vol. IX., University Geol. Survey of Kansas, p. 85.

154 Siebenthal, C. E., Mineral resources of northeastern Oklahoma; Bull. U. S. Geol. Survey No. 340, 1908, p. 219.

The upper portion of the Tulsa group consists of shale with coal and sandstone lentils interbedded, and is called the Nowata formation. It is the southern extension of the Walnut shale of Haworth's last report, but that name cannot stand owing to preoccupation. The name Nowata was first proposed by the writer in an unpublished paper of 1907 and is defined as occupying the interval between the upper Oolagah limestone and the Parsons (Lenapah) of Oklahoma; the former of these limestones has been discussed in this paper as the Altamont limestone to the point where the Bandera shale becomes unmapable when it is considered a part of the Oolagah formation.

At Nowata, where a typical section is exposed, the Nowata formation is about 150 feet thick, but in the vicinity of Mounds, it has increased to a thickness of nearly 500 feet, while Taff[155] in the Coalgate folio gives the following section for what seems to be the southern extension of the group.

	Thickness in Feet.
Holdenville shale, in part	200
Wewoka formation	700
Wetumka shale	120
Calvin sandstone	200

Thus it seems that the probable thickness of this group south of the Canadian River will aggregate nearly 1,200 feet, though it is only about 150 feet at Nowata. There is only one known coal bed of workable thickness. It is known as the Dawson coal, and is operated, chiefly by strip-pits, from Mounds to the vicinity of Watova. The largest operations are at Dawson and Mohawk.

THE SAPULPA GROUP.[156]

The rocks of the Sapulpa group comprise all rocks from the base of the Lenapah limestone to the base of the Pawhuska formation (first defined by J. P. Smith),[157] as these strata are exposed in the

155 Taff, J. A., Coalgate folio (No. 74), Geol. Atlas, U. S., U. S. Geol. Survey, 1901.

156 For detailed discussion see Oklahoma University Research Bull. No. 4, by D. W. Ohern.

157 Smith, J. P., Jour. Geology, Vol. II., 1894, p. 199, and Proc. Am. Philos. Soc. Vol. XXXV., 1896, p. 290.

region under discussion. Neither the upper nor lower limiting members have been mapped, as such, south of the Canadian River.

The area included in the group has an average width of about thirty-five miles and extends from the state line south probably to the vicinity of the Arbuckle Mountains. It comprises Nowata, Washington, Osage, Pawnee, Creek, Tulsa, Okmulgee, Payne, Lincoln, Okfuskee, Pottawatomie, Seminole, and Pontotoc counties in whole or in part, and probably portions of McClain, Garvin, and Murray counties.

Included in the Sapulpa group in Oklahoma are rocks which in Kansas have been described under the following formation names, taken from Volume IX., Kansas University Geological Survey:

Pleasanton shales, Bethany Falls limestone, Ladore shales, Mound Valley limestone, Galesburg shales, Dennis limestone, Cherryvale shales, Drum limestone, Chanute shales, Iola limestone, Lane shales, Kickapoo limestone, Lawrence shales, Oread limestone, Kanwaka shales. The approximate combined thickness of these rocks as exposed in southern Kansas is 1,000 feet. In Oklahoma the thickness of the group gradually increases until at the Arkansas River it is probably 1,200 feet or more.

So far as known, with the exception of the Lenapah, none of the limestone ledges exposed in Kansas persist as far south as the Arkansas River. The Drum limestone splits near the Kansas line, and the lower member, which Ohern calls the Hogshooter, disappears some twenty miles north of Tulsa, while the upper member disappears soon after crossing the State line. Two limestone lentils, the Dewey and Avant, come in not far from Bartlesville and persist beyond the Arkansas River where they also disappear. As the limestones disappera near the Kansas line, sandstones become prominent and farther south increases in thickness until they make up a considerable part of the rocks of the group, although, as in other parts of the general region occupied by Pennsylvania deposits, shales are the predominatin rock.

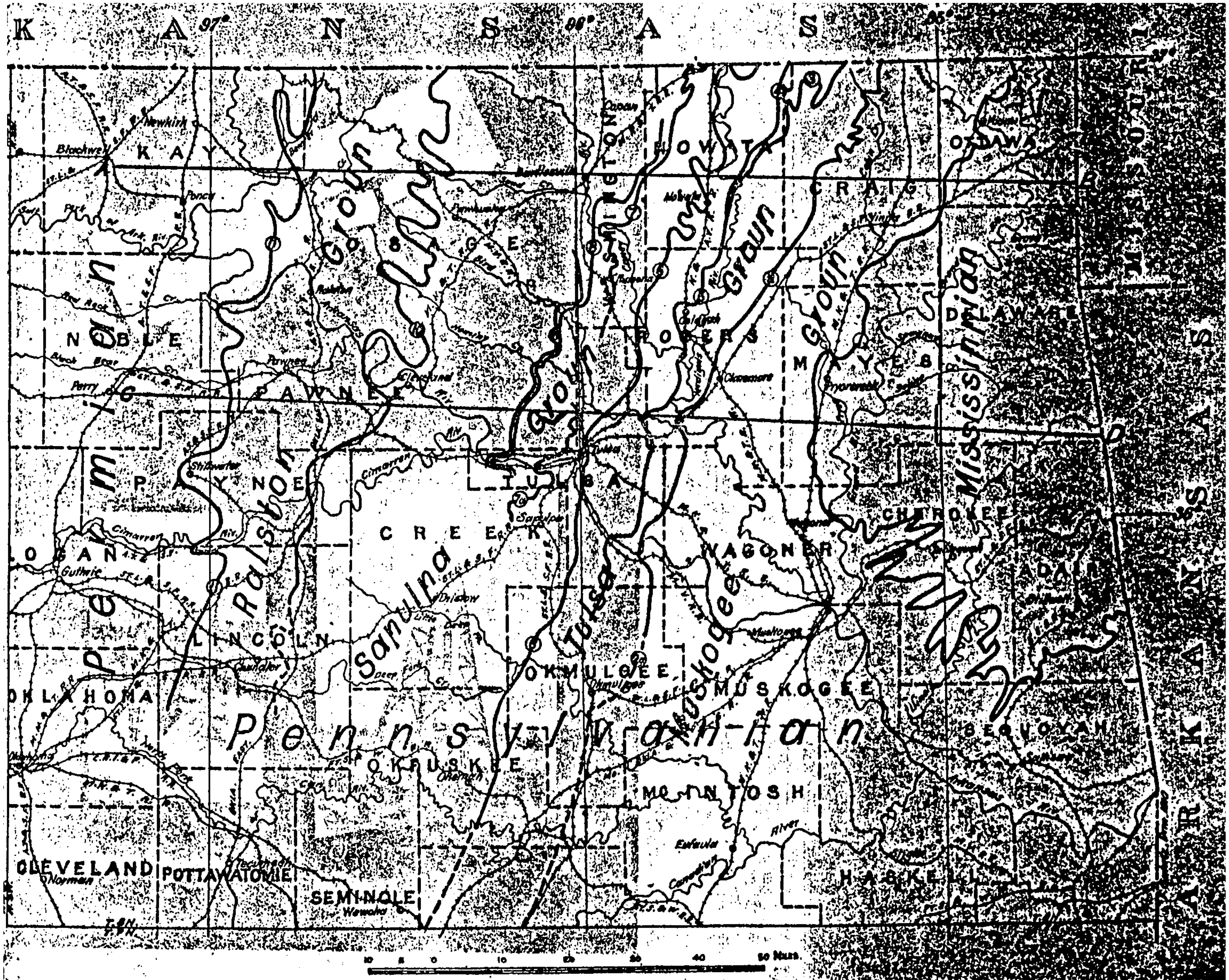
No accurate section has ever been made across the southern part of the region occupied by rocks of the Sapulpa group, and for that reason it is impossible to do more than to approximate the thickness of the group along the Canadian River, but it is probable that in this region it is somewhere between 1,500 and 2,000 feet.

In its southwestern extension, the Sapulpa group passes into and includes the eastern part of the Oklahoma Redbeds, being part of the so-called Chandler beds. (Water-Supply Paper, U. S. Geol. Survey, No. 148.)

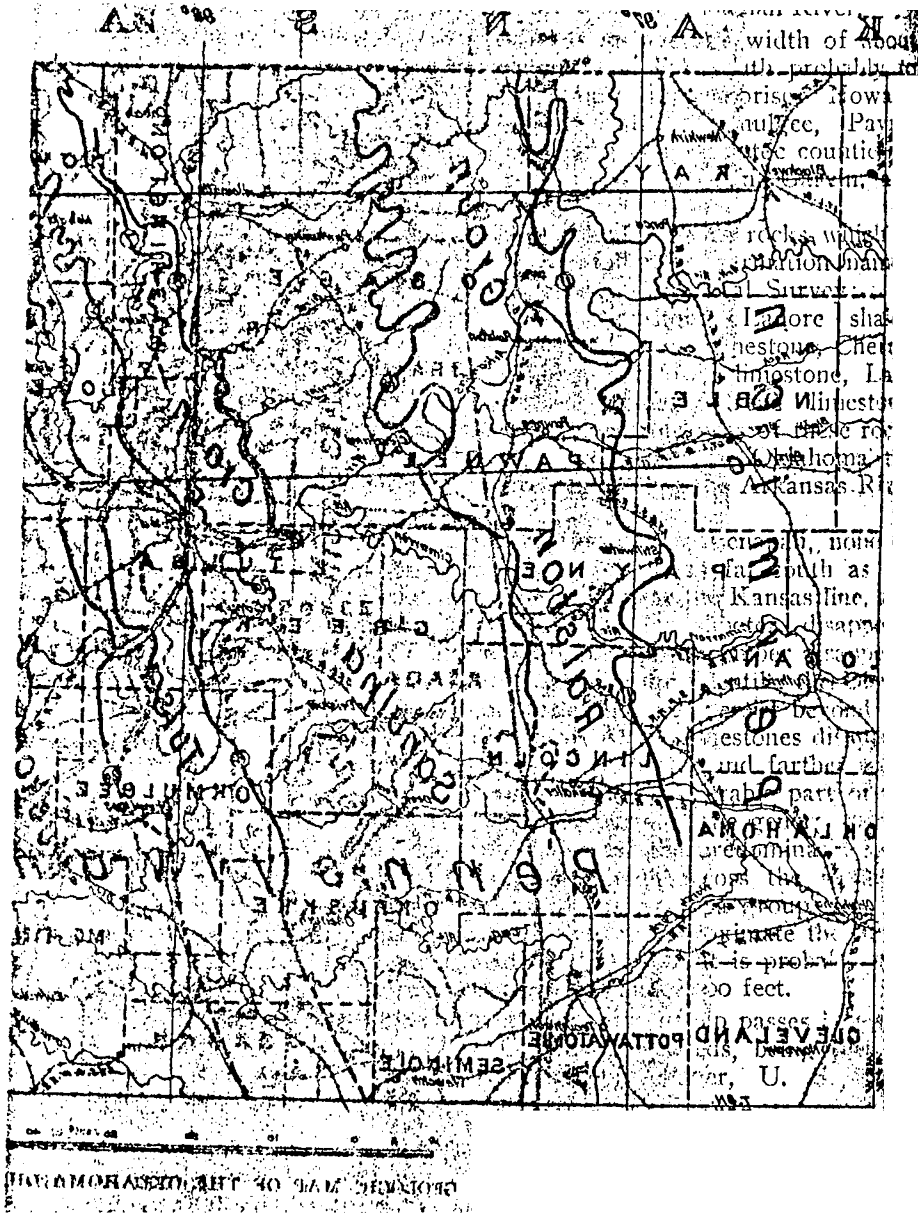
THE RALSTON GROUP.

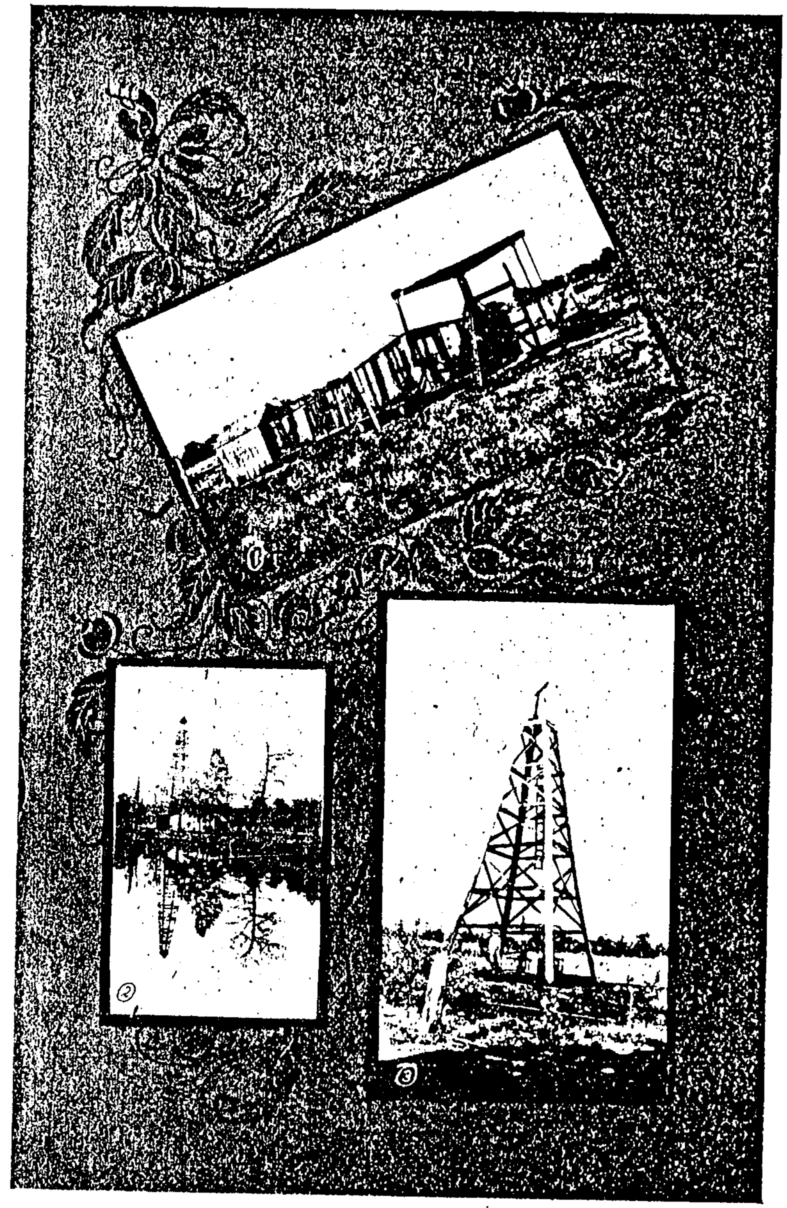
The name, Ralston group, was first proposed by the writer in an unpublished thesis on file at the Oklahoma University in 1907. As defined at that time it includes the rocks in the upper part of the Pennsylvanian series, beginning at the base of the Pawhuska

NO. I PUMPIN



GEOLOGIC MAP OF THE OKLAHOMA OIL AND GAS REGION.





NO. 1 PUMPING OIL. NO. 2 A LAKE OF OIL. NO. 3 OIL DERRICK.

formation and extending to the base of the Wreford limestone, and its southern continuation, the Payne sandstone, which has usually been considered the base of the Permian;[158] it is in this same sense that it is here used. The group is exposed as a band averaging thirty miles in width extending parallel to the other groups described in this paper from the Kansas line south toward the Arbuckle Mountains.

Neither the Pawhuska formation nor the Payne sandstone have been definitely located as far south as the North Canadian River and consequently the limits of the southern part of the Ralston group which is exposed in Lincoln, Oklahoma, Pottawatomie, Cleveland, McClain and Garvin counties can not be accurately demarked. In the northern part of the State, this group is exposed in Osage, Kay, Pawnee, Payne and Lincoln counties.

The equivalents of the following formations in Kansas (Vol. IX., Kansas Geological Survey), the combined thickness of which is approximately 800 feet, are included in the Ralston group as the latter is exposed in northern Oklahoma.

Lecompton limestone, Tecumseh shales, Deer Creek limestone, Calhoun shales, Topeka limestone, Severy shales, Howard limestone, Scranton shales, Burlingame limestone, Willard shales, Emporia limestone, Admire shales, Americus limestone, Elmdale formation, Neva limestone, Eskridge shales, Cottonwood limestone, Florena shales, Neosho formation.

These formations are exposed along the Flint Hills in southern Kansas, but near the Oklahoma line more of the limestone members thin out and disappear, while sandstones come in and thicken to the south. No accurate section across the group has been made in Oklahoma but it is probable that the group does not thicken to the south as rapidly as do the groups heretofore described. In fact, there is some evidence which indicates that in Lincoln, Pottawatomie and Cleveland counties the rocks represeting the southern extension of the Ralston group are not so thick as they are farther north.

The rocks of the group are ordinarily gray, black or blue, as far south as southern Pawnee and northern Payne counties, but at about that latitude the color changes and becomes a deep brick-red and so continues to the southern limits. This area includes the greater part of the so-called Chandler beds mentioned above.

PERMIAN SERIES—IN PART.

Above the Ralston group, the sequence of limestones and shales with occasional sandstones continues uninterruptedly for several hundred feet. Kansas geologists have described these rocks under the following names, the oldest below:

12. Wellington shales.
11. Abilene conglomerate.
10. Pearl shales.

158 Beede now considers the Elmdale as the provisional base of the Permian.

9. Herrington limestone.
8. Enterprise shales.
7. Luta limestone.
6. Winfield limestone.
5. Doyle shales.
4. Fort Riley limestone.
3. Florence flint.
2. Matfield shales.
1. Wreford limestone.

The limestones of the Chase stage contain much flint, which, being resistant, withstands erosion and gives rise to a series of pronounced escarpments which, in southern Kansas, constitute the Flint Hills The formations of the Marion stage are less resistant, and form few pronounced escarpments. The Wellington shales are all soft rocks and weather into the flat plains of Kay, Grant and Noble counties, Oklahoma.

In Oklahoma, all these formations pass into the Redbeds along the line indicated on the map. Several of the limestones, particularly the Wreford, the Florence and the Fort Riley, extend several miles into the Redbeds before finally losing their color and merging with red sandstones and shales.

This peculiarity of relations is represented on the map in Kay and adoining counties, where there is exposed an area of non-red Permian rocks, triangular in shape, bounded by the Kansas line, the Wreford limestone and the eastern margin of the Redbeds.

CHAPTER XII.

PRESENT STATUS OF OIL AND GAS DEVELOPMENT IN OKLAHOMA

INTRODUCTION

It is impossible to discuss the details of all the oil pools of Oklahoma in a work of the present limitations. The State is therefore divided into two general districts, called the Main Field and the Minor Field, and the development is discussed under these captions. The main field includes all development in the northeastern part of the State—that is, north of the main line of the Rock Island Railway and east of western Kay County—while the minor field includes all known occurrences of petroleum or natural gas in the Arbuckle-Wichita Mountain region from Madill to Granite.

In the main field the discussion will be of a general nature except in the outlying pools such as those at Muskogee, Wewoka, and Blackwell, where conditions are considerably at variance with those in what may well be called the central pools which occur under similar conditions from the Kansas line to Glenn pool, and from the shallow field to Cleveland. The occurrences in the minor field are widely separated and are found in formations of two different ages, but under strikingly similar geologic conditions.

It may appear to some that too much space is given to the outlying pools of the main field and the occurrences in the minor field, but it is the present purpose not only to set forth the conditions under which the large deposits, already discovered, occur but also to determine, if possible, the conditions which seem to limit the probably prolific territory. It is only by a careful study of the "edge pools" of the main field and of the isolated occurrences of the minor field that such probable determinations can be made. Hence the apparent over-emphasis laid upon the outlying development.

HISTORICAL SKETCH

The world's first deep well drilled with the avowed purpose of procuring a supply of crude petroleum was sunk in 1859 at Titusville, Pennsylvania by Col. Drake. The venture was successful and others followed rapidly. The production of crude petroleum was remunerative and the oil industry soon became established. The news of fabulous wealth won from oil fields spread rapidly. In a few years Ohio, Indiana and Illinois were producing more or less oil and by 1884 Kansas was rejoicing over her first gas well.

The Cherokee and Choctaw Nations, ever ready to avail themselves of revenue, were attracted by the possibilities of their domain. During the year 1884 the Choctaw Council passed a law entitled, "An Act creating the Choctaw Oil and Refining Company, for the purpose of finding petroleum, or Rock Oil, and increasing the Revenue of the Choctaw Nation." This act was approved and signed by Principal Chief, Edmund McCurtain, October 23d, 1884.

The Choctaw law legalizing oil prospecting preceded the Cherokee law of like nature only a few weeks, for a law entitled, "An Act authorizing the Organization of a company for the purpose of finding Petroleum, or Rock Oil, and thus increasing the Revenue of the Cherokee Nation," passed the Council and Senate of that Nation on December thirteenth and was signed the same day by D. W. Bushyhead, Principal Chief.

Each charter required active operation to begin within one year.

Under the provisions of the Choctaw Act, J. F. McCurtain, E. N. Wright, A. R. Durant and Allen Wright, were the incorporators of the Choctaw Oil and Refining Company, while the Cherokee Charter was granted to Robert L. Owen and James S. Stapler. Both the Choctaw and Cherokee companies associated themselves with Dr. H. W. Faucett of New York for the purpose of development. This new company erected a derrick in the Choctaw Nation twelve or fourteen miles west of Atoka on Clear Boggy and another at Alum Bluff on the Illinois River about twenty miles north of Tahlequah. Everything was progressing nicely and hope ran high, but Dr. Faucett had failed to file official notice of the commencement of work in the Cherokee Nation, and just two days before adjournment the Council of 1885 repealed the charter of the year previous. This bolt from a clear sky stopped all work in the Illinois valley. At this juncture Mr. Owen evinced his legislative prowess by inducing the next council to reinstate the charter, but the damage had been wrought. Dr. Faucett's New York associates were frightened from the field. He soon, however, secured assistance from some St. Louis men and continued work on the Choctaw well. The Indian members of the company could not appreciate the cause of delay and their uneasiness and attempt to force circumstances drove the promoters from the Cherokee field. The work was pushed forward at the Choctaw well west of Atoka until Faucett's death in 1888.

The following log taken from the dead pioneer's note book represents discovered conditions:

1888.

Choctaw, Indian Territory, Well.

Located on a branch of Clear Boggy River, 14 miles westerly from Atoka. Atoka County. Choctaw Nation. Owners National Oil Trust Co., of St. Louis. Record copied from the book of the Manager—the late Dr. H. W. Faucett.

	Thickness. Feet.	Depth. Feet.
Slate blue (troubled with mud)	168	168
Sandstone and slate	201	369
Sandstone and slate (troubled with mud)	10	379
Slate	45	424
Sandstone	30	454
Sandstone and slate (small oil indications)	70	524
Sandy	80	604
Sandstone	10	614
Shale and hard sand	45	659
Shells	25	684
Slate and shells	40	724
More sand than slate	68	792
Sandstone (807 feet casing)	29	821
Sandstone and slate (sand at 833 feet)	12	833
Sandstone (oil at 917 feet tubed and tested, much salt water)	120	953
Slate	20	973
Slate and sand	50	1023
Slate, clean	35	1058
Slate and shells	104	1162
Sandstone (salt water and good show of oil)	73	1255
Slate	13	1248
Slate and shells	11	1259
Slate and shells	18	1277
Sand, shells and slate (900 feet water in hole)	19	1296
Sandstone (1200 feet water in hole, small oil show at 1302 feet)	12	1308
Slate	27	1335
Sandstone (oil show at 1347 feet, oil and gas at 1391 feet)	79	1414

Still in sand and drilling July 23d, 1888.

The events just recited closed the first epoch of Oklahoma oil history. The next serious attempt was made by the Cudahy Oil Company fostered by Michael Cudahy of Omaha.

This company, it seems, secured a blanket lease on the Creek Nation and employed McBride & Bloom of Independence, Kansas, to drill some wells for them. The first well was drilled during 1894 on what is now a part of the Muskogee townsite. Oil was found at 1,120 feet. Drilling continued to 1,800 feet and the hole was lost. Hole No. 2 was drilled 900 feet southwest of the first location. High grade oil was discovered at 645 feet. This sand was shot and produced, but as it was only for prospecting purposes, drilling was continued to 1300 feet when for some reason the enterprise was abandoned. Title to lands could be had in 1904 so drilling was resumed and has not yet stopped in the vicinity of Muskogee.

The Osage Council passed a resolution, on the 14th day of March, 1896, to the effect that they would lease their lands for oil and gas exploitation. The lease was soon consumated with Edwin B. Foster. This gave him an exclusive franchise to operate in the Osage country. The first well, which was located three miles south of Chautauqua Springs, was sunk during the summer of 1896 to a depth of 110 feet and resulted in a five barrel producer.

Encouraged by the prospects at Muskogee, McBride & Bloom, during the early part of 1897, drilled a well at Eufaula on their own responsibility. The log of the well shows more or less oil at three horizons and gas enough at 2,475 feet to fire the boiler. Drilling was discontinued at 2,575 feet.

The same firm was running another string of tools on the west slope of Turkey Mountain, southeast of Red Fork, while the Eufaula well was going down. This hole was sunk to 1,800 feet without revealing even a show of oil or gas.

In 1886 Edward Bird secured a lease on a tract of land west of Chelsea where eleven producing wells were completed during 1891. Governmental conditions, however, were unsatisfactory and the property finally passed into the hands of the Cherokee Oil & Gas Company, the present owners of the "Big Lease." This company had a large acreage of leases but the Curtiss Bill of 1896 forced them to give up all "unproved" lands, thus reducing their acreage to twelve sections.

About 1893 the Cudahy Oil Company had secured 200,000 acres of leases in the vicinity of Bartlesville at which time they completed and began to operate several wells which they had formerly drilled as test holes and plugged. Drilling was begun in earnest and continued until 1896, when it was cut short by the Curtiss Bill. Like the Cherokee company, the Cudahy company was shorn of all "unproved" territory, and as section twelve, upon which Bartlesville was located, was the only land thus far drilled, the lease covering it was the only one approved by the Interior Department. Conditions were so unsettled that nothing was done in that country, except on the Cudahy and Cherokee leases until after 1904, when it became possible to get allottee's leases approved by the Department. Development has been rapid and constant ever since that time, and though the Coody's Bluff-Chelsea, Bartlesville, Copan and Hogshooter fields are among the best in the State it is believed that the possibilities of the Cherokee Nation are only beginning to be appreciated.

The first development of consequence in the Creek Nation was near Red Fork in 1901, when Dr. Fred S. Clinton of Tulsa and Dr. J. C. W. Bland of Red Fork "drilled-in" the first oil well of the Tulsa-Red Fork district. Since that time development has gone steadily on, with the exception of delays due to Departmental interference, and poor markets.

When the region between Bartlesville and Tulsa had been pretty thoroughly tested, operators pushed southward and during the early summer of 1906, Galbreth and Colcord finished Glenn well No. 1, which marked the opening of the greatest oil pool the world has ever known.

Arbuckle well No. 1, at Madill, was discovered during the summer of 1906, and that field is now shipping crude.

Oil was discovered at Lawton, Gotebo and Cleveland during 1904, and at Wheeler early the next year, while Granite preceded these places by reporting oil in 1901. None of these discoveries, have, except the one at Cleveland, as yet resulted in paying quantities of petroleum. The Lawton field furnishes enough gas for that city, and Gotebo has more than the town can consume. The discovery at Cleveland resulted in a good oil pool, several thousand acres in extent, that has paid well but is now on the decline. The Wheeler field supplies gas for Ardmore, and the gas field at Blackwell, in Kay County, now has more gas than local domestic use demands, while the Ponca City field in the same county is able to supply the present needs of the city.

OKLAHOMA OIL AND GAS STATISTICS

No attempt is at present made by this Survey to collect data relative to production and development, further than as it is reported by the various trade journals and the United States Geological Survey. The following statistics are compiled from those sources, the Oil Investors' Journal of February 20, 1910, being the main basis of the computations for 1909 production.

The following table gives the production and value of the oil of the Kansas-Oklahoma portion of the Mid-Continent oil field from 1896 to the present.

The Production and Value of Mid-Continent Oil.

	Year's Prod. Bbls.	Value.	Per bbl.
Before 1896	105,530	$ 52,765	$ .50
1896	113,571	51,107	.45
1897	81,098	32,439	.40
1898	71,980	35,990	.50
1899	69,700	52,275	.75
1900	83,418	75,173	.901
1901	191,486	164,098	.862
1902	368,849	325,404	.882
1903	1,071,125	1,130,622	1.050
1904	5,617,527	5,447,622	.970
1905	12,013,495	6,546,398	.545
1906	23,118,648	10,247,550	.443
1907	52,475,516	20,617,828	.395
1908	50,453,590	19,172,354	.38
1909	47,918,519	16,771,482	.35
Totals	195,779,934	$80,723,109	.558

It will be noted that the field has declined both in quantity and value of its output since 1907, but it appears that Oklahoma probably maintained her yield of last year or possibly exceeded it by a small amount.

CAR SHIPMENTS.

Car shipments of Oklahoma crude from all sources amounted to 3,540,650 barrels. Of this amount the pipe lines loaded 1,083,997 barrels and the producers and others 2,456,653 barrels. The daily average car movement for the year was 9,700 barrels. Most of the rail shipments were to Texas refineries, although Oklahoma refineries used considerable quantities and the fuel demand was of marked importance as compared with other years, while during the last quarter of the year large shipments were made from Muskogee to the Standard Oil refineries at Baton Rouge.

The car movements of the year were over the Frisco, Midland Valley, Rock Island and Frisco-Midland Valley railroads.

The shipments made over the Frisco were from Kiefer, in the western part of the Glenn pool; Mounds, a few miles south of the same field; Tanaha, north of Sapulpa in what is often called the northern extension of the Glenn pool, and from Preston, the little town that is growing up near the Preston pool at the siding formerly known as Hamilton switch. No shipments were made from the last mentioned place until December, 1909.

The Midland Valley loading stations are, Glenn Pool, in the Glenn pool oil field; Lefeber, a station south of the Arkansas River opposite Tulsa, and Watkins, a few miles north of Glenn Pool station, while Muskogee is the Frisco-Midland Valley loading point.

Of these Glenn Pool was an easy first with a total of 1,363,386 barrels while Kiefer came second with 619,723 barrels, less than half the amount shipped from Glenn Pool. Minor shipments aggregating 22,042 barrels were made in small quantities from various places. The following table shows the car shipments in detail.

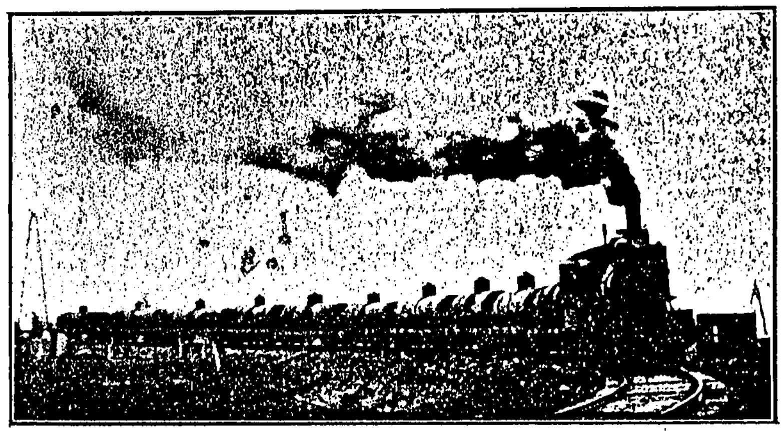
Car shipments of crude from Oklahoma, by months, in 1909.
(Barrels of 42 gallons.)

1909.	Frisco.	Mid. Val.	Frisco. Mid. Val.	R. I.	Miscel.	Totals.
January	91,330	109,298	9,669	....	3,072	213,419
February	65,018	22,082	8,076	....	....	95,176
March	101,571	72,924	6,604	....	342	181,441
April	75,573	203,768	3,172	20,797	165	303,475
May	132,603	188,140	9,418	49,656	102	379,919
June	141,603	175,812	12,227	26,630	1,115	357,387
July	175,744	155.666	13,522	960	4,419	350,311
August	98,575	150,922	18,768	767	960	269,992
September	123,636	94,895	22,327	384	3,944	245,186
October	151,997	163,852	51 166	767	2,189	309,971
November	82,925	202.499	79,145	....	3,721	368,290
December	97,771	178.843	127,456	....	2,013	406,083
Totals	1,338,396	1.718,701	361,550	99,961	22,042	3,540,650

PIPE LINE RUNS AND DELIVERIES.

The total aggregate of all pipe line runs during the year 1909 amounted to 44,471,865.83 barrels, or a daily average of 121,840.71 barrels, as against 44,103,590.42 barrels during 1908, and 44,475,516.82 barrels during 1907; the respective daily averages of the two years last mentioned was 120,501.61 barrels and 122,015.58 barrels.

Deliveries during 1909 aggregated 40,218,279.28 barrels, or 110,187.06 barrels per day, as against 36,672,022.89 barrels or a daily average of 100,196.78 barrels for 1908. Thus the runs of 1909 exceeded the deliveries by 4,263,586.55 barrels, a daily average of



OIL TRAIN LEAVING BARTLESVILLE.

11,653.65 barrels, while the 1908 runs exceeded the deliveries by 7,431,577.53 barrels, a daily average of 20,304.83 barrels.

There are no statistics available which give Oklahoma runs exclusively. All include the Kansas runs of the Prairie Oil and Gas Company, but since Kansas production for 1907 was only 2,409,521 barrels, and during 1908 it went off more than a half million barrels, it is only fair to assume that the pipe line runs of Kansas crude for 1909 did not exceed 1,000,000 barrels, though production doubtless was more. Since the total Oklahoma-Kansas runs of 1909 were 44,471,865.83 barrels the Oklahoma runs are estimated to be 43,471,865.83 barrels. Add to this the rail shipments of 3,540,650 barrels and we have a total of 47,012,515.83 barrels. Tankage, however, was drawn upon to the extent of 111,326.04 barrels during December and less this should have been counted both in being run to and from the tanks it is deducted, leaving an approximate total of 46,901,189.79 barrels for Oklahoma's 1909 production, as against 45,798,765 barrels for 1908.

The following tables set forth the pipe line movements, by months, in detail.

Pipe Line Runs and Deliveries for 1909, by Months.

Prairie, Gulf, and Texas companies, including Kansas.

1909.	RUNS.		DELIVERIES.	
	Barrels.	Daily Avg.	Barrels.	Daily Avg.
January	3,564,267.44	122,405.63	3,149,098.78	101,583.82
February	3,267,781.65	129,398.11	2,699,104.52	96,396.59
March	3,789,544.44	139,551.99	3,188,295.90	102,848.24
April	3,439,825.86	137,492.53	3,280.263.36	109,342.11
May	3,695,784.70	122,710.14	3,403,536.85	109,791.51
June	4,032,635.37	132,849.12	3.253,015.95	108,433.86
July	3,680,985.18	153,546.76	2,909,626.64	93,858.93
August	3,826,468.39	134,097.16	3,720,839.26	120,027.08
September	3,861,888.73	133,973.22	3,657,835.73	121,927.85
October	3,829,355.23	136,156.85	3,678,539.75	118,662.58
November	3,796,698.57	131,935.68	3,678,154.87	122,605.17
December	3,686,630.27	132,115.54	3,599,967.67	116.127.98
Totals	44,471,865.83	121,840.71	40,218,279.28	110,187.06

Tanked.

	Barrels.	Daily Avg.
In 1909	1,252,585.52	3,431.74

The number of barrels shown here includes oil purchased in steel storage.

Taken out of Tankage.

1909.	Barrels.	Daily Avg.
December	111,326.04	3,591.16

STOCKS.

The stocks of Mid-Continent oil on hands January 1, 1910 is in excess of those on the same date a year ago. The following table gives the latest available data on the amount of oil on hands January 1, 1910.

Pipe Line Stocks of Mid-Continent Crude.

Jan. 1, 1910.	Barrels.
Prairie O. & C. Co.	40,644,660
Gulf P. L. Co., (Est.)	*5,377,570
The Texas Company, (Est.)	*2,071,500
Totals	48,093,530

*Includes only Oklahoma crude stored in Oklahoma. It is estimated that these companies on January 1, 1910, had 3,225,000 barrels of Oklahoma crude stored in Texas, making a total of 51,318,530 barrels of Mid-Continent oil held by the three principal pipe line companies in the Southwest. In addition the Eastern lines had 3,912,295 barrels of Mid-Continent oil on January 1, 1910, indicating a grand total of 55,230,825 barrels of this grade of crude in the tanks of the principal pipe line companies at the first of the year 1910.

All Stocks of Mid-Continent Crude.

Jan. 1, 1910.	Barrels.
Prairie, Gulf and Texas Co.'s	51,318,530
Eastern Pipe Lines	3,912,295
Producers and refineries, (Est.)	7,000,000
Total	62,230,825

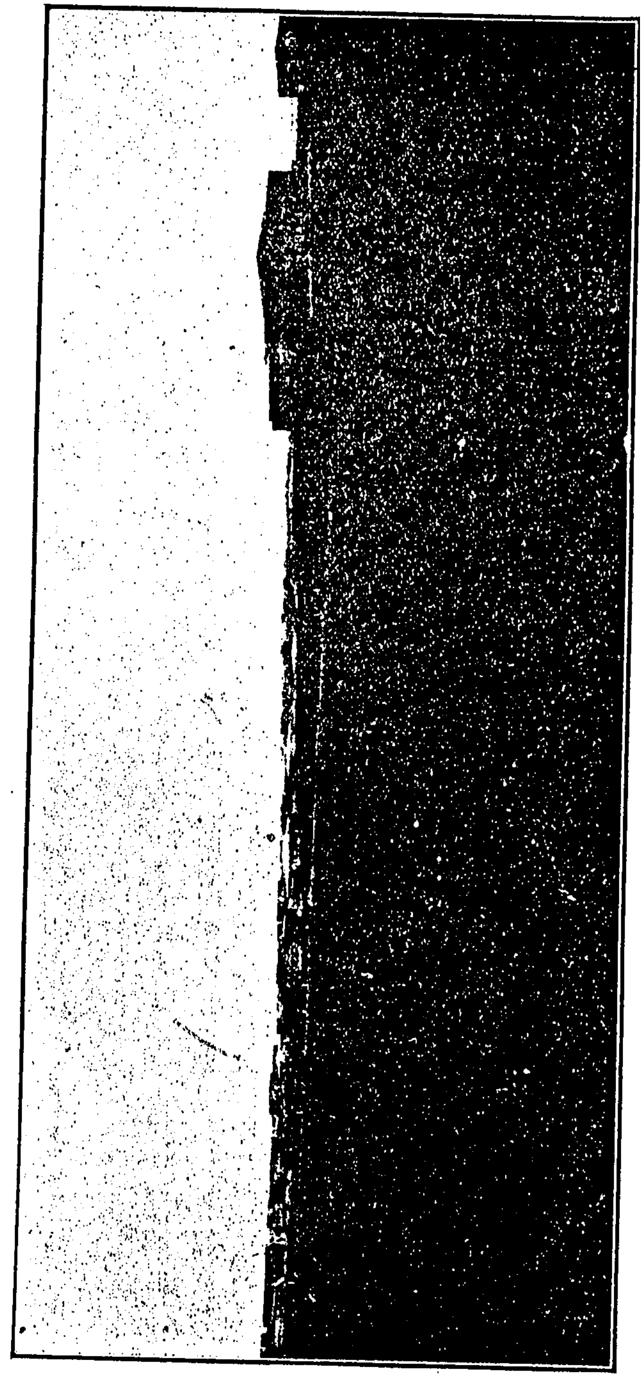
FIELD DEVELOPMENT.

At the 1909 meeting of the Mid-Continent Oil and Gas Producers' Association a motion prevailed to curtail development in the Oklahoma field as much as possible. This action was provoked by certain rulings of the Secretary of the Interior which made pipe line building across certain Indian lands almost impossible, and by a bill, then pending in the State Legislature, which proposed to make the operators of any and all domestic pipe lines, that crossed the public highways, both common carriers and common purchasers of oil, and to compel all foreign pipe line companies to domesticate.

As a result of the untiring efforts of the Association the rulings of the Interior Department have been greatly modified so that pipe lines may now cross the formerly forbidden Indian lands and in some other respects operating made less difficult. The threatened State law failed of enactment and the great pipe line companies, which are the principal purchasers of crude oil have taken out State charters so that the year 1910 has opened with a rising market and development is again resuming a more normal attitude.

In spite of the attempted restraining of development and the depressed condition of market there were 2,771 wells completed within the State during 1909, being 29 more completions than were reported for 1908. Of these 2,522 were oil wells, having an initial daily production of 200,603 barrels, which was 33,397 barrels less than the initial production of 1908. Only forty-six completions resulted in gas and but 203 holes drilled were dry.

The following tables show the results, by months, of drilling from 1904 to 1909 inclusive:



TANK FARM AT RAMONA.

Number of Wells Completed in Oklahoma, 1904-1909, by Months.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1904	....	....	....	....	....	....	....	....	....	...	....	....	361
1905	59	79	174	211	231	172	195	237	221	246	305	380	2,510
1906	310	285	217	258	404	337	218	222	142	110	96	180	2,779
1907	153	174	249	404	356	362	399	364	439	464	351	241	3,956
1908	194	162	165	194	229	208	224	282	246	263	325	332	2,844
1909	250	272	327	320	284	273	214	189	160	151	163	158	2,761

Number of Dry Holes Drilled in Oklahoma, 1904-1909, by Months.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1904	....	....	....	....	....	....	....	....	....	....	....	....	97
1905	13	14	33	45	39	30	30	30	26	23	39	31	353
1906	35	41	29	25	39	40	29	32	19	30	9	20	348
1907	13	15	17	24	27	32	45	32	33	31	31	20	318
1908	23	11	21	24	22	25	18	38	28	21	25	28	284
1909	18	17	18	27	29	24	15	15	6	13	13	8	203

Number of Gas Wells Drilled in Oklahoma, 1904-1909, by Months.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1904	....	....	....	....	....	....	....	....	....	....	....	....	21
1905	....	4	3	8	6	14	9	17	6	10	15	6	98
1906	9	17	12	16	19	24	7	14	17	10	4	14	163
1907	6	14	13	12	16	12	13	10	10	16	14	9	148
1908	16	8	8	9	7	5	7	8	11	3	13	7	102
1909	4	1	4	5	0	4	3	0	5	5	9	6	46

Number of Oil Wells Drilled in Oklahoma, 1904-1909, by Months.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1904	....	....	....	....	....	....	....	....	....	....	....	....	279
1905	46	61	138	158	186	128	156	190	189	213	251	343	2,059
1906	266	227	176	217	346	273	182	176	106	70	83	146	2,268
1907	131	145	219	368	313	318	343	322	396	317	306	212	3,390
1908	155	143	136	161	200	178	199	236	207	239	287	317	2,558
1909	228	254	305	288	255	245	196	174	149	133	141	144	2,512

The completions as recorded on page 177 were distributed as follows:

Number of Wells Completed in Oklahoma, 1905-1909, by Districts.[1]

	Completed.					Dry.					Gas.					Productive.				
District.	1905	1906	1907	1908	1909	1905	1906	1907	1908	1909	1905	1906	1907	1908	1909	1905	1906	1907	1908	1909
Cherokee, deep	....	....	941	690	707	....	....	65	53	47	....	....	61	32	15	....	....	815	605	645
Bartlesville	273	790	....	....	....	33	123	....	....	....	15	61	....	....	....	225	606	....	....	....
Cherokee, shallow.	....	....	1537	1281	1333	....	....	120	94	88	....	....	14	7	4	....	....	1403	1180	1241
Alluwe	165	441	....	....	....	4	25	....	....	....	1	7	....	....	....	160	409	....	....	....
Chelsea	244	400	....	....	....	20	44	....	....	....	6	8	....	....	....	218	348	....	....	....
Coody's Bluff	280	549	....	....	....	8	28	....	....	....	10	11	....	....	....	262	510	....	....	....
Creek	151	211	1225	683	620	33	41	97	106	57	21	35	38	52	15	97	135	1090	525	548
Oklahoma	334	107	36	....	....	47	50	12	....	....	10	19	8	....	....	277	38	16	....	....
Cleveland	....	....	....	22	21	....	....	....	7	1	....	....	....	1	2	....	....	....	14	18
Osage	482	262	184	153	90	107	30	15	16	10	16	17	15	8	10	359	215	154	129	70
Miscellaneous	581	19	33	15	....	101	7	9	8	....	19	5	12	2	....	461	7	12	5	....
Totals	2510	2779	3956	2844	2771	353	348	318	284	203	98	163	148	102	46	2059	2268	3490	2458	2522

Total and Average Initial Daily Production of New Wells in Oklahoma, 1905-1909, by Districts in Barrels.

	Total initial production.					Average initial production per well.				
District.	1905	1906	1907	1908	1909	1905	1906	1907	1908	1909
Cherokee, deep	......	......	74824	36561	35669	......	......	91.4	60.4	55
Bartlesville	14780	44367	......	......	......	65.7	73.2	......	......	......
Cherokee, shallow..	......	......	64490	80923	81754	......	......	45.9	68.6	65
Alluwe	5116	13749	......	......	......	30.9	33.6	......	......	......
Chelsea	3960	6828	......	......	......	18.1	19.6	......	......	......
Coody's Bluff	7160	22845	......	......	......	27.3	44.8	......	......	......
Creek	3108	51726	303005	76722	71239	32.0	383.2	277.9	146.1	130
Oklahoma	23178	1562	534	......	......	83.7	41.1	33.4	......	......
Cleveland	......	......	......	455	1495	......	......	......	32.5	83
Osage	36423	20047	16355	19377	10455	101.5	93.2	106.2	150.2	149
Miscellaneous	17665	160	654	114	......	38.3	22.9	54.5	22.8	......
Totals	111390	161286	459862	214152	200603	54.1	71.1	131.7	87.1	79

Total Initial Daily Production of New Wells in Oklahoma, 1905-1909, by Months, in Barrels.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1905	4982	4395	7636	8340	8415	8665	13737	10905	8918	9207	11285	14905	111390
1906	13038	11485	8755	13516	15844	15012	12240	17398	9635	8608	14495	21260	161286
1907	17700	21829	29063	36690	52157	47697	44683	40166	55371	46643	41608	26255	459862
1908	16475	17550	10865	13018	16045	1[illegible]860	14695	18834	17198	24915	25377	23320	214152
1909	21400	21405	20748	21902	17185	19006	16047	14722	12037	10200	14125	11825	200603

REFINERIES.

Oil refineries now operating within the State have an annual capacity of 1,680,000 barrels of crude. They are located as follows:

	Annual Refining Capacity, in Barrels.
Sapulpa Refining Co., Sapulpa	540,000
Chelsea Refining Co., Chelsea	150,000
Muskogee Refining Co., Muskogee	432,000
Producers Oil Refining Co., Muskogee	72,000
Oklahoma Refining Co., Oklahoma City	36,000
Okmulgee Refining Co., Okmulgee	72,000
Southwestern Refining Co., Bigheart	36,000
Tulsa Refining Co., Tulsa	54,000
Uncle Sam Oil Co., Tulsa	180,000

Other refining companies drawing large amounts of crude from the Oklahoma field are:

	Annual Refining Capacity, in Barrels.
Prairie Oil and Gas Co., (Standard Oil), about	75,000,000
The Gulf Refining Co., Port Arthur, Texas	7,200,000
The Texas Refining Co., Pt. Nechos, Pt. Arthur and Dallas, Texas,	4,000,000
The National Refining Co., Coffeyville, Kansas	780,000
The Cudahy Refining Co., Coffeyville, Kansas	108,000

GAS PRODUCTION.

Statistics on the production of natural gas in Oklahoma only date back to 1906 when fifty companies, which were producing gas, reported sales aggregating $259,862.00. The number of producing companies had increased to 155, reporting at the close of 1908, with total sales of $860,159.00, the total produtcion being estimated at 11,924,574,000 cubic feet. This was more than twice the estimated production of 1907 which was 4,867,031,000 cubic feet, with a value of $417,221.00. The increase of the production of 1909 over that of 1908 is doubtless greater than that of 1908 over the preceding year. Large quantities of gas are used for industrial purposes, the prices ranging from one and one-half cents per thousand cubic feet, in the most favored localities, to fifteen cents in more remote regions, while domestic rates are twenty-five cents per thousand cubic feet, except in one or two regions where the supply is limited and coal or wood is scarce.

In the regions of the largest fields industrial gas is often used on a flat rate, that is a certain fixed monthly charge is made for the plant. The same is occasionally true for domestic purposes. This, however, is a poor practice from every view-point. The consumer often wastes the gas by careless usage, while the producer supplies more fuel than he is paid for. Domestic consumers on a flat rate often leave the fires burning all night "because it is just as cheap." This is also a pernicious practice, for if the pressure should be checked for a short time by any cause, the fire would be stopped, and suffocation would very likely result when the gas resumes a normal flow.

During 1909, forty-six gas wells were completed. Their total initial production is not known, but it doubtless aggregates many mililons of cubic feet, as the Oklahoma wells which are reported as "gassers" range from 2,000,000 to 40,000,000 cubic feet daily.

The following is a partial list of Oklahoma towns which are supplied with natural gas for domestic and manufacturing purposes, excepting Lawton and Ponca City, which have domestic gas only: Bartlesville, Cleveland, Tulsa, Ramona, Collinsville, Pawhuska, Ponca City, Sapulpa, Muskogee, Claremore, Inola, Ochelata, Bigheart, Nowata, Lenapah, Delaware, Skiatook, Oolagah, Gotebo, Okmulgee, Blackwell, Wagoner, Owasso, Vinita, Lawton, Mounds, Morris, Beggs, Coweta, Bristow, Stroud, Chandler, Shawnee, Edmond, Guthrie, Oklahoma City, Wheeler, and Ardmore.

The following table gives such data as are available concerning the natural gas industry of the State:

Record of Natural-Gas Industry in Oklahoma in 1906, 1907, *and* 1908.

YEAR	GAS PRODUCED		GAS CONSUMED			WELLS		
	No. of Producers	Value	No. of Consumers: Domestic	No. of Consumers: Industrial	Value	DRILLED: Gas	DRILLED: Dry	Productive Dec. 31st
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	b155	860,159	17,567	356	860,159	73	40	c374
1909	....	....	....	....	....	46	......	....

a. Includes 87 wells "shut in" in 1907.
b. Includes 40 companies using gas from oil wells only.
c. Includes 100 wells "shut in' in 1908.

Statistics for the gas production of 1909 are not available and it is hard to estimate—even approximately—the probable sales, because of the fact that a Federal Court granted a temporary injunction restraining the State from enforcing the law forbidding the piping of gas beyond its boundaries. After the granting of this injunction, gas was immediately piped out of the State in greater quantities than ever before; therefore statistics for previous years are no criteria for estimates of production for the past year. If this temporary order becomes permanent and the State is not allowed to conserve her gas supply for the development of her vast deposits of raw material, in the manufacture of which gas is the most desirable fuel, it is safe to say that the gas field will doubtless develop more rapidly and that the State will soon become the first in the Nation in the production of gas. It is also apparent that the interests controlling the gas output will realize more largely on their investments under the ruling of the Federal Court than under the present State law, but the State manufacturing possibilities in Portland cement, clay, and gypsum products, lime, glass, the smelting industries, cotton manufacture, and mills generally will be greatly hindered, so that the ultimate loss to the State will be billions of dolars in profits and property and hundreds of thousands of inhabitants.

OCCURRENCES OF OIL AND GAS IN THE MAIN FIELD

INTRODUCTION.

As defined at the beginning of this chapter the main field includes all occurrences of petroleum or natural gas north of the main line of the Rock Island Railway, from Oklahoma City to Memphis, and east of a north and south line passing through Kay County west of Blackwell.

There have been discovered within this region, a number of large oil and gas pools, some of which, notably the Hogshooter gas field, and Glenn pool oil field, are world renowned.

The fact that operations began in what is now Oklahoma before county lines were established led to a grouping of the production according to Indian nations in which the development was located. This grouping, though very awkward at present, still obtains. The following is a list of the principal pools in the main field:

Cherokee Nation, shallow sand:—Delaware-Childers, and Coody's Bluff-Chelsea pools.

Cherokee Nation, deep sand:—Canary, Copan, Wann, Jackson, Cox, Webber, Ross, Hogshooter, Rice Creek, Wilson, Silver Lake, Bartlesville, Chambers, Caney River, Ramona Bird Creek, and Flatrock pools.

Osage County:—Bigheart, Nelagony, Pawhuska, and Prue pools.

Pawnee County:—Cleveland pool.

Kay County:—Ponca City and Blackwell gas pools.

Creek Nation:—Glenn, Redfork, Morris, Baldhill, Tanaha, Preston, Henryetta, and Haskell pools, and the two pools at Muskogee known as the townsite field and Chicken farm pool.

Seminole County:—Wewoka pool.

THE CHEROKEE FIELD

The oil and gas fields of the Cherokee Nation are in two general areas, one known as the "Shallow Field" and the other as the "Cherokee Deep Field." Of these, the former extends from Delaware and Childers southward along the Verdigris River to a point about five miles west of Chelsea, while the latter consists of a number of scattered pools. scattered throughout the greater part of Washington County and northern Tulsa County.

THE CHEROKEE SHALLOW FIELD

The shallow field consists of two large pools, the Coody's Bluff-Chelsea, and the Delaware-Childers, and a small pool on California Creek about two miles north of Nowata.

Of the two largest fields the Delaware-Childers has been most active during the year of 1909. The operations resulted in extending the known limits of the pool toward Delaware. The wells brought in were surprisingly large for the district and caused considerable local congestion. This, however, has been relieved by added facilities for storing and transporting the oil, so that conditions, though still active, are normal. The Coody's Bluff-Chelsea field has been active but it has attracted less attention owing to the fact that its limits have been fairly well defined for several years.

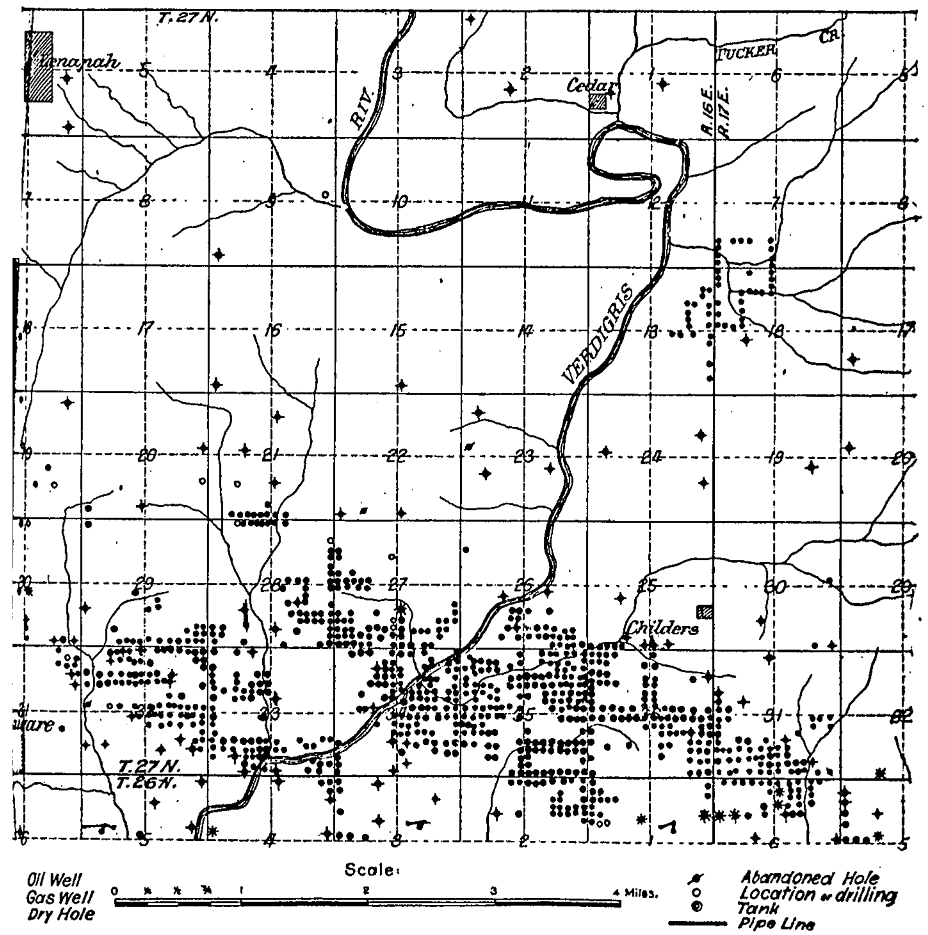
In the year 1909 there were 1,333 completions in the entire shallow field. Of these eighty-eight were dry and four were gas wells. The average daily production per well was a little more than 65 barrels.

THE COODY'S BLUFF-CHELSEA POOL.

The Coody's Bluff-Chelsea field extends along the Verdigris River, east of Nowata, from the NE. cor. T. 26 N. R. 17 E. to a like point in T. 23 N. of the same range. The productive area attains its greatest breadth, about six miles, in the vicinity of Alluwe, while the narrowest point is about three miles east of Nowata where the width scarcely exceeds two miles. In area this is the largest field in the State.

The wells of the northern part are from 450 to 600 feet deep, depending mainly on the varying surface elevations, while oil is often found at not more than 200 feet in the southeast portion of the field.

The rocks of the region consist of limestones, sandstones and shales of lower Pennsylvanian age. The wells are all started within



NORTH PART OF THE SHALLOW FIELD.

the horizon of the Tulsa group as defined in this report, while the production is found within the Muskogee group below. The wells in the extreme northern part of the field are commenced above the Pawnee limestone and since they finish in the same sand as those at the south end of the field, which are begun a short distance above the horizon of the Claremore formation (Oswego lime) they are correspondingly deeper.

The producing sand of the Coody's Bluff-Chelsea field is correlated, by some, with the Bartlesville sand farther west. There are not sufficient data at hand to either confirm or disprove this correlation, but, owing to the lenticular character of the sandstones of the region, this field seems rather remote from the Bartlesville region to definitely correlate with that sand.

The following logs from this field are representative of conditions:

In NW. ¼ sec. 19, T. 25 N., R. 17 E., about one mile northeast of Alluwe. Authority, Lightning Creek Oil and Gas Co.

	Thickness. Feet.	Depth. Feet.
Soil	16	16
Gravel	4	20
Shale (Labette shale, in part)	15	35
Oil sand	3	38
Limestone (upper member of Claremore formation)	30	68
Slate	5	73
Limestone (middle member of Claremore formation)	10	83
Shale	29	112
Limestone (base of Claremore formation)	6	118
Sandy shale	3	121
Shale	16	137
Shale	273	410
Oil sand	12	422
Shale	42½	464½

Well in sec. 35, T. 26, R. 16 E. on hill west of Verdigris River Bridge east of Nowata.

	Thickness. Feet.	Depth. Feet.
Shale	45	45
Limestone (Altamont limestone)	40	85
Shale	5	90
Limestone (Pawnee limestone)	15	105
Shale	150	255
Limestone (Claremore formation)	100	355
Sand	25	385
Shale	400	785
Sand	40	825
Shale	20	845

This log does not show the separate members of the Claremore formation (Oswego lime) as it should.

Structurally the Coody's Bluff-Chelsea field is anticlinal. The fold plunges toward the north and disappears near the north end of the development, while southward the rocks level up and have assumed their normal westerly dip by the time the big Cherokee Lease is reached at the southern end of the fild.

A sample of oil collected from a 400 foot well, near Alluwe, by Horace M. Adams and sent to the United States Geological Survey for analysis was of a dark green color, tested 36.4° Baume at 60° F., and began boiling at 67°. This oil contained 6.14 per cent of paraffin and 0.55 per cent of asphalt. Another sample taken from the same neighborhood was of a greenish black color, tested 36.4° Baume, at 60° F., boiled at 65° F., and contained 2.89 per cent of paraffin, and 4.01 per cent asphalt. The third sample from this region was taken from a well, 500 feet deep, near the west side of the field. It was of a greenish black color, tested 34.3° Baume at 60° F. The paraffin content was 9.10 per cent while the asphalt amounted to only 1.26 per cent.

THE DELAWARE-CHILDERS POOL.

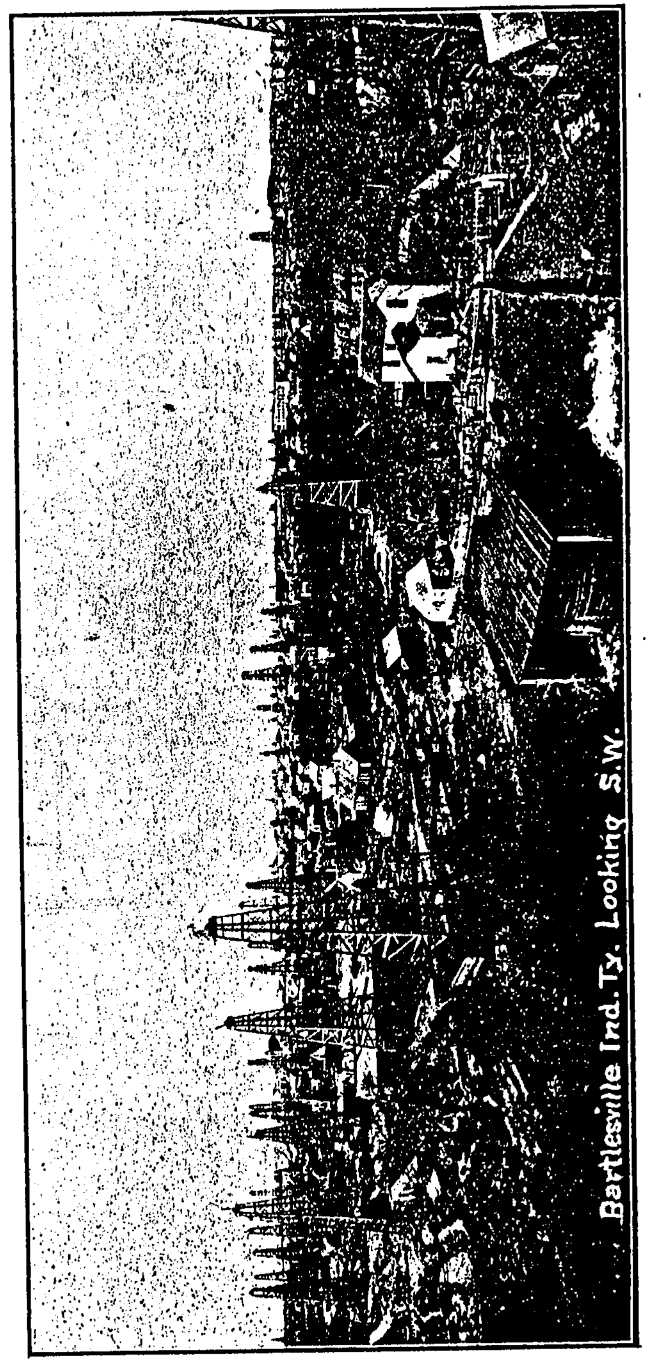
This pool lies between Delaware, a station on the Iron Mountain Railway about six miles north of Nowata, and Childers Postoffice seven miles to the east. It is roughly triangular in shape, its greatest extension, which is about six miles, being east and west. Its greatest breadth is three miles. The total area approximates eight square miles.

The depth of the wells in this pool varies from 670 to 830 feet.

The rocks of the Delaware-Childers pool consist of lower Pennsylvanian sandstones, limestones and shales. All of the wells are started within the horizon of the Tulsa group, but higher up in the series than are the majority of the wells of the Coody's Bluff-Chelsea region. Drilling in the west end of the pool is begun, except perhaps in the stream valleys, in the Nowata formation, while at the eastern end, the wells are started at or near the Pawnee limestone. The oil is found within the Muskogee group in what seems to be the same sand as that in the field previously described. It therefore may or may not be the Bartlesville sand.

No logs of wells in this field are at hand but in all major features it should be about the same as those given in the discussion of the Coody's Bluff pool.

A sample of oil, from sec. 35, T. 27 N., R. 16 E., (Susan Conner's lease) analyzed by the Federal Survey, was of a dark green color, tested 35.7° Baume at 60° F., boiled at 80° F., and contained 4.51 per cent of paraffin and 0.75 per cent of asphalt. The well sampled was 735 feet deep. A second sample taken from a well, 812 feet deep, on the Wolf lease in sec. 31, T. 27 N., R. 16 E., was light green in color, tested 34.8° Baume at 60° F., boiled at 65° and contained 4.18 per cent of paraffin and 1.69 per cent of asphalt.



OIL DERRICKS IN BARTLESVILLE.

CHEROKEE DEEP FIELD

The Cherokee deep field consists of seventeen major pools, besides several minor ones not mentioned in the list given in the above introduction. Detailed data on each of these pools could not be had and the discussion is therefore of a general nature. The pools of the Cherokee deep sand lie mainly west of the range line between ranges fourteen and fifteen east and the Osage line on the west, and are found at intervals between the Kansas line and Tulsa.

The largest single field in the group is the region immediately surrounding Bartlesville and extending to a point about four miles north of Dewey, known as the Bartlesville field. As was stated in the historical sketch, some of the earliest discoveries in the Cherokee Nation were made in this pool.

The rocks of the region consist of alternating limestone, sandstone and shales, belonging to the lower part of the middle Pennsylvanian series. With the possible exception of those in the Flatrock and one or two other minor pools, all wells in this region are started within the horizon of the Sapulpa group as defined in this paper. The wells in the north end of the Bartlesville field are begun above the horizon of the Dewey limestone as defined by Ohern. This limestone, however, disappears from the section before Canary pool is reached, and the wells of that pool are started a short distance above the horizon of the Hogshooter limestone. From the available data it seems that the greater part of the wells, at least in the northern half of the Cherokee deep sand region, procure their production from the Bartlesville sand. There are a few small pools, however, the production of which does not come from the Bartlesville sand, while some of those that do produce from that horizon, especially northwest and northeast of Dewey, produce from a higher sand as well as from the Bartlesville.

From such logs as could be obtained it appears that the Bartlesville sand occurs within the horizon of the Muskogee group. That is, all those wells which produce from the Bartlesville sand penetrate the Claremore formation which is the Oswego lime of the drillers.

The following logs will give some idea of the records of wells in the Cherokee deep sand, but many of them seem to have been so carelessly kept that it will be impossible to definitely correlate the formations The general geological conditions can be pretty accurately determined by reference to the geological map and cross sections given in a previous chapter of this report.

Bell Oil Co. on Wm. W. Lowery Allotment in sec. 17, T. 28, R. 14 E., about six miles east of Copan.

	Feet.
10 inch casing	16½
Lime	470
Lime	490
Shallow sand	506
Shallow sand	556
Big lime	625
Big lime	710
Oswego lime	850
Oswego lime	950
Sand (showing of gas)	1226
Sand (showing of gas)	1234
Sand	1273
Sand	1293
Lime	1420
Depth	1443

Well in sec. 6, T. 25, R. 14 E., about twelve miles west of Nowata.

	Thickness. Feet.	Depth. Feet.
Soil	4	4
Clay	30	34
Gravel	8	42
Shale	20	62
Sand	30	92
Shale	88	180
Sand	12	192
Shale	108	300
Limestone	18	318
Shale	90	408
Limestone	35	443
Shale	3	446
Limestone	40	486
Shale	156	642
Limestone	30	672
Shale	6	678
Limestone	30	708
Shale	4	712
Limestone	10	722
Sand	40	762
Limestone	8	770
Shale	130	900
Sand	20	920
Shale	122	1042
Oil sand	21	1063
Shale	20	1083

Well five miles southeast of Bartlesville in T. 26 N. R. 13 E. Authority, Gilchrist and Weaver, Contractors, American Oil Co.

	Thickness. Feet.	Depth. Feet.
Lime	26	26
Shale	214	240
Lime	40	280
Water sand	15	295
Shale	250	545
Sand (heavy oil showing)	20	565
Shale	75	640
Lime	90	730
Shale	10	740
Peru sand	40	780
Shale	120	900
Lime, (Oswego)	85	985
Shale	310	1295
Oil sand	8	1303
Shale to bottom	26	1329

In sec. 33, T. 21 N. R. 13 E., about three and one-half miles east of Turley. Authority, R. H. Johnson.

Gas, 1062-1080; first oil showing, 1120-1128; second showing of oil, 1142-1162.

	Depth, Feet.
Gas and water	86
Top of lime	235
Bottom of lime	360
Top lime	546
Gas sand	569
Bottom lime	584
Top water sand	584
Black shale	592
Shale black	665
Lime	680
White shale	700
Sand	705
Black shale	710
White shale	730
Sand shells	778
Black shales	851
Lime	866
Black shale	876
White shale	896
Black shale	1042
White shale	1052
Sand, gas	1052-1062
Sand, good gray	1062-1080
Top of oil sand	1080

3,000,000 gas well.

The normal structure of the region is monoclinal, with low dips westward and northwest. The normal dip, however, is occasionally interrupted by entire reversals, thus forming what is technically known as anticlines. The writer has, from time to time noticed anticlinal folds in various parts of the region now under discussion, but time and funds have thus far forbidden a careful study to determine whether or not there seems to be any relation between structure and accumulation. There are, however, a number of places, such as the Hogshooter field, a portion of the Flatrock pool and in the Bartlesville field, well defined anticlinal arches to which the production seems to be pretty closely confined and it has always been the writer's opinion that these anticlinal folds have to a marked degree controlled the accumulation of oil and gas within these fields.

A sample of oil taken from well No. 4, 1,200 feet deep, on the Williams lease north of Dewey, was of dark green color, tested 32.7° Baume at 60° F., began to boil at 103° C., and contained 6.07 per cent of paraffin and 0.47 per cent of asphalt. Another sample from a 2,150 foot well in the Webber pool was black in color, tested 38.7° Baume at 60° F., began to boil at 80° C., contained 3.68 per cent of paraffin and 1.06 per cent of asphalt. Both of these oils yield less than ten per cent in volume on evaporation below 150° C.

OSAGE COUNTY.

The oil and gas production of Osage County is located in the eastern third of the county. Development has been extensive in local regions. The first development was just south of Chautauqua

Springs, Kansas, but it has never resulted in more than a comparatively small pool. The two regions of most extensive development are just west of Bartlesville and in the region between Matoaka, Washington County, and Avant. Small pools have been discovered in a number of other places, notably northwest of Tulsa and in the region from Bigheart to Pawhuska.

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 subleasing 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.

Operating activities were considerably hindered in Osage County during the last half of 1909 by some legal questions which, however, were settled and operations have again begun to be normal. So far as reports show there was nothing of phenomenal interest developed in this county during the year, but such drilling as was done only tended to increase the developed territory and maintain the general output. There were ninety wells drilled within the year. Of these ten were dry, ten produced gas, while only seventy were oil wells. The initial produtcion of oil was 10,445 barrels, being an average production per well of 149 barrels per day, or an average of nineteen barrels per well better than the Cherokee completions, which were the second best in the State.

The rocks of this portion of the country are of middle Pennsylvanian age and belong to the Sapulpa group, as defined in this report. They consist of alternating, heavy bedded sandstones and shales with two heavy limestone lentils in the southeastern portion of the county. Nothing has ever been published on the detailed stratigraphy of Osage County, though in 1909 a field party with C. D. Smith as chief, collected data on northeast part of the county for a folio to be published by the U. S. Geological Survey.

The normal structure is monoclinal with low dips to the west of northwest. These normal dips, however, are occasionally interrupted by terracing and anticlinal folding which results in arrested anticlines and true anticlines. As in the regions previoulsy discussed the relation of the oil and gas development to the structure has not been determined in detail. However, several pools have been developed which have an elongated extension which suggests that there is some intimate relation between the structure and production. Evidences of anticlinal folding are often noticed in the region of development, while many dry holes are known to occur in the vicinity but they are often well removed from the effects of the folding. The following logs which are from various parts of Osage County, give an idea of conditions as reported by the drillers.

The first well drilled in Osage County was by McBride and Bloom, contractors of Independence, Kansas. It was drilled about three miles south of Chautauqua Springs and starts at about the same horizon as the well on Lot number 32 and therefore passes through approximately the same formations. No correlations are attempted.

Three miles south of Chautauqua Springs in northeastern part of Osage Nation. July and August, 1896.

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

The following log is of a well located on Osage Lot number thirty-two, about five miles northwest of Bartlesville. This well started down about the horizon of the Stanton limestone of Kansas, which is occasionally found on the tops of the hills along the Osage line from a point about four miles northwest of Bartlesville to the Kansas line. It is probably about the horizon of the LeRoy formation of Kansas. Further correlation of the formations passed through is not attempted here. By reference to the map accompanying this report one can probably determine the formations drilled through.

Well No. 12 in Lot No. 32 in the Osage Nation. Authority, Indian Territory Illuminating Oil Co.

Commenced producing June, 1902; pulled and plugged July 31, 1906.

	Thickness. Feet.	Depth. Feet.
Sand and gravel	35	35
Blue mud	53	88
Shell	4	92
Dark shale	10	102
Lime	7	109
Light shale	14	123
Lime	28	151
Light shale	88	239
White shale	28	277
Light shale	47	324
Sand	24	348
Light shale	206	554
Shale	31	585
White lime	5	590
Dark shale	10	600
Lime	20	620
Light shale	103	723
Lime	24	747
Dark shale	10	757
Lime	37	794
Shale	133	927
Lime	24	951
Black shale	4	955
Lime	21	976
Dark shale	6	982
Lime	10	992
Dark shale	43	1035
Sand, show of oil	13	1048
Light shale	3	1051
Lime	6	1057
Black shale	5	1062
Lime	3	1065
Light shale	8	1073
Shell sand	5	1078
Light shale	20	1098
Lime	4	1102
Shale	108	1210
Sand	10	1220
Light shale	15	1235
Shell lime	3	1238
Light shale	42	1280
Shell lime	2	1282
White shale	18	1300
Brown gritty shale	15	1315
Hard shell sand	3	1318
Dark shale	2	1320
Oil sand	20	1340

The following is the log of a well situated about four miles southeast of Pawhuska. It enters the ground below the horizon of the Pawhuska limestone, probably about 100 feet below the top of the Sapulpa group of this paper. The heavy limestone entered at 230 feet is as yet unidentified. It is not known whether this formation outcrops at the surface or not, but it probably does.

FLOWING OIL WELL, FLAT ROCK POOL, NEAR TULSA.

Well four miles southeast of Pawhuska.

	Depth. Feet.
Soil, etc.	20
Shale	185
Red rock	250
White lime	260
Slate and shale	360
Lime	400
Slate	420
Lime	460
Red rock	480
Lime	520
Slate and shale	600
Shale	640
Lime	700
Shale	720
White sand	760
Shale	780
Lime	795
Slate and shale	823
Sand	840
Lime	910
Slate and shale	940
Shale	1010
Shale	1200
Slate	1275
Sand	1356
Shale	1500
Lime	1550
Shale	1640
Lime	1656
Sand and salt	1660
Lime	1670
Slate	1673
Lime	1850
Shale	1920
Lime	1940
Shale	1950
Sand	1956

A sample of oil taken from a well 1,487 feet deep, located on Osage Lot number thirty-one, was black in color, tested 34.3° Baume at 60° F., began to boil at 115° C., and on distillation yielded only about three per cent below 150° C. The sample contained two and seventy-three hundredths per cent paraffin and one per cent of asphalt. To show the rapid change in the character of oil in this field, another analysis of oil is given, taken from a well, 1,500 feet deep, on Lot number thirty-two, immediately south of Lot number thirty-one. This oil was dark green in color, tested 33.8° Baume at 60° F., began to boil at 113° C., and on distillation yielded about three and one-half per cent below 150° C. This sample, however, contained seven and nine-tenths per cent paraffin and one and twelve-hundredths per cent asphalt.

PAWNEE COUNTY.

CLEVELAND FIELD

The Cleveland field consists of an oil pool discovered in 1904, lying within and immediately south of the town of Cleveland, in T. 21 N., R. 8 E., and a small pool, sometimes called the Olney pool, about six miles southeast of Cleveland near the headwaters of Bear Creek.

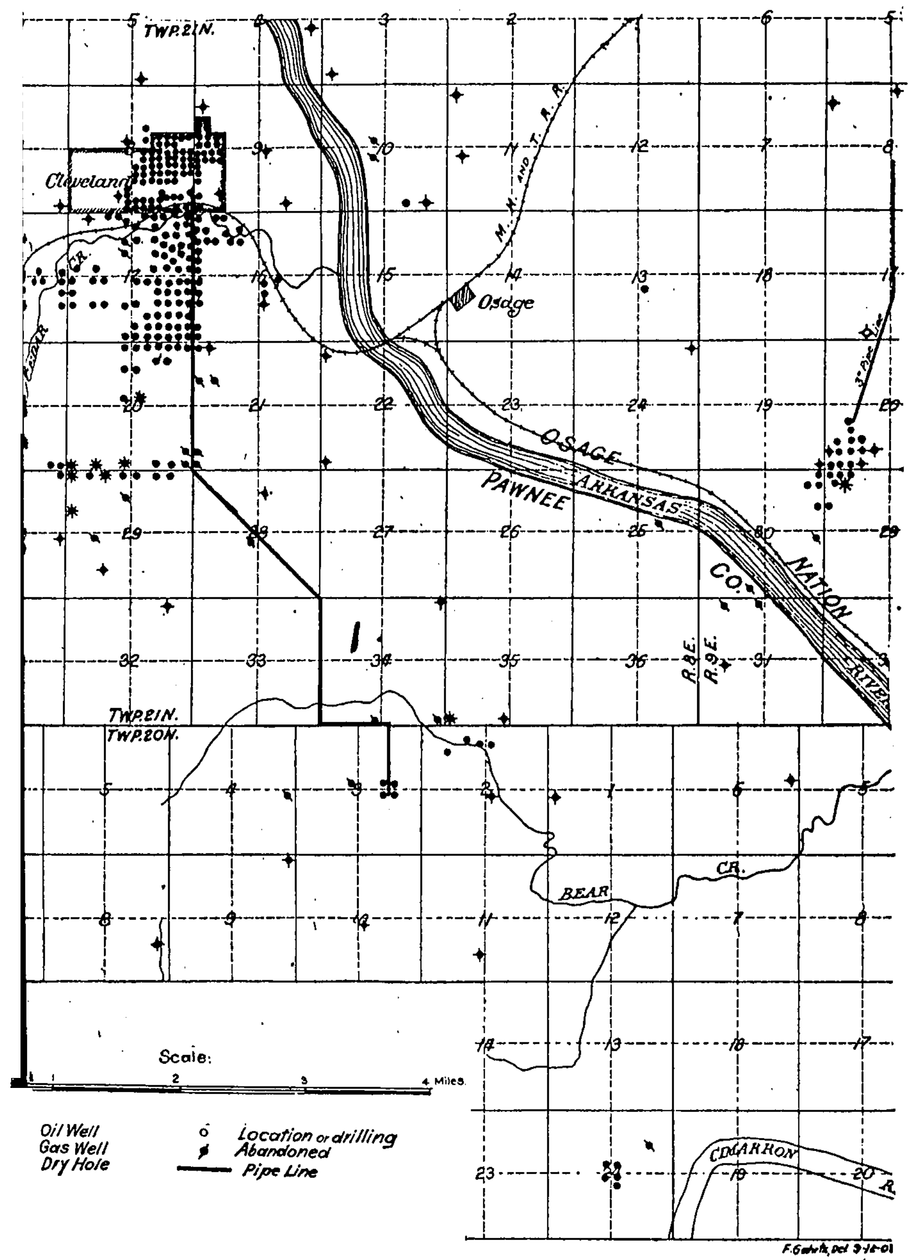
The first well drilled was on the Bill Lowery farm, just south of the townsite and was known as "Uncle Bill No. 1." The enterprise was promoted by local capital and resulted in a paying well at 1615 feet. Development followed rapidly and almost every town lot was soon drilled. The city council had to 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 on 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.

The rocks in the vicinity of Cleveland consist of alternating sandstones and shales, though there are some limestones reported in the bluffs southeast of town, and the Pawhuska formation which is the upper limit of the Sapulpa group as defined in this paper, occurs five or six miles north of town and again in the vicinity of Hallett and Jennings. The age of the rocks is, therefore, middle Pennsylvanian. All wells in the Cleveland field are begun below the Pawhuska formation, and since the exact thickness of the Sapulpa group is not known, it is difficult to determine at what horizon the oil sand occurs. It seems, however, that it is probably not lower than the middle of the Tulsa group. If the driller's log of "Uncle Bill No. 1" is any criterion it is probably not that far down the geologic scale.



CLEVELAND OIL AND GAS FIELD.

The following is a log of the first well drilled in the Cleveland field, as it was given to the writer:

	Thickness. Feet.	Depth. Feet.
Red shale	180	180
White sandstone	25	205
Red shale	35	240
White sandstone	25	265
Red shale	195	460
Limestone	25	485
White sandstone	10	495
Red shale	39	534
Limestone and sandstone	8	542
Red shale	28	570
White sandstone	25	595
Red shale	5	600
White sandstone	100	700
Black shale	100	900
White sandstone	20	820
Black slate	200	1020
Gray sandstone	195	1215
Black slate	125	1340
Gray sandstone	15	1355
Black slate	215	1570
Oil sand	20	1590
Gray sandstone	15	1605
Second oil sand	10	1615

The limestone recorded at 485 feet in the above log is probably the Avant limestone. It will be noted, however, that no deeper limestones were recorded. If the Lenapah limestone, which marks the base of the Sapulpa group, extends westward as far as Cleveland, it was either drilled through without being noticed, or was not reached at all. It is probable that the latter, however, is not the case, as an approximate section from Tulsa to Jennings taken in 1906 shows the Sapulpa group to be about 1,300 feet in thickness. The Tulsa group is estimated to be about 400 feet at the outcrop due east of Cleveland, thus giving a total thickness of 1,760 feet for the two groups. This would seem to indicate that the Cleveland sand is between the base and middle of the Tulsa group as above suggested.

The normal structure in the vicinity of Cleveland is monoclinal with low dips toward the west. The writer, however, has noticed what appears to be some reverse dips within the Cleveland field. No detailed work has been done and it cannot be said with certainty how extensive the folding may be, nor in fact is it certain that the apparent eastward dips were not due to causes other than structure.

The following is a record of the hole drilled on the Ralston townsite in the northeastern part of Pawnee County, from 1,000 to 3,300 feet. This portion of the log was obtained through the courtesy of Mr. John Shepler of Pawnee, but he was unable to obtain the first thousand feet of the record. There are no attempts to correlate the formations because they, as a rule, seem to be more or less dissimilar to anything found in the outcrops farther east. It seems possible, however, that the four heavy ledges of limestone near the bottom of the hole may be tentatively correlated with the Claremore formation, which is the Oswego lime of the driller.

Well in T. 23 N., R. 5 E. on Ralston townsite.

	Thickness. Feet.	Depth. Feet.
Unrecorded	1000	1000
Sand, oil	20	1020
Red shale	15	1035
Salt sand	5	1040
Blue shale	5	1045
Salt sand (water)	15	1060
Blue shale	5	1065
Blue sand	25	1090
Blue shale	5	1095
Red shale	10	1105
Salt sand	15	1120
Blue shale	20	1140
Sandy shale	10	1150
Blue shale	15	1165
Red shale	10	1175
Lime	5	1180
Blue shale	40	1220
Salt sand	25	1245
Blue shale	45	1290
Salt sand	15	1305
Blue shale	18	1323
Sand	28	1351
Blue shale	20	1371
Lime	7	1378
Lime	8	1386
Blue shale	69	1455
Lime	18	1473
Shale	15	1488
Salt sand	15	1503
Lime	5	1508
Blue shale	12	1520
Lime	5	1525
Salt sand	10	1535
Blue shale	5	1540
Salt sand	5	1545
Blue shale	10	1555
Salt sand	195	1750
Blue shale	70	1820
Salt sand	60	1880
Blue shale	8	1888
Salt sand	72	1960
Shale	60	2030
Salt sand	20	2050
Blue shale	75	2125
Cap rock	15	2140
Oil sand	70	2210
White sand	15	2225
Blue shale	50	2275
Blue shale	100	2375
Black shale	5	2380
Lime (Oil)	5	2385
Sandy lime	20	2405
Sand	5	2410
Sandy shale	30	2440
Blue slate	3	2443
Lime (gas)	6	2449
Black shale	5	2454
Shelly lime	8	2462
Shale	3	2465
Lime	5	2470
Shale	4	2474
Lime	5	2479
Shale	2	2481
Lime (gas)	6	2487
Blue shale	20	2507
Lime	20	2527
Black shale	4	2531
Lime	40	2571

ack shale	4	2575
me	40	2615
ack shale	4	2619
me	20	2639
nd (gas)	5	2644
recorded	656	3300

The Federal Survey has analyzed several samples of the Cleveland rude oil. One collected from the Laterette lease within the townsite as of a dark green color, tested 34.4° Baume at 60° F., began to boil t 100° C., and contained 7.75 per cent of paraffin and 0.03 per cent f asphalt. The second sample from well number two, 1,620 feet eep, on the Lowery lease, tested 35.5° Baume at 60° F., began to oil at 85° C., and upon evaporation yielded 15.5 per cent by volume elow 150° C. It contained 4.38 per cent paraffin and 0.82 per cent sphalt. The heaviest sample reported tested 31.5° Baume at 60° F., nd contained 7.26 per cent of paraffin and 0.63 per cent of asphalt.

KAY COUNTY.

The Kay County oil and gas development consists of two small as pools, one at Ponca and one at Blackwell, and one or two isolated ells in which a small amount of heavy petroleum was discovered. One well belonging to the last named class was drilled near Newkirk. n approximate analysis of the oil will be given later.

PONCA CITY FIELD

The production of the Ponca City pool consists entirely of gas, hough occasionally a little oil is encountered. The operations are wned and controlled by the Ponca City Oil, Gas, and Mineral ompany, composed of local business men. They first began distributing gas in 1906 and during the three years 1906, 1907, and 1908 ey sold 178,000,000 cubic feet of gas, for household use only, at the ate of twenty-five cents per thousand.

The first gas wells were drilled in the southern part of the ownsite, and in section 34, just south of the city. During 1909, owever, several gas wells, which are excellent for the district, were rought in northeast of town. Statistics as to the production of 1909 re not at hand but it doubtless exceeds that of previous years. The aily capacity of the wells ranges from 100,000 to a little more than a illion cubic feet.

According to the latest available data there are about a dozen ells which produce gas and probably as many which have been bandoned for different causes. Wells have been drilled to various epths, ranging from 500 feet to 1,215 feet. The first pay sand is t a depth of approximately 500 feet, while the second occurs at from 40 to 960 feet. The initial rock pressure at the shallow wells was rom 375 to 425 pounds. The present rock pressure, however, of the lder wells, is only from about 75 to 175 pounds per square inch.

Geologically the Ponca City field is the highest yet described in the main field. The wells are begun above the horizon of the Wreford limestone which, according to Prosser, is the base of the Permian series. From the log of well No. 38, on the Shelby lease south of Ponca City, it appears, however, that the Wreford limestone is probably encountered at a depth of about 74 feet. The following log seems to be an average of the logs of the deep wells in the Ponca City field. No correlations are attempted, because the stratigraphy from Pawhuska to Ponca City is not well enough understood to warrant definite conclusions.

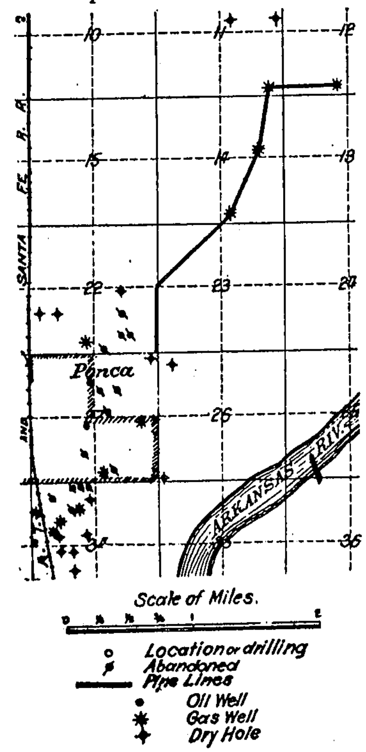
Shelby Lease Well No. 38 south of Ponca City.

	Thickness. Feet.	Depth. Feet.
Soil	6	6
Limestone	12	18
Red shale	32	50
Limestone	24	74
Red shale	61	135
Blue shale	25	160
Red shale	10	170
Blue shale	20	190
Lime	25	215
Red shale	50	265
Blue shale	10	275
Lime	5	280
Blue shale	15	295
Lime	30	325
Sand, no gas	40	365
Lime	5	370
Red shale	25	395
Lime	10	405
Red shale	25	430
Lime	22	452
Red shale	28	480
Lime	12	492
Red shale	18	510
Broken sand	10	520
Red shale	30	550
Cased at 550.		
Red shale	20	570
Blue shale	15	585
Lime	35	620
Blue shale	25	645
Lime	25	670
Blue shale	15	685
Lime	20	705
Blue shale	5	710
Lime	55	765
Blue shale	25	790
Lime	10	800
Blue shale	47	847
Lime	43	890
Blue shale	32	922
Sand	18	940
Sand, blue shale	35	975
(Pulled all casing and plugged hole according to law.)		

The operations during the past year in the Ponca City field have only been what might be considered normal, that is, the drilling of 1909 has averaged pretty well with that of previous years since the discovery of gas. Structural conditions in the region have never been carefully studied and it is impossible to make any suggestions as to the probable future of the field.

NEWKIRK WELL

During the early part of the present decade a company of local men at Newkirk banded themselves together and prospected for oil. Their endeavors did not repay their outlay, though they found some heavy oil. The quantity, however, was too small to operate. After a few more wells had been driled in eastern Kay County the Newkirk people abandoned the enterprise.



PONCA CITY GAS FIELD.

The following is a log of the Newkirk well as reported in a thesis written in 1906 by Guy Y. Williams:

	Thickness. Feet.	Depth. Feet.
Surface and limestone	8	8
Red sandstone and limestone	5	13
Limestone	12	25
Light shale	10	35
Red shale	10	45
Limestone	25	70
Sandy shale	5	75
Red shale	30	105
Limestone	13	118
Red shale	17	135
Limestone	7	142
Shale	5	147
Red shale	53	200

Limestone	10	210
Red shale	25	235
Sandstone	10	245
Shale	5	250
Red sandy shale	10	260
Sandstone	5	265
Red shale	24	289
Limestone	10	304
Limestone	41	345
Light shale	5	350
Limestone	5	355
Shale	8	363
Limestone	25	388
Shale	15	403
Limestone	43	446
Sandy shale	10	456
Limestone	19	475
Light shale	40	515
Limestone	5	520
Shale	130	650
Limestone	5	655
Shale	115	770
Limestone	10	780
Light shale	23	803
Limestone	10	813
Shale	12	825
Limestone	7	832
Shale	63	895
Limestone	10	905
Shale	33	938
Gas and oil sand	10	948
Shale	20	968
Salt water sand	37	1005
Shale	65	1070
Limestone	8	1078
Shale	22	1100
Limestone	15	1115

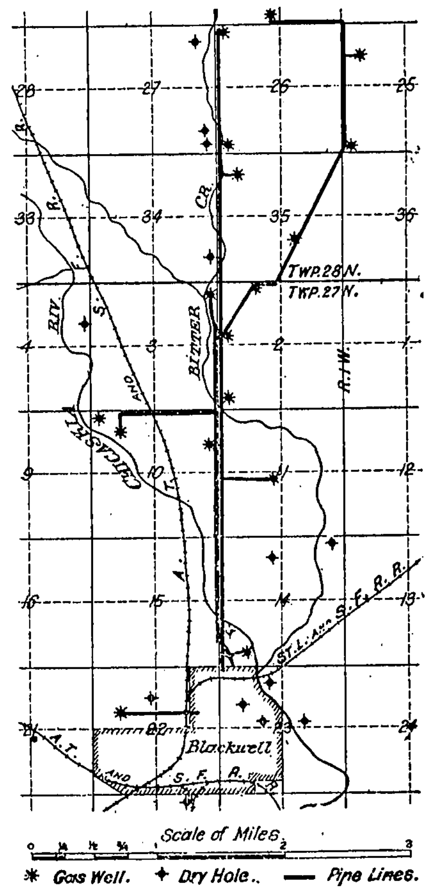
No correlations are attempted, further than to state that the lime stone at the surface is what is locally known as the Newkirk limestone. The geological section of the region is not yet well understood, but it seems probable that the twenty-five feet of limestone from forty-five to seventy feet may be the Wreford or the base of the Permian series.

A sample of oil taken from the above well was analyzed by Mr. Williams, now assistant professor of Chemistry in the State University at Norman. His results were in part as follows: Gravity, 34° Baume at 60° F. On distillation, 7.48 per cent was given off below 302° F., while 40.43 per cent was vaporized between 302° and 572° F. After the second distillation the residuum was found to contain 81. per cent of lubricating oils and 17.99 per cent of coke. The oil also contained a trace of calcium oxide and iron oxide and nearly one per cent of sulphur.

BLACKWELL POOL.

The Blackwell gas pool consists of a number of wells lying due north of the city of Blackwell, in western Kay County. The nearest production is within one quarter of a mile of the city limits, while that farthest out is more than five miles to the north. Until within the past few months the output was controlled by two companies. These, however, have now consolidated and the city is served by a single corporation. So far no paying oil wells have been discovered.

The development in the Blackwell pool during the year 1909 was steady but there was nothing phenomenal in the drilling results, except that the best well of the field, located in the northernmost extension of the field, was brought in during the last days of December.



BLACKWELL GAS FIELD.

Geologically the Blackwell field is the highest in the State. The wells are begun well up in the Wellington and Marion formations of Permian age, perhaps not less than 500 feet above the base of the Wreford limestone which has, for a number of years, been considered the lower limit of the Permian rocks in Oklahoma and Kansas. Beede, however, now considers the Elmdale formation as the base of the Permian. If Beede's conclusions are correct the Blackwell gas occurs within the Permian series. If, however, Prosser's conclusions are confirmed the production is from the upper portion of the Pennsylvanian series.

The rocks of the region consist of alternating sandstones, shales, and limestones of varying texture and thickness. Of the formations, the shales are usually gray to black, while the limestones are whitish to cream colored. The sandstones are usually nearly white. Red formations seldom occur, although the logs given in the following pages show several thin strata of red shales or sandstones. It is to be noted, however, that the non-red formations predominate. The Permian rocks of this portion of the State are more often highly fossiliferous than are the typical Redbeds. These two facts, namely, that the rocks are usually dark in color and frequently contain quantities of fossils, make it probable that oil and gas have originated in the rocks of the Blackwell and Ponca City regions. Furthermore, there seem to be no unconformity between the Pennsylvanian and Permian rocks of northern Oklahoma. Therefore it does not seem necessary to look beyond the Permian for a source of supply for the oil and gas of Kay County, though it is not yet certain that production comes from rocks of that age.

The region surrounding Blackwell is a nearly level-lying plain covered with several feet of residual soil so that exposures of rock in place are very rare. This makes it impossible to determine the structure in detail. Such observations as have been made seem to indicate that the normal structure is monoclinal with low dips to the westward. There are no data at hand which tend to account for the fact that the gas development lies in a narrow belt with a nearly north and south trend.

The following logs quite thoroughly represent conditions as reported by the drillers who have worked in the field.

O. GREEN WELL NO. I.

On SW. ¼ sec. 23, T. 28 N., R. 1 W., about six miles north of Blackwell. Authority, Union Oil and Gas Co.

	Thickness. Feet.	Depth. Feet.
Surface soil	25	25
Water sand (fresh water)	12	37
Clay	15	52
Gypsum	1	53
Shale	27	80
Limestone	4	84
Shale	2	86
Lime (gas show at 150 feet)	26	112
Lime and shale	104	216
Shale	44	260
Sandy shale	15	275
Shale	9	284
Red rock	128	412
Lime and shale	13	425
Sand (salt water)	8	433
Lime	7	410
Red rock	30	470
Lime and shale	50	520
Sand and lime (salt water)	13	533
Shale	3	536
Lime	2	538
Shale	8	546
Red rock	16	562
Red rock (hard)	2	564
Red rock	3	567
Lime	20	587
Red rock	6	593
Lime	7	600
Shale	5	605
Red rock	15	620
Sand (salt water)	24	644
Shale	4	648
Lime	20	668
Shale	15	683
Red rock	44	727
Lime	3	730
Shale	3	733
Red rock	31	764
Lime	10	774
Sand (gas)	6	780

Rock pressure 350 pounds.
Capacity 2,250,000 cubic feet per day.

BRANINE WELL NO. I.

In W. ½ NW. ¼ sec. 2, T. 27 N., R. 1 W., about three miles north of Blackwell. Authority, Union Oil and Gas Co.

	Thickness. Feet.	Depth. Feet.
Surface soil	45	45
Sand (water at 55 feet)	10	55
Shale	40	95
Limestone	20	115
Shale	150	265
Red rock	40	305
Shale	40	345
Limestone	20	365
Shale	25	390
Salt water at 400 feet.		
Limestone	35	425
Shale	5	430
Red rock	20	450
Sand	10	460
Limestone	20	480
Red rock	10	490
Limestone	15	505
Sand	10	515
Salt water at 510 feet.		
Limestone	20	535
Blue shale	5	540
Red rock	15	555
Red rock	5	575
Limestone	10	585
Red rock	45	630
Limestone	10	640
Shale	10	650
Limestone	10	660
Shale	20	680
Red rock	85	765
Limestone	25	790
Sand (gas)	10	800
Shale	10	810
Limestone	15	825
Sand (gas)	3	828
Limestone	112	940
Shale	35	975
Sand (gas)	5	980
Limestone	5	985
Sand	40	1025
Limestone	10	1035
Shale	35	1070

Limestone	10	1080
Sand	15	1095
Shale	75	1170
Limestone	10	1180
Shale	5	1185
Limestone	10	1195
Shale	45	1240
Limestone	30	1270
Sand	15	1285
Shale	30	1315
Sand	10	1325
Limestone	20	1345
Sand	45	1390
Shale	25	1415
Limestone	30	1445
Shale	15	1460
Limestone	10	1470
Sand (salt water)	30	1500
Plugged at 835 feet—producing well.		

CITY WELL NO. 2.

In NW. ¼ NW. ¼ sec. 23, T. 27 N., R. 1 W., on townsite of Blackwell. Drilled by City of Blackwell.

	Thickness. Feet.	Depth. Feet.
Surface soil	4	4
Red clay	8	12
Sand	5	17
Clay	25	42
Slate	40	82
Blue slate	90	172
Limestone	10	182
Light shale	58	240
Limestone	23	263
Lime (water)	67	368
Red shale	62	430
Light shale	35	465
Limestone	10	475
Shale	25	500
Lime (salt water)	40	540
Red shale	75	615
Limestone	45	660
Red shale	56	716
First gas at 708 feet.		
Black sand	18	734
Light shale	10	744
Limestone	26	770
Red rock	15	785
Fine sand (salt water)	25	810
Red shale	55	865
White sand	27	892
Light flow of gas at 865 feet.		
Light shale	10	902
Fine sand	8	910
Red rock	15	925
Limestone	45	970
Fine sand (salt water)	20	990
Too much salt water. Lost reamer and string of tools—had to abandon well.		

By inspection of the above logs it will be noted that the gas occurs at various depths ranging from 640 feet to 980 feet. So far as exposed the formations do not have sufficient dip to warrant the supposition that this is the same sand throughout the field. It is more probable that several different sands produce gas in the Blackwell district. The deepest well in the field of which we have record, is

known as Branine well No. 1, about three miles north of the city. It was dug to a depth of 1500 feet but no gas was found below 980 feet.

So far there has been no crude oil discovered in the vicinity of Blackwell. Considerable quantities of naphtha, which sometimes tests as high as 70° Baume, collects in the gas mains. This, however, does not indicate the presence of large quantities of oil of that nature in the sand, as is supposed by some, but is due to the condensation of some of the heavier gases when exposed to temperatures lower than those of the well.

It seems that production in western Kay County has been confined to the region as defined in this report. Several wells have been drilled in the Redbeds farther west in the State but thus far none of them have yielded either petroleum or natural gas. At present there is a well being drilled at Alva with the hope of finding either oil or gas. At last reports they had attained a depth of nearly 3,000 feet and were still drilling.

THE CREEK FIELD

For convenience in discussing the oil and gas development of the Creek Nation is divided into four districts, namely the Muskogee district, the Bald Hill-Morris district, the Redfork-Glenn pool, and the Preston-Henryetta district. This division is not entirely artificial but is based on the fact that these groups place the development in a series of pools, the wells of which are begun at about the same geological horizons.

MUSKOGEE DISTRICT

The Muskogee oil and gas field consists of two pools known as the Townsite pool and the Chicken farm pool.

THE TOWNSITE POOL.

The first well drilled on the Muskogee townsite was in 1894 by McBride and Bloom of Independence, Kans., who were drilling for the Cudahy Oil Company. They discovered a small amount of light oil but the find was not followed up until 1904 when between thirty and forty wells were drilled near the Katy railroad on what is now the southern part of the townsite. None of the wells in the townsite pool were large producers, although all yielded a very high grade of oil. The limits of the field were pretty thoroughly determined by the close of 1905 and drilling was suspended because the pool was very small. A refinery was built at Muskogee which used practically the entire output of the field. The production decreased and from time to time wells have been abandoned until now only a few of the original ones are producing.

The townsite field is, geologically, the oldest production in the State. That is to say, the wells occur farther down the geological scale than those of any other pool. The rocks belong to the lower half of the Winslow formation, of lower Pennsylvanian age. That formation has an average thickness, according to Taff's description in the Muskogee folio, of about 800 feet. The oil of the townsite pool occurs at depths ranging from 1020 to 1060 feet. Logs of the wells show that the rock section consists almost entirely of sandstones and shales to a depth of 700 feet, where a heavy limestone, the Morrow also of Pennsylvanian age, is encountered. The Pitkin limestone, of Mississippian age, occurs below the Morrow. It also seems to be represented in some of the townsite wells. This, however, is not the universal condition as will be seen from the following log.

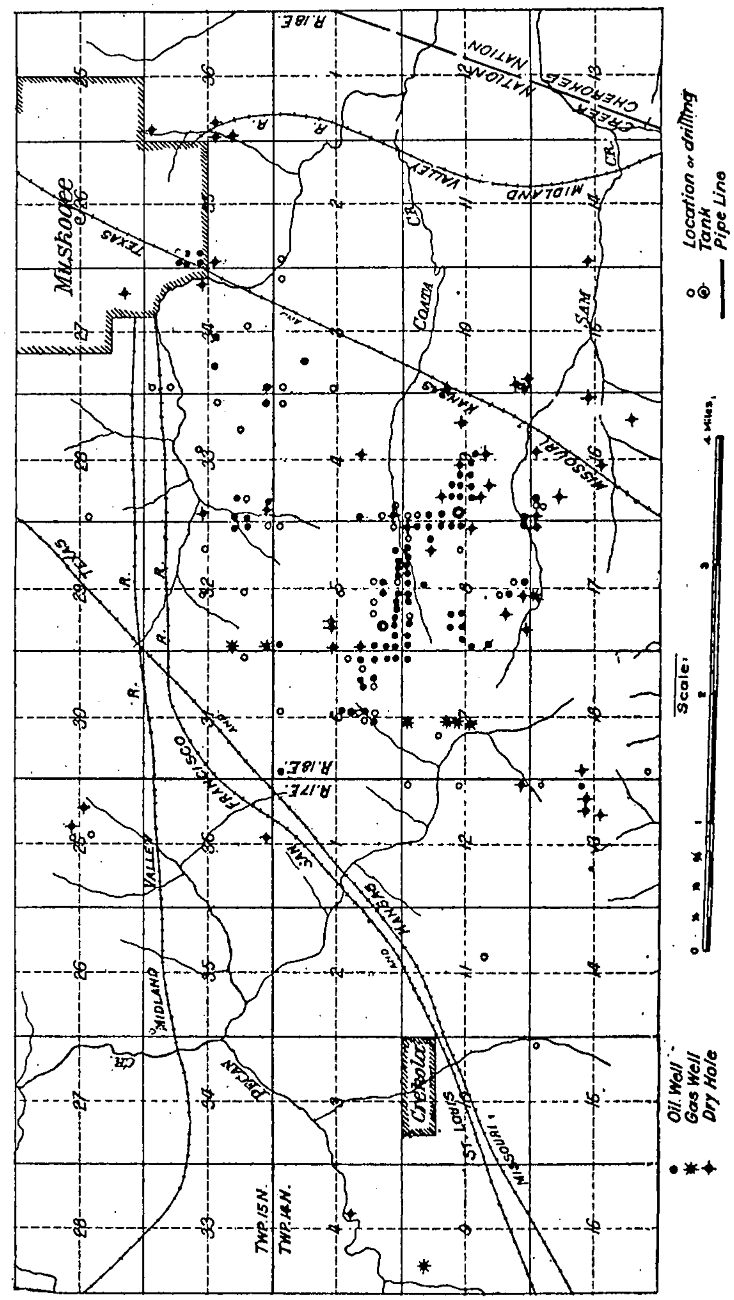
Well in old townsite field, Muskogee, Oklahoma. Drilled October and November, 1896. Authority, A. P. McBride.

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

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

By inspection it will be noticed that but one limestone of importance is recorded in the above log. This has a thickness of twenty-five feet and as it is the first limestone encountered it is, beyond reasonable doubt, the Morrow. If such is the case, the Mississippian series was not entered in this well, thus making it appear that the Winslow and Morrow, at this point, are very much thicker than the section given by Taff in the folio above mentioned.

Structural conditions around Muskogee are very irregular. From such data as the writer has been able to collect it is impossible to determine whether the oil of the townsite pool occurs within the horizon of the Pennsylvanian series or near the top of the



MUSKOGEE OIL AND GAS FIELD.

Mississippian. In some cases it seems that the latter is true, while in others it appears impossible for the bottom of the well to be below the Pennsylvanian rocks.

A sample of oil from a townsite well, 1000 feet deep, tested 40.4° Baume at 60° F., was light olive green in color and began to boil at 110° C. On distillation about six per cent by volume was vaporized below 150° C. The sample contained 3.88 per cent paraffin and no asphalt.

CHICKEN FARM FIELD.

The first well drilled in this pool is located on sec. 9, T. 14 N., R. 18 E. It was drilled during the winter of 1906 and 1907, and was the largest producer of high grade crude that had ever been discovered in the State, so it attracted a great deal of attention. As a result operations became very active and drilling was rapid. The field has been found to be very spotted, but was extended over a considerable area lying mainly west of the Missouri, Kansas and Texas Railroad and southwest of Muskogee, though development of the past few months has extended northeast nearly to the old townsite pool, and across the Katy tracks along Coata Creek.

The occurrences are very erratic. Some of the wells went to a depth of more than 1000 feet, while at the distance of only a few hundred feet another well sometimes develops good pay at much less depth. The Chicken farm pool is the one which is now referred to in current discussions of the Muskogee field.

The rocks of the Chicken farm pool are alternating clay shales and friable sandstones nearer the top of the Winslow formation than those of the Townsite pool. The sandstones on the hill south and west of the field belong to the Boggy formation as described by Taff in the Muskogee folio. Thus the rocks on the surface of the field are about 150 feet from the top of the Winslow formation. If, therefore, the thickness of the Winslow formation is not more than 800 or 1000 feet, and the Morrow, Pitkin and Fayetteville formations do not exceed 240 feet as estimated by Taff one would expect to enter the Boone formation (Mississippi lime) in this vicinity at a depth of about 1100 or 1200 feet. No carefully kept well records are at hand and it is not known what the formations penetrated by the drill are. It has, however, been the writer's privilege to examine a number of logs from this field and so far as he has been able to determine none of the wells of which they were records had entered the Boone formation or Mississippi lime. It therefore seems that at least the greater part of the oil of the Muskogee region is found above the so-called Mississippi lime of the drillers.

Operating activities in this pool during the year of 1909 were below normal but owing to the fact that the oil was of a high grade, and therefore usually commanded a better price the region was looked upon with more general favor than those pools which produce heavier oil, but the erratic nature of the occurrences discouraged development to a marked degree.

Several analyses of crude oil from the Chicken farm pool have been made. Of these the following seem to be fairly representative. One sample, collected by the Prairie Oil and Gas Company, was olive green in color, tested 37.5° Baume at 60° F., began to boil at 99° C. and yielded 3.5 per cent by volume when distilled below 150° C. This sample contained 12.45 per cent paraffin and no asphalt. Another sample which gave a Baume test of 39.4° at 60° F., began to boil at 83° C. and contained 6.02 per cent paraffin and no asphalt. Of ten samples of oil analyzed from the Muskogee district not one contained a trace of asphalt and some ranged as low as 1.24 per cent in paraffin.

THE BALD HILL-MORRIS DISTRICT

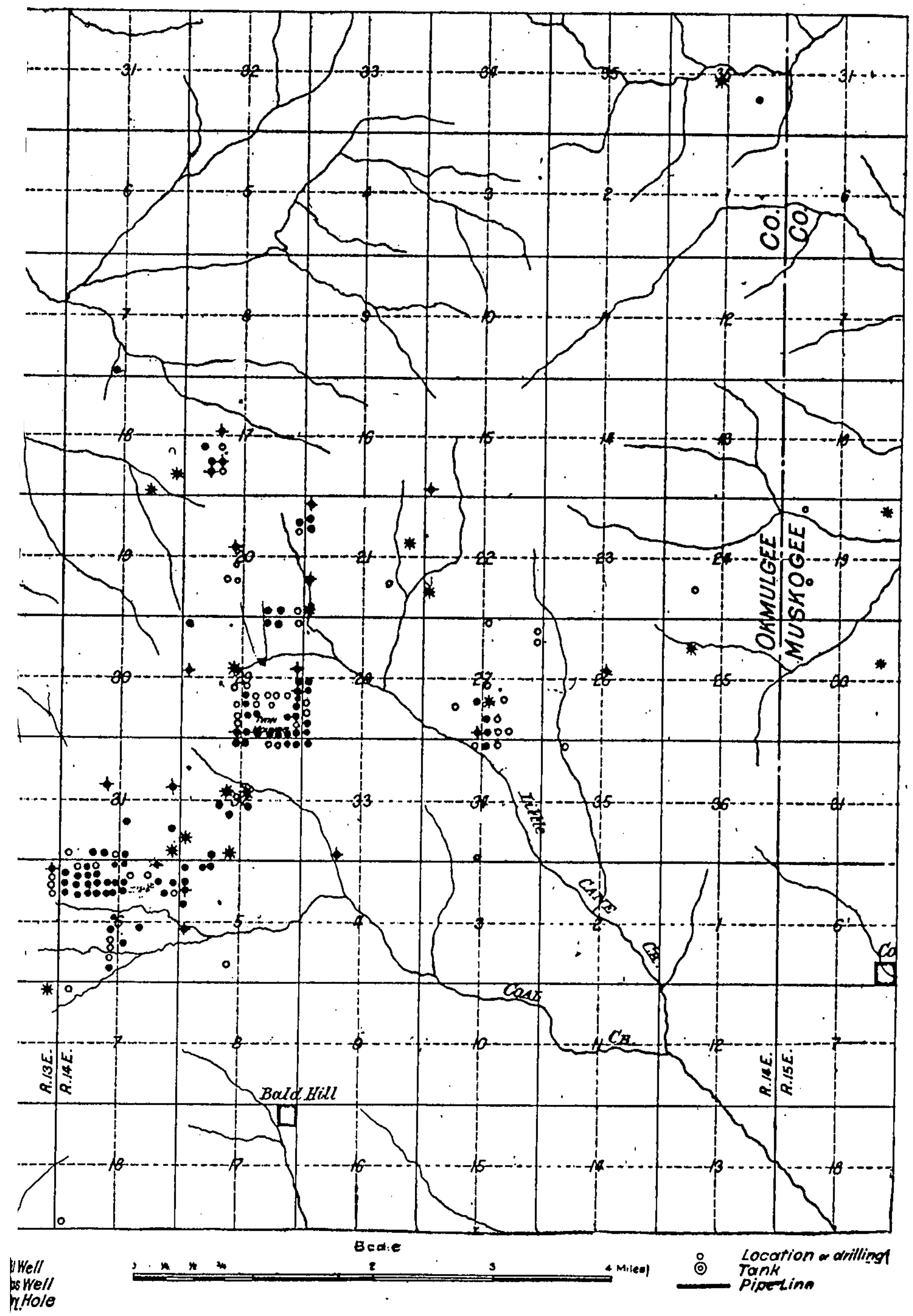
This district contains two pools known as the Morris and Bald Hill pools. A third area of considerable promise is being prospected along Ash Creek near Haskell, but it is yet in the preliminary stages of development and little is known of its value.

MORRIS POOL.

The Morris pool was the first to be developed in the Bald Hill-Morris district. The first pay well brought in was on sec. 5, T. 13 N., R. 14 E. This was a good gas well and development proceeded with considerable rapidity. It was soon discovered, however, that the field was more or less erratic and holes were sunk in various directions and at distances from the original well. Gas was discovered on the Morris townsite and both oil and gas were found about three miles southeast of the town, while later prospecting developed several good gas wells between Morris and Okmulgee. Development failed to establish any connection whatever between the pool southeast of Morris and the gas on the townsite.

The first pay well southeast of Morris was brought in during the summer of 1906. It is in this region that the main pool has been developed. The formations of the region, however, are broken and the pay is usually spotted.

The rocks of the region consist of alternating sandstones and shales (with occasional beds of workable coal) belonging to the upper members of the Muskogee group as already defined. As at present understood, the sandstone capping the ridge on which the old Okmulgee Mission, between Morris and Okmulgee, is located, is the upper limit of the Muskogee group. If this correlation is correct, the wells of the Morris pool are started and completed within the Muskogee group. It seems, therefore, that the production in the pool is entirely from rocks of Pennsylvanian age. The following log gives an idea of conditions as recorded by the drillers.



BALD HILL OIL AND GAS FIELD.

Well in Morris field. On SW. ¼ sec. 5. T. 13 N., R. 14 E. Near Morris.

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

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.

Surface exposures in the vicinity of the Morris pool are few and it is difficult to determine the structure in detail. Such data as can be collected indicate the region to be one in which the soft friable sandstones and shales have been mashed and crumpled. Where conditions are favorable for inspection narrow anticlinal and synclinal folds are often seen which probably do not extend to sufficient depths to influence accumulation. However, since the rocks exposed reveal short local crumplings, it seems reasonable that similar conditions may obtain at greater depths. It therefore appears possible that the accumulation of the oil and gas of the Morris region is controlled, in part at least, by local structure the effects of which cannot be seen at the surface.

Operations in the Morris pool during the past year have been fairly active when the depressed conditions of the market and the general ban on operations is considered. In general, however, the prospecting has been more in the nature of wild-catting than of steady development.

Analyses show that the Morris oil is especially high in paraffin and contains little or no asphalt. Analyses reported show that the oil tested from 35.5° to 37° Baume, while the paraffin content varied from 6.75 per cent to 11.9 per cent. Only one sample reported contained asphalt and that only to the extent of 0.10 per cent.

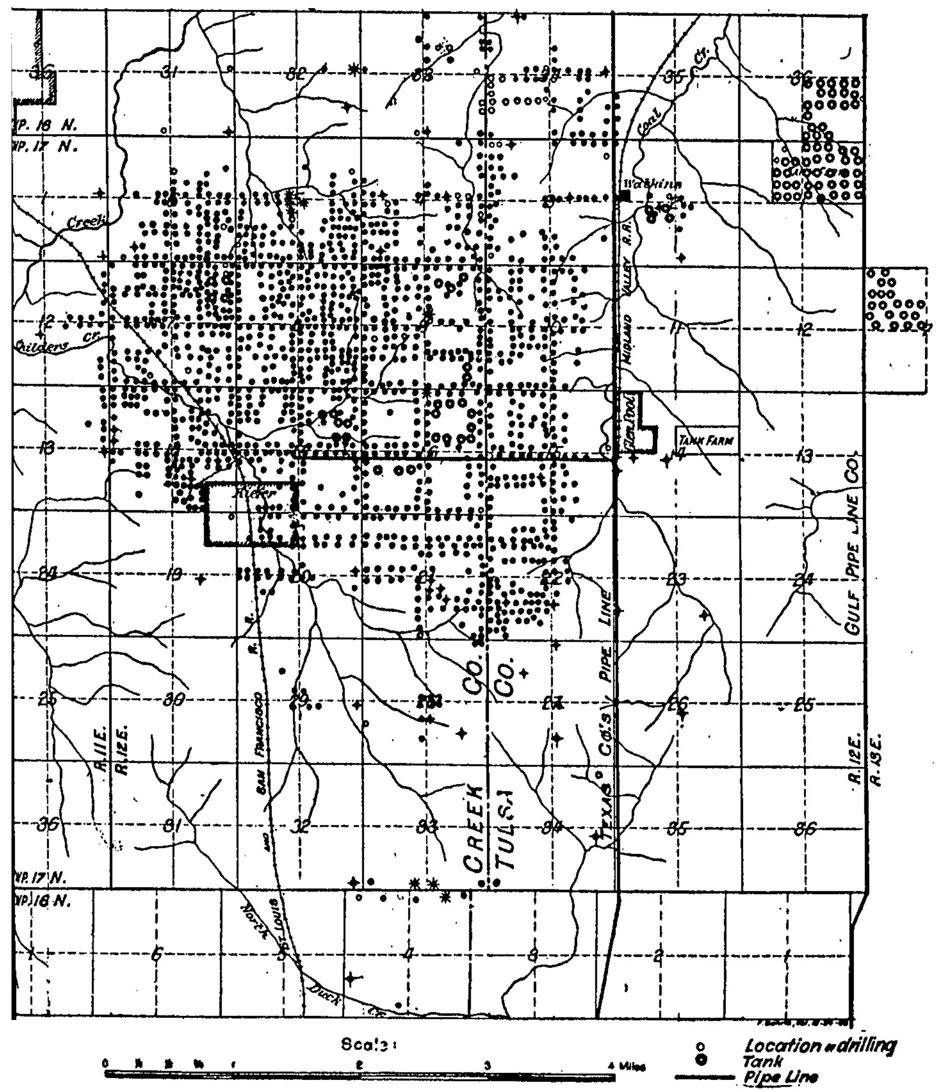
BALD HILL POOL.

The first well drilled in the Bald Hill field was completed during the winter of 1907 and 1908. It was drilled by Galbreth and Chesley in the southwestern portion of T. 15 N., R. 14 E. The results were satisfactory and a pool of considerable importance has been developed in that vicinity.

The geological and structural conditions are very similar to those described in the Morris pool, excepting that the wells are usually started in the Sapulpa group above the top of the Muskogee group in which the Morris wells occur.

Activities during the past year have not been phenomenal though some good wells have been discovered. Drilling in the vicinity of Haskell, about fifteen miles northeast of this field, has resulted in some very promising wells. Conditions are such that there is reason to believe that a considerable pool will be discovered extending from the vicinity of Porter southwest toward sec. 31, T. 15 N., R. 15 E.

The oil of the Bald Hill pool is of a lower grade than that of the Morris pool. Only two analyses are reported. Of these, one is from a 1,680 foot well on the Buchanan lease. It was dark green in color, tested 34.1° Baume at 60° F., and boiled at 120° C. It contained 3.43 per cent of paraffin and 0.15 per cent of asphalt, while a second sample tested but 33.2° Baume under similar conditions, boiled at 131° C., contained 5.7 per cent of paraffin and 0.76 per cent of asphalt.



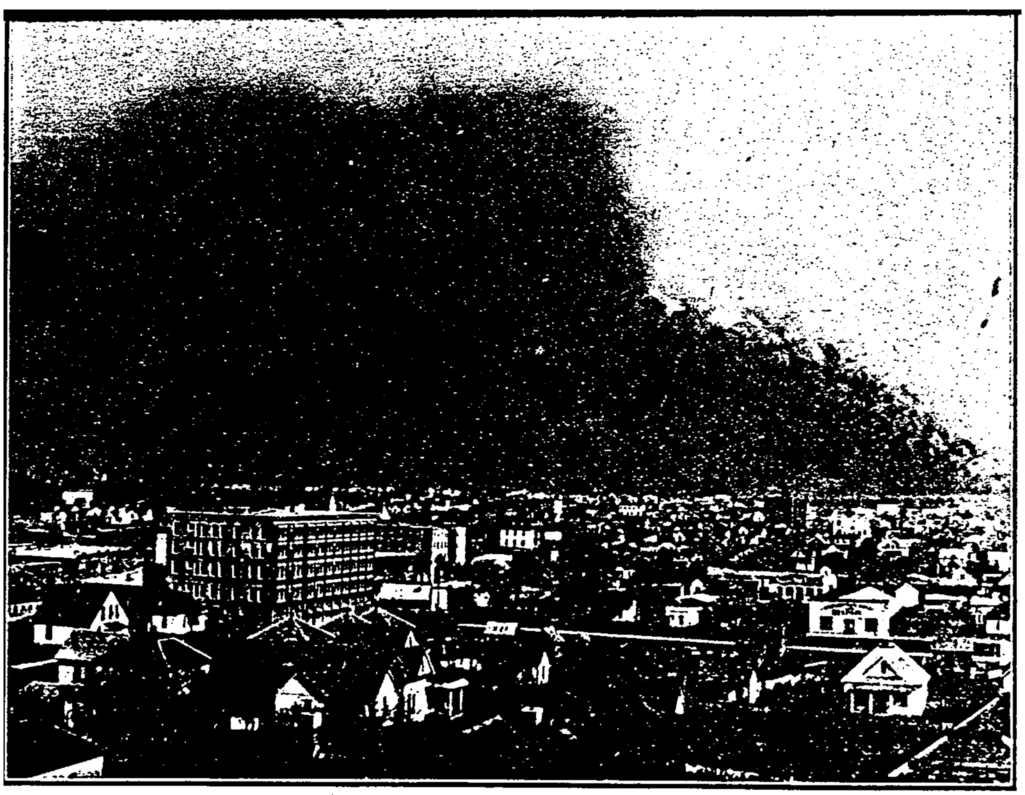
GLENN POOL OIL AND GAS FIELD

REDFORK-GLENN POOL DISTRICT

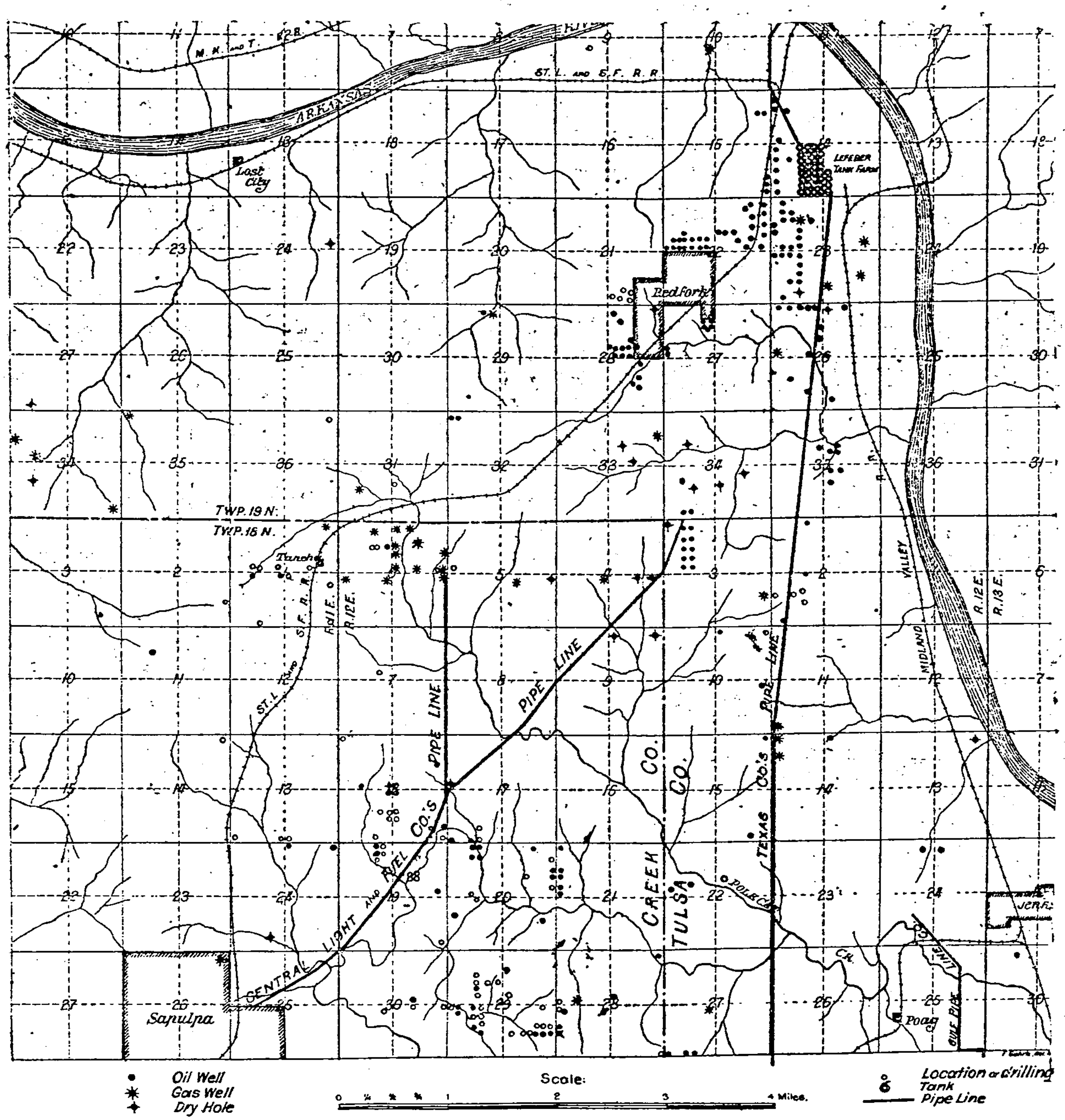
This district extends from the Arkansas River bottom, opposite Tulsa, south to the southern limit of the Glenn pool north of Mounds, and is divided into three pools or fields, namely the Redfork pool, the Tanaha pool and the Glenn pool. In point of production, this is by far the most important district in the State, its importance being largely due to the phenomenal production of the Glenn pool, which is the most remarkable field the world has ever known.

The first discovery of oil in this district was near Redfork in 1901. Two sands were developed in this region, known as the Redfork sand and the deep sand. While the pool is a good one there is nothing phenomenal in its production. The Glenn pool was discovered by Galbreth and Colcord during the summer of 1906. The wells have been of remarkable production and promise great longevity. The Tanaha field was discovered in 1908 in attempting to extend the Glenn pool northwestward. Development has been steady in that region and good pay has been almost uniformly discovered, but it in no wise rivals the Glenn pool.

The geological conditions of this entire region are very similar. The Lenapah limestone, known to the drillers as the "Checkerboard" limestone, outcrops on the north bank of the Arkansas River, just above the Frisco bridge at Tulsa, in the wagon road northeast of Redfork, and on the hills in the vicinity of the "ninety-sixth meridian pool." It is also exposed in several places in the Glenn pool and east



BURNING OIL NEAR SAPULPA.



REDFORK OIL AND GAS FIELD.

of Mounds. It is thus apparent that the wells in the Redfork and Glenn pools are begun at almost exactly the same geological horizon, while those of the Tanaha pool are started perhaps 100 to 150 feet higher up in the Sapulpa group.

The normal structure is monoclinal with low dips to the west. The writer has noticed several reversals of dip in various places from the Arkansas River south to Mounds. No detailed work, however, has been done to determine whether there is any relation between the structure and oil accumulations or not. A series of carefully kept logs from east to west across the Glenn pool seems to indicate that the oil sand is an old beach bar of large dimensions, the greatest development of which appears to have extended nearly north and south through secs. 4, 9, 16 and 21 of T. 17 N., R. 12 E. The sand in this portion of the field has its maximum thickness and the upper surface seems to form a broad gentle arch. The sand is overlain with close-grained formations, which form a splendid cap rock. In addition to the arching due to the contour of the sand there are some evidences of slight folding. So the Glenn pool accumulation, as far as can be determined by a superficial examination, seems to be controlled by anticlinal folding accompanied with irregular sedimentation.

The following logs of the Glenn and Redfork pools seem to be an average of the drillers records in the district.

On sec. 3, T. 17 N., R. 12 E. In the vicinity of Sapulpa and in the Glenn Pool.

	Thickness. Feet.	Depth. Feet.
Soil	20	20
Blue shale (doby)	45	65
Lime	5	70
Water sand	5	75
Sandy slate	20	95
Blue shale (doby)	50	145
Sandy slate	40	185
Doby	60	245
Sand	30	275
Blue sand and shells	50	325
Lime	12	337
Blue shale and shell	70	407
Blue slate	243	650
Slate	100	750
Black slate	40	790
Lime	45	835
Blue slate (show of gas at 889½)	65	900
Sand	21½	921½
Blue shale	33½	955
Lime	15	970
Sandy shale	20	990
Sand	6	996
Black slate	50	1044
Blue shale	100	1144
Black slate	68	1212
Sandy limestone	8	1220
Blue shale	80	1300
Black slate	50	1350
Sand and shells	18	1368

Sand and shells	40	1408
Blue shale	8	1416
Sandy shale	80	1496
Gas at		1500
Oil		1557
Oil sand to		1610
Total depth		1612

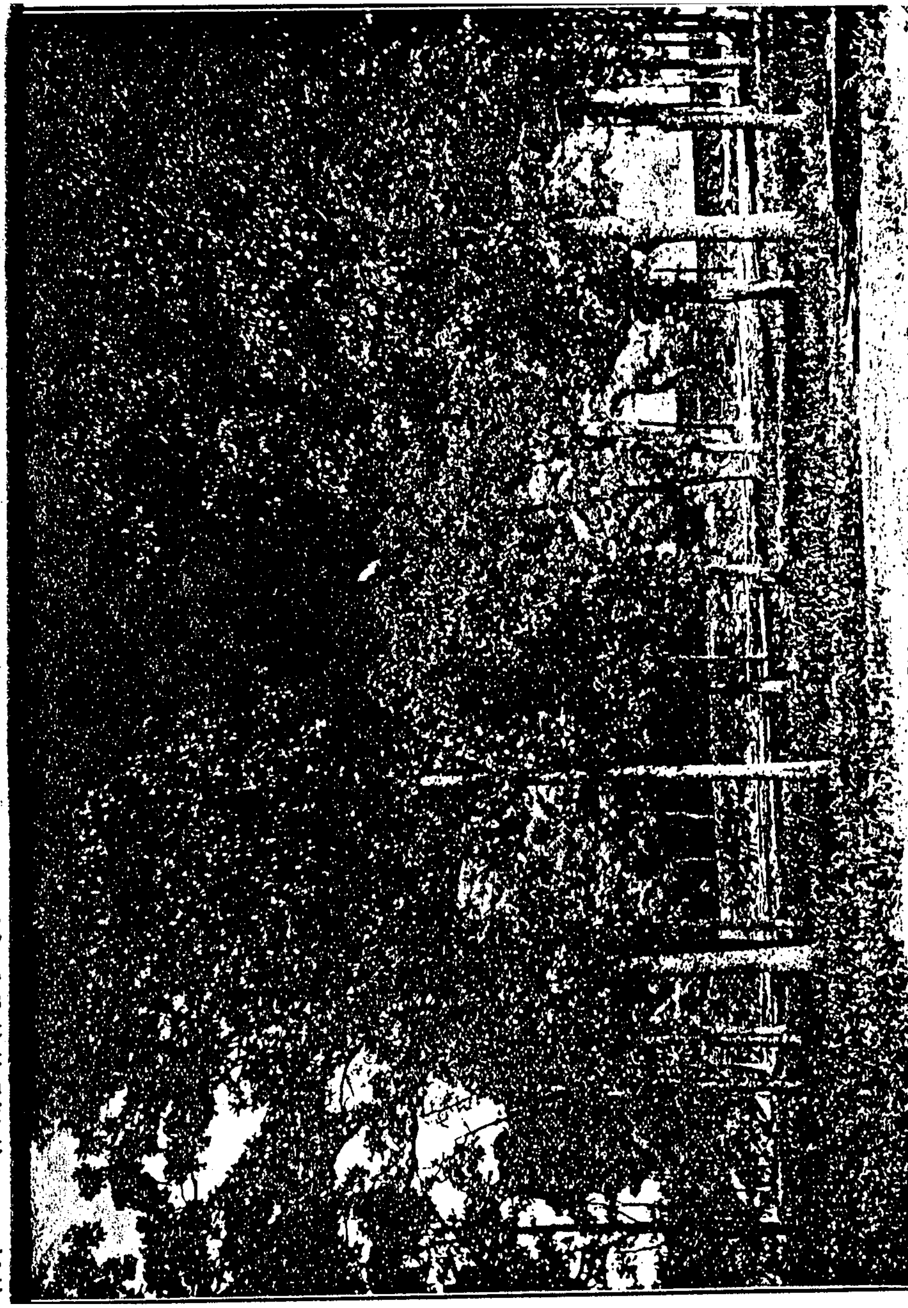
Well at Red Fork, Oklahoma. Located close to Turkey Mountain. Drilled in January and February, 1897 to 1,440 feet. Later it was sunk to 1,800 feet without finding any oil or gas.

	Feet. Thickness.	Feet. Depth.
Soil	38	38
White sand	52	90
Slate	13	103
White sand	35	138
Dark shale	47	185
Lime	75	260
Dark shale	40	300
Lime	10	310
Black shale	100	410
White shale	90	500
Dark shale	40	540
White shale	40	580
Dark shale	83	663
Gray lime	10	673
White lime	27	700
Black shale	5	705
White sand	10	715
Shale	120	835
Lime	30	865
Black shale	30	895
Sand	8	903
Dark shale	76	979
Gray lime	10	989
Black shale	15	1004
White shale	20	1024
Black shale	25	1049
White shale	81	1130
Sand	30	1160
Black shale	128	1288
Black slate	10	1298
Sand	34	1332
White shale	108	1440

A number of analyses of Glenn pool crude have been reported. The oil is uniformly black and ranges from 35.5° to 38° Baume at 60° F. The boiling point varies from 80° to 112° C., while the paraffin content ranges from 3.12 per cent to 11.46 per cent. All samples reported contained some asphalt, the maximum being 0.90 per cent and the minimum being 0.11 per cent. A sample from a 2,340 foot well in sec. 18, T. 16 N., R. 12 E., east of Mounds, was light green in color, began to boil at 175° C., and contained 8.44 per cent of paraffin and 0.62 per cent of asphalt. This boiling point is the highest recorded in the Mid-Continent field.

PRESTON-HENRYETTA DISTRICT

The Preston-Henryetta district consists of the development lying between Preston, formerly known as Hamilton Switch—northwest of Okmulgee—and Henryetta. Development in this district is comparatively recent and no well defined pools have been outlined. Oil



BURNING OIL NEAR TULSA.

was first discovered at Henryetta early in the present decade but the quality was poor and the quantity small so that the discovery attracted little attention. Later, however, some good wells were drilled in what is known as the Tiger Flat, south of Okmulgee, which created considerable interest. During the summer of 1909 one of the best wells of the year was brought in near Hamilton Switch, northwest of Okmulgee on the Preston farm. This discovery led to active operations and the Preston pool was rapidly developed.

Oil wells having an initial daily capacity of 1,000 barrels or more were drilled in and some gas wells had a reported capacity of from 36,000,000 to 40,000,000 cubic feet per day. Later prospecting, however, has made the field appear rather disappointing in that the great promise of the first few wells was not fulfilled. Several dry holes have been drilled at comparatively short distances from the original Preston well. Operators, however, are not discouraged and prospecting goes on. It is thought likely that a very creditable pool will be developed in this vicinity though it is not probable that it will be a second Glenn pool, as was predicted by some during the first few weeks of its history.

What is ordinarily called the Henryetta field is the development in T. 12 N., R. 13 E., or thereabouts, lying northeast of the town of Henryetta. The wells of this district are usually in the neighborhood of 1,200 to 1,500 feet in depth. Production is reported to range from 250 to 500 barrels. There has been some deep drilling done in the vicinity of Schulter on the Frisco road a few miles north of Henryetta. The deepest well reported is 2,340 feet but it seems to have been dry.

The Preston-Henryetta district was the most active region during 1909 and is apparently still in the lead of the older fields in drilling operations.

The rocks of this region consist almost wholly of sandstones and shales with one or two beds of workable coal. As at present understood the sandstone on the hills in the vicinity of Henryetta and just east of Okmulgee marks the upper limit of the Muskogee group, while those in the vicinity of the Preston pool are considered to belong to the lower portion of the Tulsa group. The wells of the Henryetta field are therefore started and completed within the Muskogee group, while those of the Preston pool began drilling in the Tulsa group and are completed in the Muskogee group. The following log was reported to the Survey by W. B. Pine.

Well one-half mile south of Henryetta, Oklahoma. Authority, W. B. Pine.

	Thickness. Feet.	Depth. Feet.
Soil	10	10
White slate	89	101
Hard gray limestone	4	105
Soft white slate	100	205
Soft grayish blue slate	197	402
White sand (some water)	32	434
White shale	76	510
Grayish blue shale	245	865
White sand (some water)	45	910
Soft white slate	50	960
Hard gray slate	56	1016
White sand (heavy paraffin oil and gas)	11	1027
White slate, few lime shells	865	1892
White sand (dry)	15	1907
Hard gray limestone	101	2008
Soft white slate	5	2013
Hard gray limestone	7	2020
Coal, fine quality	4	2024
Hard gray limestone	256	2276
Soft gray slate	30	2306
Hard sandy lime shell	3	2309

When we consider the fact that all the formations which underlie the district outcrop between Henryetta and the mouth of the Canadian River without revealing any limestone members of more than a few inches in thickness it does not seem possible that the report of a limestone formation nearly 400 feet thick can be correct.

The normal structure of the district is monoclinal with low dips to the northwest. Faulting, which is said to disappear toward the northeast as an anticlinal fold, is reported in the immediate vicinity of Henryetta. It is not known whether the development northeast of Henryetta is associated with this folding or not.

In passing through the region of Hamilton Switch before there was any development in the field the writer noticed some terraces or arrested anticlines, but it is not known whether there is any probable relation between structure and production in the Preston pool or not.

ISOLATED OCCURRENCES.

Wildcat drilling has discovered a number of occurrences in the old Creek Nation which are not without promise. One of these is a gas well southeast of Bristow which developed an initial rock pressure of about 900 pounds and is at present supplying the city of Bristow with gas. Another is a well recently drilled a few miles south of Keystone, at the mouth of the Cimarron River, which is reported to have had an initial production of 200 barrels, but has settled to a good steady well of about fifty barrels. Two or three small wells were drilled several years ago near the town of Manford, while the small development known as the Smith and Swan wells northwest of Sapulpa have been producing for a number of years. In 1906-'07

some small production was obtained about four miles northwest of Beggs, and later a good gas well was drilled farther west. Paying wells have also been discovered south of Mounds.

CONCLUSION.

At present the development in the main oil and gas field of Oklahoma is bounded on the north by the Kansas line, on the east by the main line of the Katy railroad and on the west and south by a line from Henryetta to Blackwell, passing through Jennings. There seems every reason to believe that the development will go southward from Muskogee and Henryetta, and westward at least as far as Wewoka, Bristow, and Pawnee. As one approaches the Redbeds, drilling will become continuously more difficult due to the caving tendency of the formations.

SEMINOLE COUNTY.

As at present developed, the only occurrence of petroleum or natural gas in Seminole County is in the 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 has 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 profitable 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.

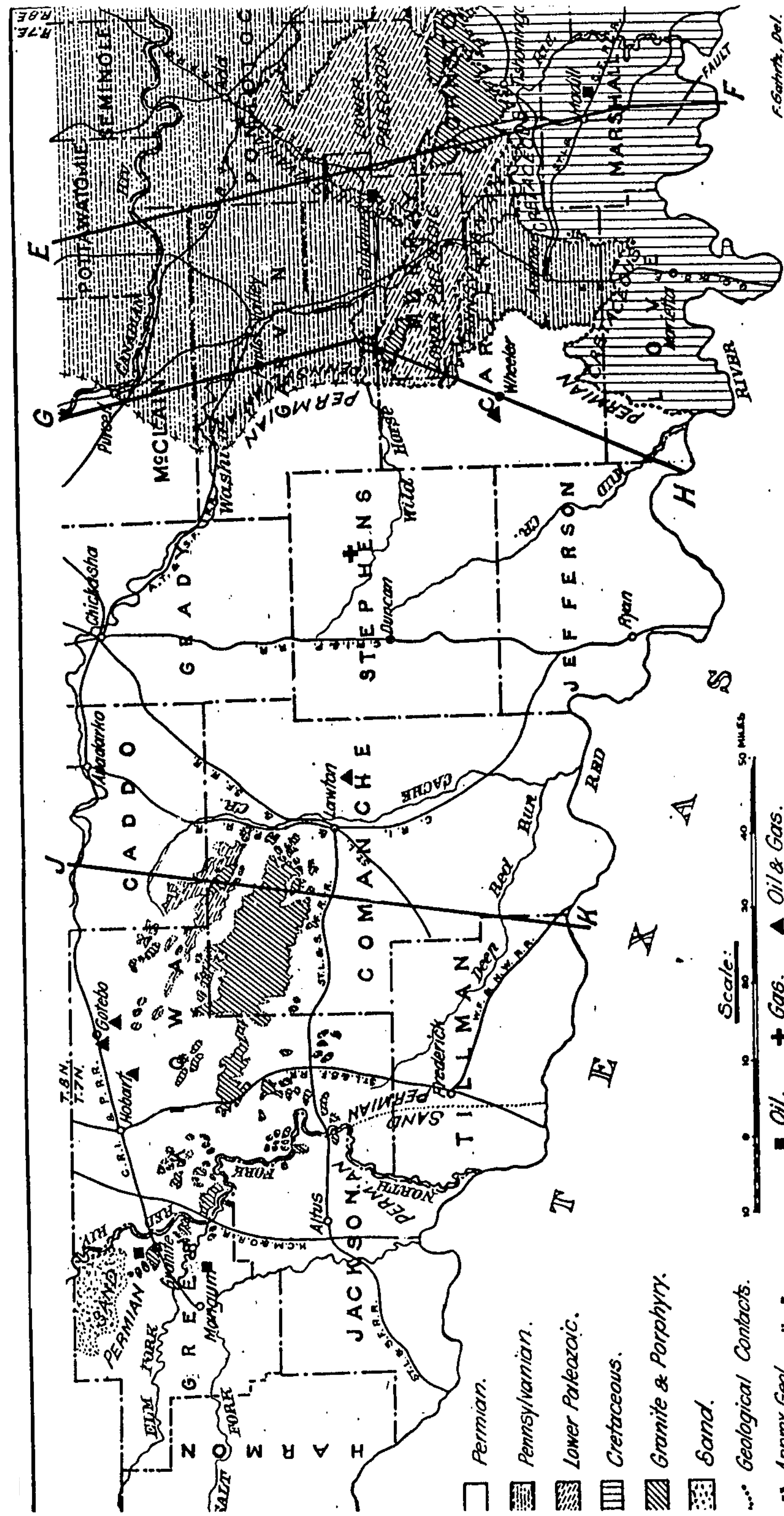
Wewoka Trading and Realty Co. Well No. 4 on sec. 19, T. 8 N., R. 8 E.

	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 abou t170 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
P'a^k 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	10	845
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 region from Tulsa north, in all probability, do not extend this far south. It may be, however, that some of the liemstones 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 Turly 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



SOUTHWEST OIL AND GAS FIELD.

sandstone, the southern representative of the horizon of the Claremore 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.

MINOR OCCURRENCES OF OIL AND GAS

INTRODUCTION.

It is the purpose of the writer to discuss under this caption the small fields and isolated occurrences of petroleum and natural gas which have been discovered in the southern part of the State near the Wichita and Arbuckle mountains. Either oil or gas, or both have been found in considerable amounts at Madill, Hope, Wheeler, Lawton, Gotebo, and Granite, while seeps of viscous asphalt and heavy oil have been found, as stated in Part I. of this report, at numerous places from Bokhoma to Granite, north as far as Ada and Page, and south to the Red River. Petroleum and natural gas, however, have not been found in paying amounts east of Madill. The area, therefore, to be considered in a discussion of the geology of the petroleum bearing belt of southern Oklahoma includes that portion of the State lying south of the township line between townships eight and nine north and west of the range line passing near Durant. The general geological features of this region have already been discussed in Part I. of this report and the reader is referred thereto for data on the regional geology of the district.

GRANITE.

The first attempted oil development in the vicinity of Granite was in 1901, when a local company drilled a dry hole in the NE. ¼ sec. 35, in the southern part of the townsite. The hole was drilled 380 feet deep, when granite was encountered and drilling stopped. Nothing further was done until the summer of 1901, when another hole was drilled north of Headquarters Mountain in the SE. ¼ NE. ¼ sec. 10 about four miles northwest of the town of Granite. A little oil was discovered at a depth of 168 feet. A pump was installed and production proved to be about three or four barrels per day. The yield continued nearly uniform until the following year when an attempt was made to increase the production by shooting, but the well was destroyed. During that summer (1901) Dr. Price and associates of Chicago, drilled a dry hole in the NE. ¼ sec. 10, T. 6 N., R. 21 W., to a depth of 800 feet. The following summer the same persons drilled two holes in the SE. ¼ sec. 28, T. 5 N., R. 21 W., to a depth of 900 feet. It is reported that a little gas was found and that indications were good for oil, but for some reason both holes were lost. In 1903 there was a hole drilled on the NW. ¼ sec. 10, T. 6 N., R. 21 E., about 100 feet from the one which had produced at a depth of 168 feet. The oil was again encountered at the same depth, but after producing a few hundred gallons, the enterprise was abandoned. There was nothing further done in the region until 1904, when the Myers Oil Company undertook the drilling of a deep well in the SW. ¼ SW. ¼ sec. 24, T. 7 N., R. 21 W. Work on this well was carried on at different times during the years 1904-'05-'06 until a total depth of over 2135 feet was finally reached. No pay sands were struck. It was reported, however, that oil and gas showings were encountered at various horizons. According to the driller's log, furnished by Mr. Stacy, who was in charge of the drilling, several showings of oil and gas were encountered. The log follows:

Well on W. ½ of NW. ¼ sec. 24, T. 7 N., R. 21 W., about seven miles north of Granite.

	Thickness. Feet.	Depth. Feet.
Red clay	8	8
Quick sand	10	18
Green shale (trace of gas)	92	110
Brown shale	4	114
Green shale	20	134
Red shale	46	180
Light gray shale	5	185
Red shale	135	320
Gip rock (hard)	3	323
Green shale	5	328
Red shale (hard)	28	356
Green shale (some gas)	15	371
Red shale (hard)	307	678
Green shale (hard)	3	681
Mixed red and green shale (hard)	19	700
Mixed hard and soft strata of red and green shale, strong gas and oil showing at 750 feet	100	800
Green and red shale, hard and soft, caves badly	50	850
Conglomerate, hard (salt water)	65	915
Conglomerate, hard and soft (some gas)	5	920
Light shale (soft and salt water)	8	928
Conglomerate, soft green and red shales (caves)	10	938
Green shale	77	1015
Sand, close, ricky, hard (oil showing)	44	1059
Hard sand rock	12	1071
Soft sand rock (gas forces oil and water from hole		
Blue limestone	5	1663
Sandy conglomerate, some shale (gas)	73	1150
Sandy conglomerate	30	1180
Sandstone (quartz appearance)	35	1215
Sandy conglomerate (yellow oil, gas)	25	1240
Quartz sand (pockets of oil and gas)	176	1416
Green and red shale, soft sand (caves)	15	1590
Quartz sand, gray (some oil and gas)	241	1865
Quartz sand, soft (gas, oil, salt water)	5	1870
Quartz sand, greenish	90	1960
Quartz sand, very hard	25	1985
Sand, light green, soft (some gas)	30	2015
Sand, grayish	67	2082
Sand, blackish	53	2135

It appears that traces of either oil or gas were encountered in nearly every sandstone of importance from the top to the bottom of this hole, but no pay was developed. The formations penetrated were sandstones and shales only. No limestone is reported.

At the time the writer visited the field, January 1909, there was a little sulphur gas escaping from one of the 168 foot wells in sec. 10, T. 6 N., R. 21 E. This, however, seemed to be entirely an

emanation of hydrogen-sulphide which probably had its origin in the disintegration of iron pyrite (fool's gold) crystals of which are often seen in the outcrops of the shales.

At present, everything is quiescent in the field and no new development is being attempted.

STRATIRAPHY

The geology of the Granite region is comparatively simple. The mountains of that country consist of red pre-Cambrian granite, composed chiefly of feldspar, quartz, and hornblende.

The mountains rise like islands from the Permian Redbeds, which form the surface of the surrounding country. The Redbeds consist of alternating red shales and sandstones with occasional blue, gray or white streaks and are geologically younger than the Pennsylvanian rocks of the oil fields in the northeastern part of the State. The Permian rocks lie unconformably on the crumpled and faulted formations of earlier geological times.

What is believed to be the true oil bearing formations of the vicinity of Granite are covered by a blanket of Permian rocks and it is impossible to get at their structure from surfacial observation.

While it is possible that oil and gas may be found in paying quantities in this vicinity the geological conditions are such that one would not be warranted in considering it as probable a region as the main Oklahoma field, even though neither region had ever been tested by the drill.

GOTEBO FIELD.

The Gotebo field lies south and southwest of the town of Gotebo in northeastern Kiowa County. There have been, in all, between thirty and fifty wells drilled in the field. The drilling was chiefly done by five companies: the Whitewater Oil and Gas Company; the Gotebo Oil, Gas, and Brick Company; the Deering Oil and Gas Company; and the New State Oil and Gas Company. Each of these companies has met with some degree of success, but the first one named has been the most fortunate and is now supplying the town with gas.

The rocks of the region are composed, in the main, of typical Redbeds sandstones and shales, though there are occasional calcareous streaks, conglomerate beds, and thin members of gray to greenish shales. As a whole the formations have the general appearance of being near the base of the Redbeds though their horizon was not determined with certainty. The formations are cross-bedded, to some extent, and the structure could not be readily outlined. There are, however, evidences of folding in the vicinity of the main field directly south of Gotebo, but no attempt was made to determine whether or not there seemed to be any relation between production and structure.

At the last detailed report the Whitewater Oil and Gas Company had drilled twenty-five wells, five of which were dry; eight yielded some oil but five of the oil wells had been abandoned, and the remainder produced gas on completion. The best oil well had an initial flow of fifteen barrels but had settled to a daily capacity of five to ten barrels at the beginning of 1909. The best gas well tested 550,000 cubic feet daily when it was first brought in. The deepest well drilled by the Whitewater Company is 600 feet. It made a show of oil but was abandoned.

Several wells have been drilled by the Whitewater Oil and Gas Company since these data were procured but the results are as yet unknown.

During the year 1908 the consumption of gas from the Whitewater Oil and Gas Company's wells amounted to about 13,000,000 cubic feet. The rate is higher than in the main field, being for domestic purposes $0.70 per thousand for the first 5,000 feet, then $0.30 per thousand until the customer has consumed 20,000 cubic feet, when it is raised to $0.40 for the remainder of his consumption. At the time the field was visited the gas supply exceeded the demand and an industrial rate of $0.10 per thousand cubic feet was being offered. The rates now current are not known.

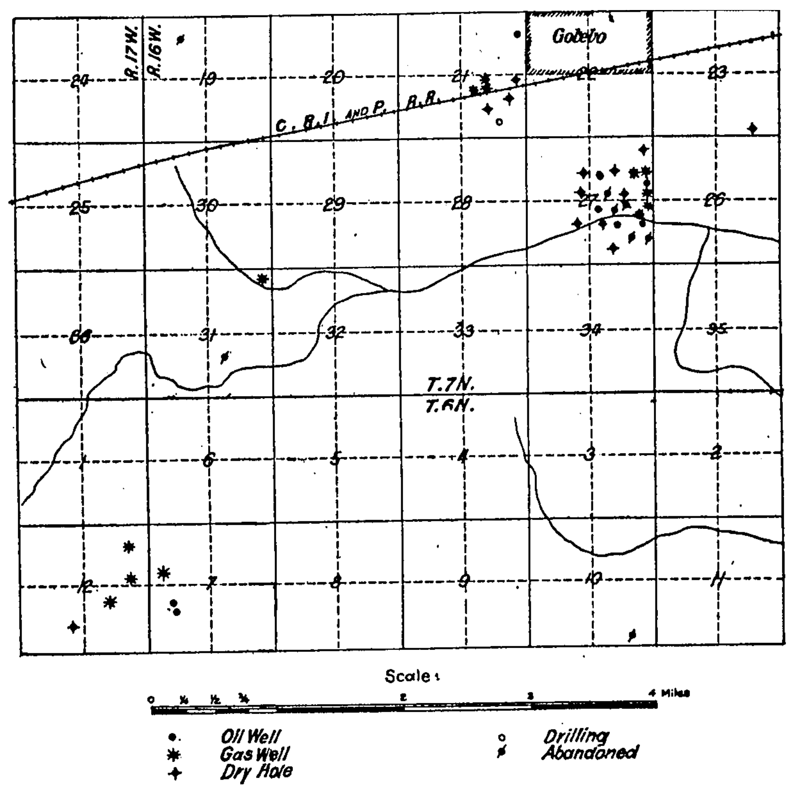
The Gotebo Oil, Gas, and Brick Company had, at the beginning of 1909 three dry holes and three gas wells. They were at that time down nearly 1,700 feet on their seventh well but had met with no success. It was reported that they intended to go to 2,500 feet but nothing is known of the results. So far as known this is the deepest hole in the field.

A log of this well was procured and seems to bear out the idea exepressed in the beginning of the discussion on the Gotebo field that the surface rocks are near the base of the Permian, as no heavy limestones are known at any horizon of the Permian in western Oklahoma. It is as follows:

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 drilling was stopped.

The Deering Oil and Gas Company had, at the beginning of the year, three wells, one a gas well of about 300,000 cubic feet per day which also produced a little oil, and two oil wells which yielded about



GOTEBO OIL AND GAS FIELD.

ten barrels each. Since that time they let a contract for six more wells, the first of which was completed at 480 feet and is a good gasser for the Gotebo district. The results of the other five in the contract are not known.

When the field was examined the New State Company had two small gassers each of which had an estimated daily capacity of about 300,000 cubic feet. Some of their leases are adjacent to the Gotebo Oil, Gas, and Brick Company's leases and more drilling has probably resulted from the activity of that company.

CONCLUSION

In general the production of the Gotebo oil and gas field comes from depths ranging from 300 to about 400 feet; though traces of both oil and gas have been found at deeper horizons, none have paid to operate except, perhaps, the new wells of the Deering Company.

The sand ranges from a few, to thirty-five feet in thickness and is usually very open. The rock pressure is low, and water is often troublesome.

So far as known at present only one deep hole has been drilled. It was found barren and seems to bear out the belief that the oil and gas are found near the unconformity between the Permian Redbeds and the older Paleozoics involved in the Wichita Mountain Uplift. In the light of present data it is impossible to predict the probable presence or absence of commercial quantities of oil and gas at greater depths in the field.

THE LAWTON FIELD.

In general the geology of the Lawton field is analogous to that of the regions around Granite and Gotebo. The Permian Redbeds overlie the older Paleozoic rocks which are thought to be petroliferous at some horizons, and have doubtless yielded the supply found in the wells of this region. The Redbeds thin out, owing to uplift and erosion, a few miles northwest of the field and are asphalt bearing at one or two places near the base.

The gas produced by the Lawton Oil and Gas Company is piped to Lawton and distributed for domestic purposes only. The production supplies the demand only in part.

The prospecting for oil and gas in the vicinity of Lawton has been done chiefly by a local concern, the Lawton Oil and Gas Company. A number of dry holes have been sunk in other parts of the field by various persons but this company is the only one that has secured paying production.

The first well was located on the N. ½ NW. ¼ sec. 6, T. 1 N., R. 10 W., just five miles east of Lawton. It was completed in August of 1904 at a depth of 400 feet, and had an initial rock pressure of 125 pounds and a production of about half a million cubic feet of gas per day.

During the same year the company completed a well southeast of their number one. Gas was not found, as had been anticipated, but a light production of black oil was obtained. Nothing more was done in the pool until 1906 when a dry gas well was drilled in the E. ½ NE. ¼ sec. 1, T. 1 N., R. 11 W., being less than a half mile from the first one. It had an initial rock pressure of 100 pounds and produced a little less than a half million cubic feet of gas per day.

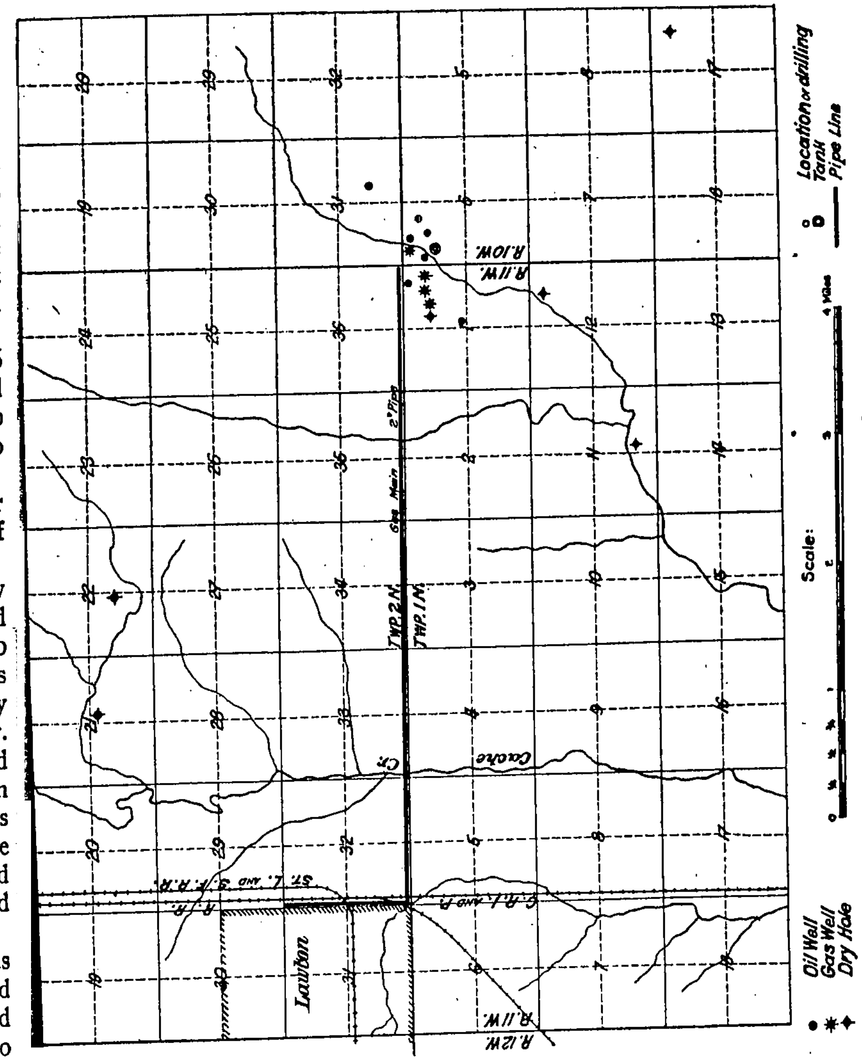
The third well drilled by the Lawton Company was on N. ½ NW. ¼ sec. 6, a location southeast of the first gas well. Oil was found at a depth of 320 feet. Packers were so set as to save the oil and the well was drilled on to the 400 foot sand where gas was found. The initial rock pressure was about 100 pounds, and the well is estimated to have produced 300,000 cubic feet per day, while the oil produced from the 320 foot sand originally amounted to about 15 barrels daily. A pump has been installed and the well is still producing a little oil.

The same company's well, number five, was drilled during 1906 in the north half of the northwest quarter of section 1, a few hundred feet northwest of number three. Oil was found at a depth of 400 feet. The capacity has never been tested, though oil is reported to be standing within thirty feet of the top.

The next well drilled was 200 feet to the southwest of number five and was brought in, during 1906, as a dry gasser at a depth of 400 feet. In 1907 the well tested nearly 450,000 cubic feet per day.

Well number seven was drilled, during December 1906, a few hundred feet southwest of the one last mentioned. Oil of an estimated capacity of two or three barrels a day was found at a depth of 250 feet. Drilling continued to a depth of 390 feet where the gas was found and the well completed as a gasser. The last well reported by this company was completed during January of the present year. Showings of oil were encountered at 225 and 250 feet, but the sand was dry at 380 feet. Owing to the general topography of the region the sand at 380 feet appears to be the regular 400 foot sand, so it is probable that this will ultimately prove to be a dry hole. Besides the wells already enumerated the Lawton Natural Gas Company drilled one in the E. ½ NW. ¼ sec. 6. It was completed during 1907 and produced oil in the 400 foot sand but has since been abandoned.

Wells drilled by companies other than the Lawton Natural Gas Company have uniformly been failures, as none of them have produced either oil or gas in merchantable quantities. Those to the southward from the Lawton Natural Gas Company's productions were drilled to various depths ranging from 500 to 700 feet, while one in sec. 21, T. 2 N., R. 11 W. is reported to have been drilled to a depth of 2,250 feet. Neither oil nor gas was found, but an artesian well, flowing the full capacity of a four inch pipe, resulted. Another well drilled about a mile farther east is reported to have produced a little gas at 500 feet.



LAWTON OIL AND GAS FIELD.

GAS AT HOPE.

The occurrence of gas at Hope consists of a single well drilled four or five years ago in sec. 12, T. 1 N., R. 6 W., about three miles northeast of the town. Little is known, save that a considerable acreage of leases was secured and this one test drilled. It is reported that a flow of about 3,000,000 feet of gas was developed but no authentic record could be obtained. The residents of the region say the well could be heard roaring for a distance of nearly a mile. The gas was ignited by accident and the rig was burned. The well is now plugged and a large cedar pole has been driven into the casing, which is still intact.

STRATIGRAPHY.

The rocks of the region consist of typical Permian Redbeds to an unknown depth. The well is located on an anticline which trends slightly west of north and seems to be the last expression of the fault which passes northwest from Arthur across sec. 6, T. 1 S., R. 5 W. The rocks on either side of the fault are slightly asphaltic in the section named.

The possibilities of the region are unknown but it is thought not improbable that a field at least as good as those at Lawton, Wheeler, and Gotebo is probable. Structural conditions rival those at Petrolia, Clay County, Texas, and are better than in any of the Oklahoma fields just mentioned. The occurrence and source of supply it appears, must be analogous to those at Wheeler to be described later.

THE WHEELER FIELD.

INTRODUCTION

The Wheeler oil and gas field is located in the west central part of Carter County in secs. 16, 17 and 21, T. 3 S., R. 2 W., about eighteen miles northwest of Ardmore, and is often spoken of as the Ardmore field. It is within fifteen miles of the southwestern part of the Arbuckle Mountain Uplift and on the water shed between Caddo and Walnut creeks. Ardmore is the nearest railway station, though the proposed line from Ardmore to Waurika is expected to pass about eight miles to the southward of the field.

The information concerning the field was obtained through the courtesies of H. B. Goodrich, manager of the fuel oil production of the Santa Fe Railroad, from published reports of the United States Geological Survey, and by personal observations.

The presence of oil seeps and the occurrence of asphaltic bitumen saturating some of the sandstones has been known in the vicinity for many years, and Eldridge[159] in his report on the Asphalt

159 Eldridge, Geo. H., Asphalt and bituminous rock deposits of Indian Territory: 22nd Ann. Rept., U. S. Geol. Survey, pt. I., 1900-'01.

and Bituminous Rock Deposits of the Indian Territory suggested the possible presence of oil in the vicinity, however it was not until 1904 that actual prospecting, under the direction of the fuel oil department of the Santa Fe Railroad Company, proved its presence. During 1903, a careful study of geological conditions in the region was made by H. B. Goodrich who recommended the present site as a possible producing area. The company then secured 1,980 acres of land in fee and began drilling in May, 1904.

There are two classes of rocks involved in the Wheeler region. These have been described in considerable detail in Part I. of this report and will only be mentioned here in a general way. The rocks consist of Paleozoic strata from Cambrian to mid-Carboniferous times, and the Permian Redbeds. Of the first group only the Glenn formation of Carboniferous age, probably Pennsylvanian, is of immediate interest in considering the Wheeler field.

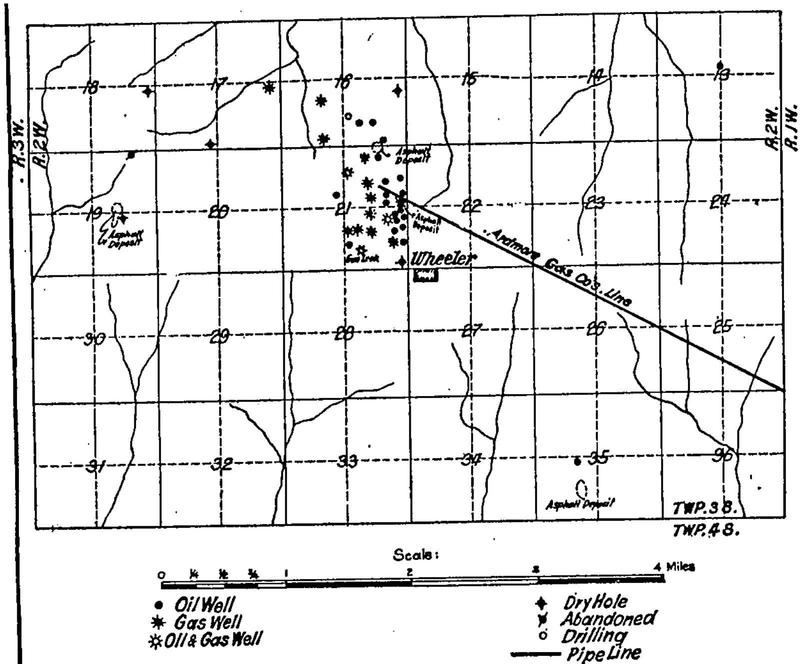
The Glenn formation consists of alternating sandstones and shales, bituminous at many places where exposed, with some unimportant limestone lentils interbedded. It is the rock asphalt bearing horizon at Overbrook near Ardmore and at Woodford, while the Permian rocks consist of typical Redbeds sandstones and shales, constitute the surface in the immediate vicinity of Wheeler, seem to yield the oil and gas of the field, and lie unconformably upon the Glenn formation.

STRATIGRAPHY

Sedimentation was interrupted during or probably near the close of Pennsylvanian times by a profound uplift in the Arbuckle Mountain region which resulted in folding, faulting and upturning of the strata involved in the deformation. Thousands of feet of rocks have been removed from above the present Arbuckle Mountains so that the strata which once arched over the entire system are now represented only by a narrow rim which outcrops around the core of older rocks. Practically the same conditions obtained in the Criner Hills region so that the expanse between the Arbuckle Mountains and those hills represents a structural trough, or syncline, of the closed type composed almost entirely of rocks of the Glenn formation. The entire region

STRUCTURE

appears to have been worn down nearly to a plain so that the rocks in the syncline outcrop in a nearly vertical attitude, and have a northwest-southeast strike. Subsidence succeeded erosion and the Permian Redbeds encroached from the northwest and were deposited in a nearly level-lying position across the upturned members of the Glenn formation. There are occasional irregularities in the Redbeds which seem to suggest folding but owing to the unevenness of



WHEELER OIL AND GAS FIELD.

deposition no definite structural forms have been determined in the region of the oil and gas production. It is not thought that the Redbeds of the Wheeler pool have been sufficiently folded to influence the accumulation of the oil and gas.

DEVELOPMENT

Development of the Wheeler field was begun by the Santa Fe Railway Company in May, 1904, after they had secured nearly 2,000 acres of land in fee. The first well was undertaken with a Columbia drilling machine on the NE. ¼ SE. ¼ sec. 21, T. 3 S., R. 2 W., but it was soon discovered that the formations caved badly and the hole was abandoned. The second attempt resulted in a flow of gas at about 150 feet which supplied fuel for operating purposes for about two months, when the gas was cut off by a cave. The hole was then continued to 516 feet and converted into a water well. The third attempt resulted in the loss of nearly all the tools in the field at a depth of about 500 feet. It was not until October 1905 that a strike was made which seemed to assure success. The company had found the work so heavy that they began the use of the standard drilling outfit and carried their fourth well to a depth of 860 feet where a flow of 6,000,000 cubic feet of gas was struck. Deeper drilling developed a pay of oil, and an attempt was made to take the gas off through an eight inch casing and the oil through a four inch tubing, but the casing was not down to the gas sand and the shale caved and stopped the flow of gas. In 1906 it was discovered, in the sixth well drilled in the pool, that there are two pays, one of gas the other of oil, separated by a few feet of shale, the oil being below. Since that discovery many of the wells have been finished as combination oil and gas wells. In such the gas is taken from the higher sand through the outside casing while the oil is procured through a smaller casing or tubing.

The paying production both of oil and gas comes from a depth of 860 to 1,000 feet, depending, it appears, on the present surface irregularities and the unevenness of the old pre-Permian land surface upon which the Redbeds lie. Some of the wells produce gas only, and others oil alone, but as a rule both gas and oil are encountered and occasionally one or the other is present in appreciable amounts in every Redbeds sandstone penetrated by the drill. Although the Santa Fe Company has completed more than thirty wells in the field only a few of which, comparatively speaking, have been dry. Production in gas has ranged from three and three-fourths million cubic feet per day to 13,500,000 cubic feet, while oil tests have shown from five to sixty-eight barrels per day of a heavy black asphaltic oil from 20° to 23° Baume. The marketing of oil has never been attempted as the amount available does not warrant the construction of transportation facilities. Two of the wells were put to a pumping test for one year and were found to produce as much oil on the last day as on the first. This seems to be a remarkable showing for wells of heavy oil, and probably indicates a long life for the field.

Two deep wells have been drilled in the field: one to 2,427 feet, the other to nearly 4,000 feet, but no pay was found below the 1,000 foot sand. The records indicate that the horizon of the Redbeds is passed at from 860 to 1,000 feet and the Pennsylvanian entered. From the vast thickness of shale and limestone recorded and the difficulty of keeping the hole straight, the formations seem to be dipping at high angles.

Other companies have taken leases surrounding the field and from time to time have drilled wells but none have developed paying properties, either in oil or gas.

PROBABLE SOURCES OF THE OIL

The conditions under which the oil or gas, or both, occur at Granite, Gotebo, Lawton, Hope and Wheeler seem to be similar in all essential respects: that is, they occur near the base of the Redbeds close to the unconformity between the Permian rocks and the older Paleozoic formations, so that what is said concerning the source of supply of the Wheeler oil is equally applicable to the other four mentioned.

The Redbeds formations contain asphaltic bitumen in the Wheeler field, and at numerous places in nearly every diretcion from the developed area, as may be seen by reference to Part I. of this report. The same is true in northern Texas in the region of Petrolia and Wichita Falls. So far as has yet been determined the Redbeds are at least several hundred feet thick at all places where these asphaltic deposits occur, and since the high state of oxidation in the Redbeds is due to the absence of organic matter at the time of the formation of the rocks it does not seem possible that the oil and gas could have originated within the Redbeds.

In Carter, Jefferson, and Love counties, Oklahoma, and in that portion of Texas immediately south, thick deposits of Pennsylvanian rocks that contain either oil or oil residuum (asphalt) where exposed, pass under the Permian Redbeds. In Oklahoma the Pennsylvanian beds are so tilted and broken that the Permian formations lie in immediate contact with their upturned edges. If those Carboniferous rocks which lie buried had remained exposed there would now be nothing left but the heavy non-volatile residuum: but since the Permian rocks were deposited before the petroliferous strata of the older rocks had been exposed long enough for the volatile oils to escape they had a tendency to seal up the leaks. Deposition, however, is slow so that the petroleum and gas became disseminated through the strata. Furthermore there is no reason to believe that transportation of the hydrocarbons from one formation to the other should cease with deposition especially when the deposited members are as porous as the Redbeds. Thus, in the course of time, any oil in the carboniferous beds below the Permian would be conveyed upward and would either collect in the Redbeds or escape through them. It seems that for a long period of time the latter was true in the Wheeler field for, it contains one of the largest deposits of brea known in the United States, and even yet gas is escaping on the SW. 1/4 SE. 1/4 sec. 21, about three quarters of a mile southwest of the place where the first well was drilled. In the light of present data the underlying Paleozoic rocks seem to be the only reasonable source from which the Wheeler oil and gas could have come.

Owing to the fact that deep drilling has failed to locate the source of supply in the Pennsylvanian rocks immediately below the Wheeler field, it is suggested that the oil and gas may have been transported long the line of unconformity and the original deposit may be encountered at greater depths at some other place in the general region. There are, however, no data at present available on which to base this probability.

THE MADILL OIL FIELD.

LOCATION

The Madill field consists of a half score or more of oil wells, usually showing a little gas, located in the southeastern part of T. 5 S., R. 5 E., or about one and one-half miles southeast of Madill, the county seat of Marshall County.

TOPOGRAPHY

The region surrounding Madill is essentially an undulating plain, sloping southwestward. The Washita River flows through its broad shallow valley about six miles north of Madill and the Red River is at a little less than twice that distance to the southward.

STRATIGRAPHY

The general stratigraphy of the region has been discussed in Part I. of this report, so but brief mention need be made here.

By reference to the geological map of the region and to the cross section attached to the map of the Madill field it will be seen that the rocks north of the Washita are granites and older Paleozoic sediments. At the time of the Arbuckle uplift the older sediments were raised to a nearly vertical position, then worn down almost to a plain. Subsidence followed this wearing down, the sea encroached from the southeast, and the Cretaceous sandstones, limestones, and shales were deposited unconformably, upon the worn surface of the older rocks.

So far, oil has been found only in the Trinity sand—the breaking down of which affords the sand in the Washita River, and Glasses Creek bottoms—of Cretaceous age. The Trinity sand is locally conglomeratic at or near the base, with occasional streaks of clay shale at higher horizons. The composition of the conglomerate varies from place to place, depending upon the character of the older formations from which it was derived. Usually both the sand and conglomerate of the Trinity are porous, and it is these which form the reservoirs for the oil which has been developed near Madill. The approximate thickness of the Trinity sand in this region is 400 feet but owing to irregularities in the old pre-Cretaceous land surafce this thickness may greatly increase or decrease in comparatively short distances.

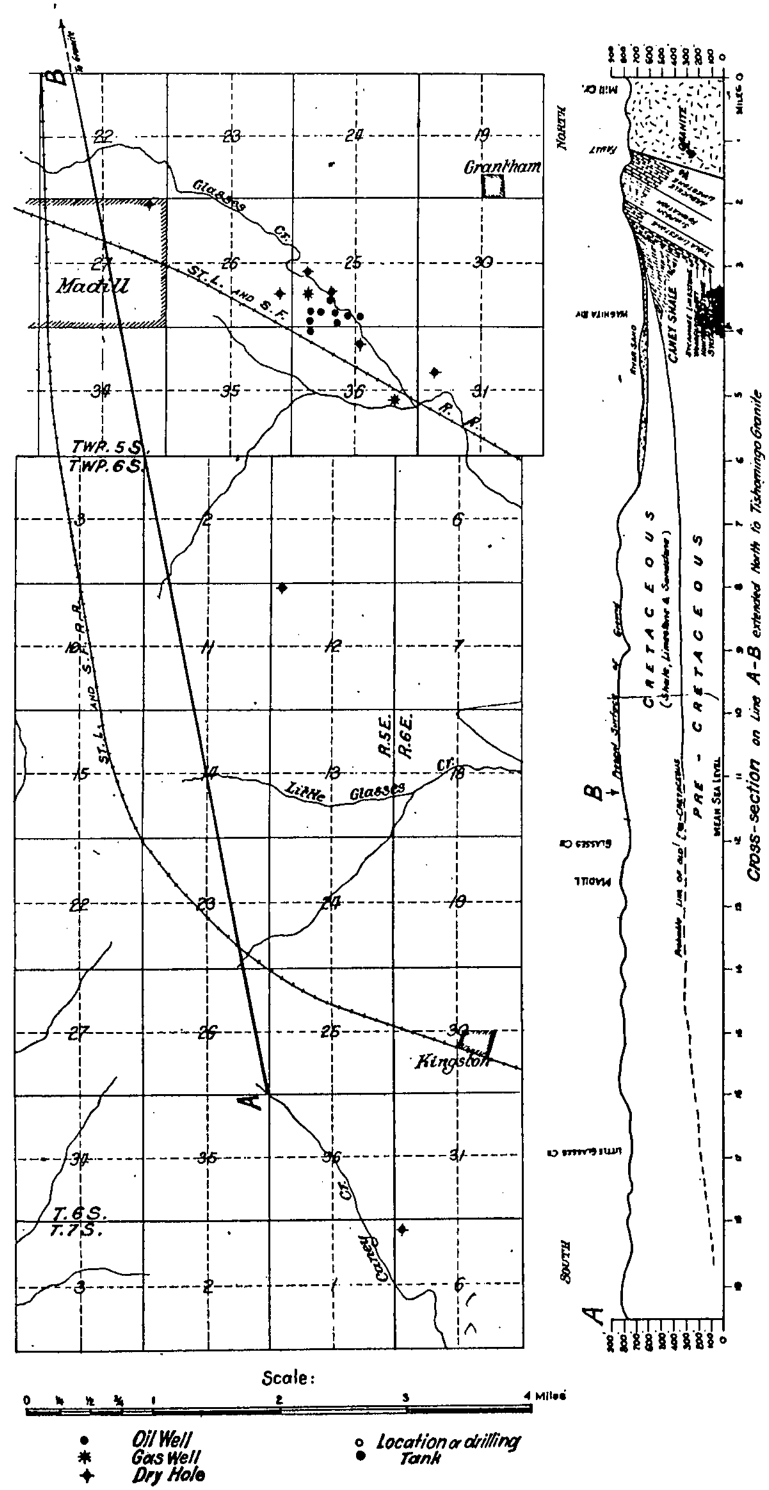
The Goodland limestone lies conformably upon the Trinity sand and is the limestone which occurs at the surface in the vicinity of the development, and forms the bluffs of Glasses Creek. Farther south, however, higher members of the Cretaceous series appear, thus increasing the depth to the Trinity sand.

STRUCTURE

Broadly speaking there are two structural features in the vicinity of Madill which may have a direct bearing on the deposits of oil and gas in the region. One of these is the Arbuckle Uplift, the other is the Cretaceous monocline. The Arbuckle Uplift involved the pre-Cambrian granites of the Tishomingo district and all Paleozoic rocks up to and including the mid-Carboniferous or Pennsylvanian formations. All of the rocks were brought up together; the granites being faulted and the sedimentaries folded and upturned, with occasional breaking and mashing, so that they are often found on edge, or dipping in various diretcions at high angles, in marked variance to the younger Cretaceous rocks which lie almost flat or incline gently in a single direction forming what is structurally known as a monocline.

Carboniferous and older Paleozoic strata are not exposed in the immediate vicinity of Madill but they have been examined in considerable detail beyond the limits of the Cretaceous overlap both to the north and west. Where exposed, the older formations are steeply inclined toward the southwest, trend northwest-southeast parallel to the Arbuckle Mountain uplift, and thus pass from view under the Cretaceous formations which occur as shown on the map of the southwest field.

The structure of the Trinity sand and overlying formations is simple. They succeed each other as a conformable series, and probably now have nearly the same attitude as at the time of deposition, that is they lie almost flat. However, at the time of the post-Cretaceous uplift the Arbuckle Mountain region rose higher than the region to the southeast, thus giving the Trinity sand and succeeding formations



MADILL OIL AND GAS FIELD.

a gentle southeasterly dip. There are some very slight warpings reported but none which are thought to be of sufficient magnitude to have in any wise affected the accumulation of oil and gas.

The most prominent structural feature of the Cretaceous of Oklahoma is the Red River fault which trends west of northwest in the vicinity of Red River, but it is not at all probable that it has in any way influenced the oil deposits near Madill.

No careful examinations of the Madill oil have been made by this Survey so the United States Geological Survey[160] is quoted:

A fresh sample of crude petroleum was obtained from a well one and one-half miles southeast of Madill and shipped to Washington in a gas and oil tight receptacle and analyzed in the laboratory of the United States Geological Survey by David T. Day.

The crude Madill oil is very liquid. Its color in reflected light is dark olive and in transmitted light a dark wine. The specific gravity at 60° F. was 0.7887; the Baume' gravity 47.5°. On distillation by Engler's method 100 cubic centimeters of crude oil began to boil at 65° C. While heating from 65° C. to 150° C. 22 cubic centimeters of gasoline were given off, the specific gravity of which was 0.7118. From 150° C. to 300° C. 38 cubic centimeters of kerosene were given off, with a specific gravity of 0.7788. After heating to this temperature 36.8 cubic centimeters remained as a residuum, of which the specific gravity was 0.8669. In this residuum 7.41 cubic centimeters were determined as paraffin, no trace of asphalt being found. Eight per cent of the crude sample and one per cent of the kerosene proved to be made up of unsaturated hydrocarbons.

The gravity of this oil, 47.5° Baume', is approximately 7° higher than that of the best oil produced at Muskogee, or 13° higher than that of the average Mid-Continent crude oil. On distillation the crude petroleum gave 60 per cent of lighter oil (gasoline and kerosene), about 7 per cent of paraffin, and little or no asphalt. The 60 per cent of lighter oil yielded approximately 22 per cent of gasoline and 30 per cent of kerosene. The average crude oil from the Mid-Continent field, when distilled, produecs hardly 50 per cent of lighter oils, with a ratio of about 1 to 4, kerosene predominating.

OCCURRENCE OF THE OIL.

The oil of the Madill district so far as developed, is all within the horizon of the Trinity formation but in uncemented sand and gravel near the base. Gas has often been encountered at higher levels and asphalt occurs locally impregnating other Trinity horizons along the outcrop in the bluffs of the Washita River and Oil Creek to the north. This would seem to indicate that oil may occur at these higher horizons further south where they lie further below the surface. There are, however, no known structural or other geologic features observable which will enable one to even approximate the most probable place of oil accumulation.

The exact thickness of the oil sand is unknown, but from the most reliable data at hand it appears that it is from twenty-five to thirty feet.

DEVELOPMENT.

The first paying well in the Madill pool was completed during the summer of 1906 on the Arbuckle farm in the SW. 1/4 sec. 25, T. 5 S., R. 5 E. The exact number of wells that have been drilled since

160 Taff, J. A., and Reed, W. J., The Madill oil pool, Oklahoma: Contributions to Economic Geology, 1908, Part II., Bull. U. S. Geol. Survey No. 381-D, 1909, p. 38-39.

is not known, though they have been drilled in every direction from the pool. In April 1909 there were only four or five producing wells. The largest oil producing well of the field was completed on the twenty-second day of March 1909, and was rumored to be making 1,000 barrels, natural, per day. On investigation, however, it seems that 400 barrels would have been a liberal estimate of its capacity. The striking of this well revived operations in the field and a large acreage was leased by various companies, and several new wells were drilled but so far as has yet been learned the effort did not extend the prolific territory far beyond the limits of the Arbuckle farm.

PROBABLE SOURCE OF THE OIL

Taff and Reed[161] have summarized conditions which appear to control the source of the Madill oil in a report to the United States Geological Survey, and are here quoted on that subject:

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

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

Whether the oil in its present position near the base of the Trinity sand is contiguous to the original oil-bearing strata of the subjacent rocks, or whether it has migrated laterally, may possibly be determined by the drill. Should original oil-bearing strata beneath the Trinity sand be tapped by the drill, the inference is that such oil-bearing rocks would be found to trend in a northwest-southeast direction, with the strike of the rocks in the Arbuckle uplift as exposed in the district to the north and west of Madill.

161 Taff, J. A., and Reed, W. J., The Madill oil pool, Oklahoma: Contrib. Econ. Geol., 1908, Part II., Bull. U. S. Geol. Survey No. 381-D, 1909, p. 41.

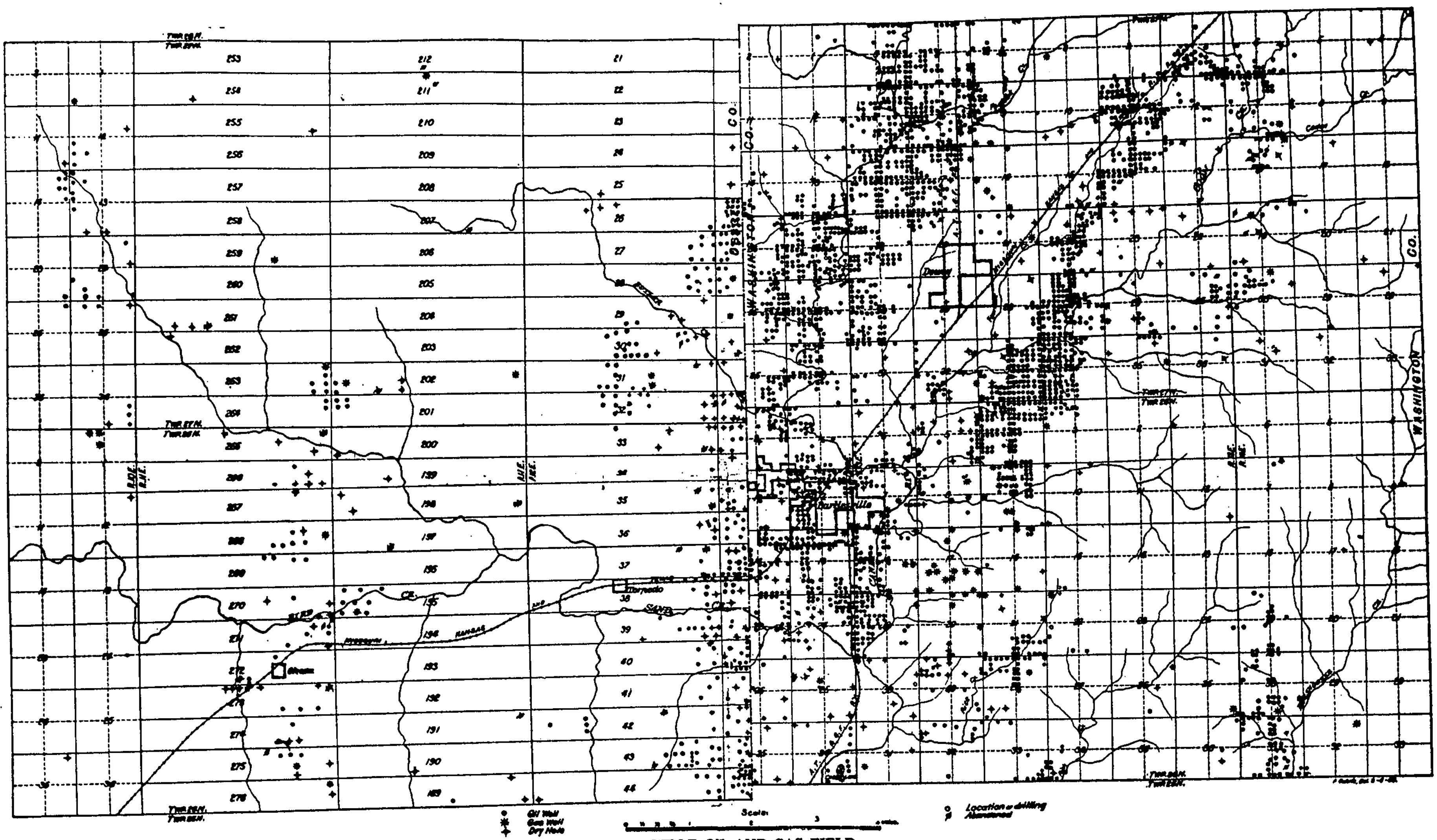


FIG. 13—BARTLESVILLE OIL AND GAS FIELD.

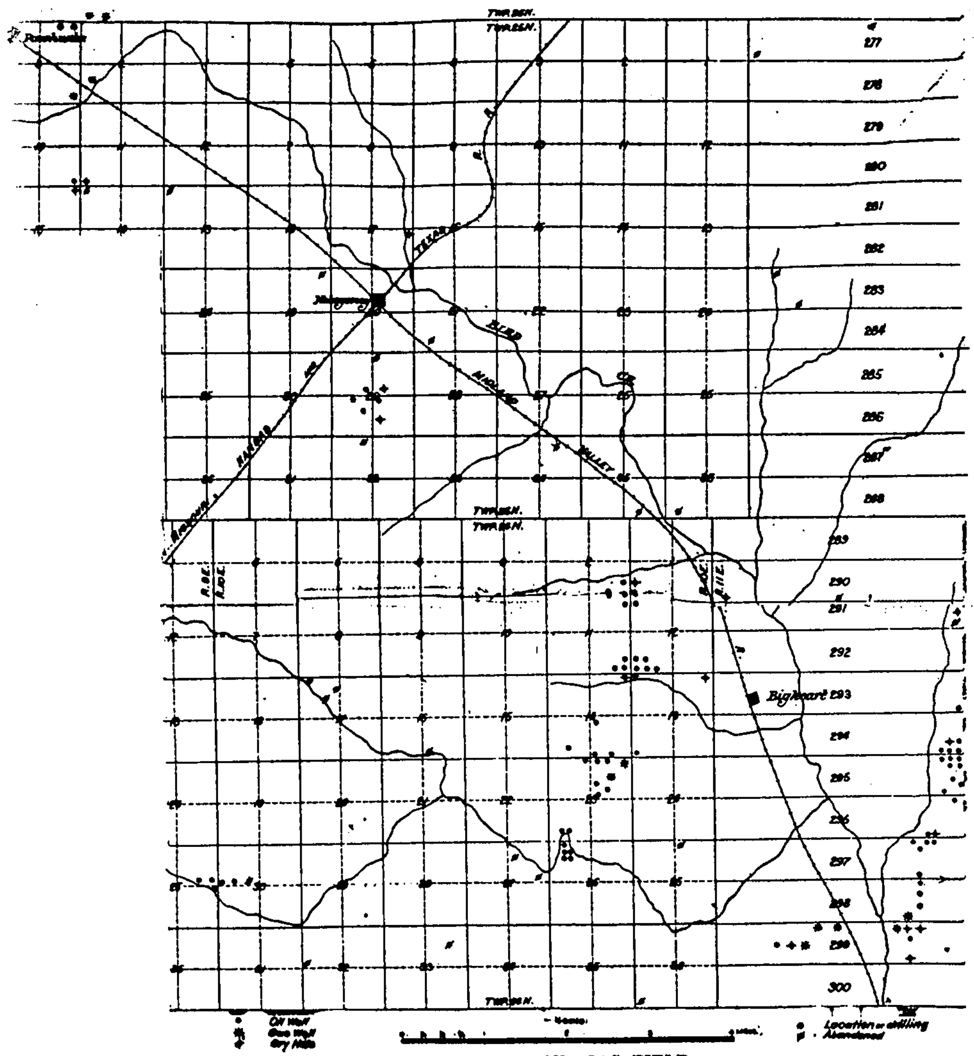


FIG. 16—BIGHEART OIL AND GAS FIELD.

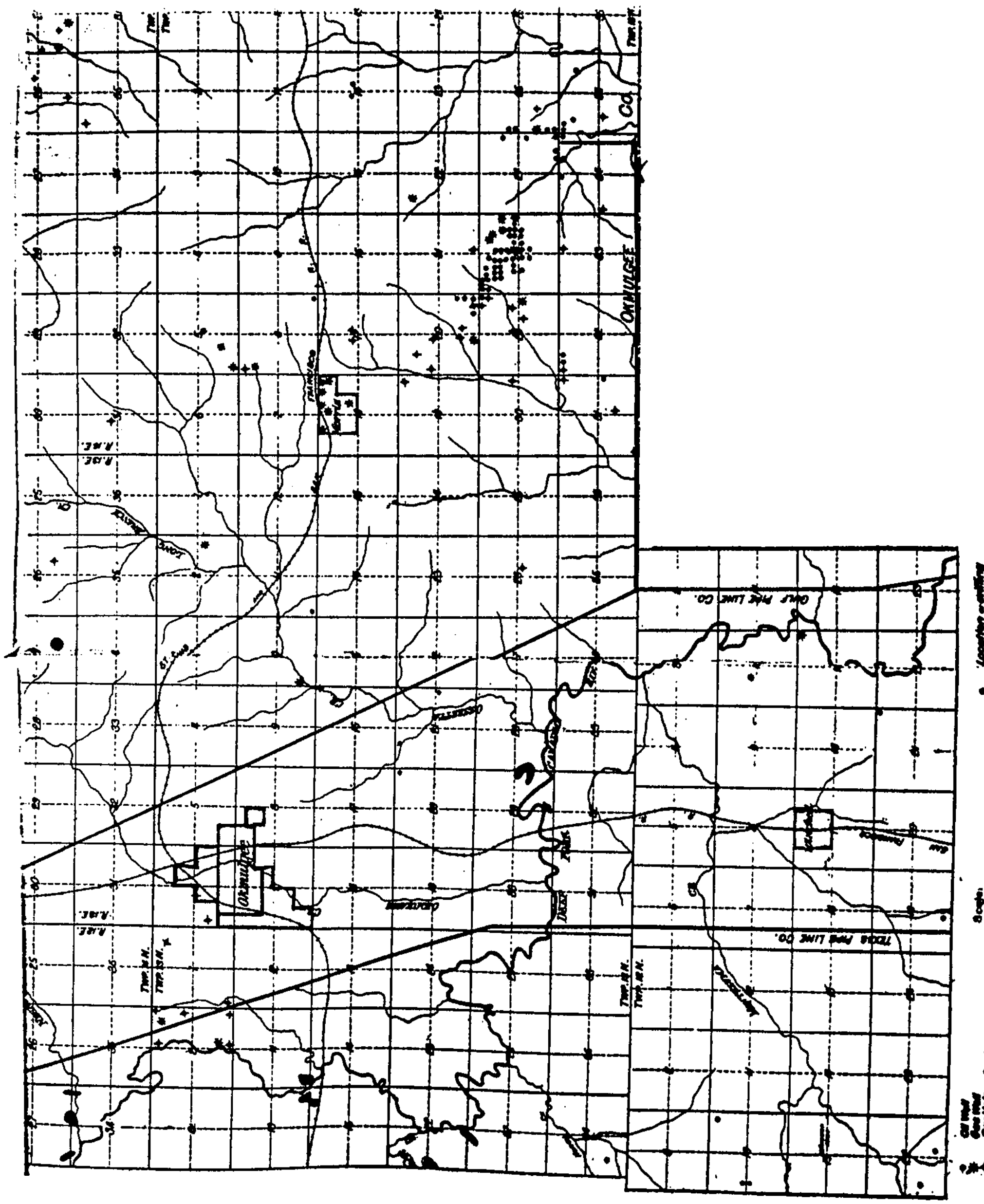


FIG. 21—MORRIS OIL AND GAS FIELD.