OKLAHOMA GEOLOGICAL SURVEY
Chas. N. Gould, Director

Bulletin No. 40-R

OIL AND GAS IN OKLAHOMA

GEOLOGY OF ATOKA, PUSHMATAHA, McCURTAIN, BRYAN AND CHOCTAW COUNTIES

By
C. W. Honess

NORMAN
NOVEMBER, 1927

CONTENTS

ILLUSTRATIONS

FOREWORD

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

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

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

Dr. Honess, the author of this report, is better acquainted with the geology of this part of Oklahoma than perhaps any one else. He spent seven consecutive years working in McCurtain and adjacent counties and is the author of a very comprehensive report entitled "Geology of the Southern Ouachita Mountains of Oklahoma," published as Bulletin 32, of the Oklahoma Geological Survey. He has also written several other shorter papers dealing with the same general region. The present chapter epitomizes Dr. Honess' observation in the matter of oil geology and oil possibilities of the region.

CHAS. N. GOULD,
Director

November, 1927

OIL AND GAS IN OKLAHOMA

Atoka, Pushmataha, McCurtain, Bryan, and Choctaw Counties

By

C. W. Honess

LOCATION AND ACCESSIBILITY

Atoka, Pushmataha, McCurtain, Bryan, and Choctaw counties lie in the southeast corner of Oklahoma, and comprise an area of approximately 6,000 square miles,—about one-twelfth of the total area of the State. The northern half of Atoka County, most of Pushmataha County, and the northern half of McCurtain County cover a large area in the Ouachita Mountains; the southern half of Atoka County, the southern half of McCurtain County, and all of Choctaw and Bryan counties lie in the Red River Plain, which is a part of the Gulf Coastal Plain, contiguous on the south.

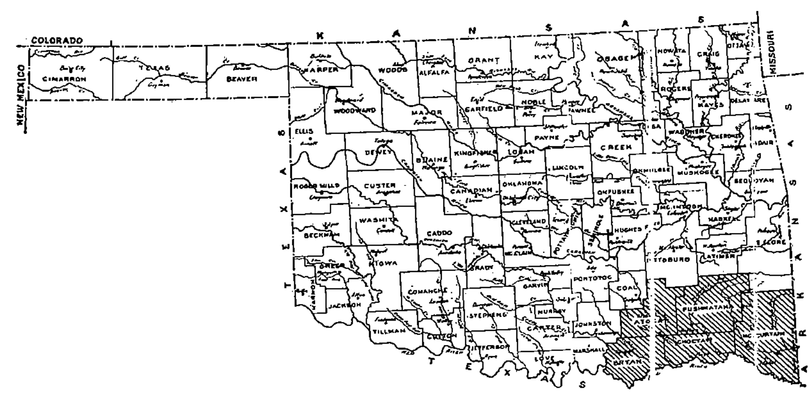

Fig. 1—Index map of Oklahoma showing area covered by this report.

The principal towns in the area are: Atoka, Antlers, Idabel, Durant, and Hugo, each of which is accessible by rail. Durant, Hugo, and Idabel are situated on the Ardmore branch of the Frisco Railroad, which runs east-west, and makes connections north and south over the Santa Fe Railroad at Ardmore, Oklahoma; and north and south over the Kansas City Southern Railroad at Ashdown, Arkansas. Connections are made north and south also over the Missouri, Kansas and Texas Railroad, and over the Kansas, Oklahoma and Gulf Railroad at Durant; and north and south over the main line of the Frisco Railroad at Hugo. The main line of the Frisco passing through Hugo passes also through

Antlers, the county seat of Pushmataha County; and the Missouri, Kansas and Texas Railroad, goes through Atoka, the county seat of Atoka County. There is no railroad north or south from Idabel, the county seat of McCurtain County, but the Kansas City Southern Railroad approaches very close to the Oklahoma-Arkansas State line over its right-of-way, and points in northern McCurtain County are accessible from it. The Texas, Oklahoma and Eastern Railroad, originally a logging road, joins Valliant, a town on the Frisco in McCurtain County, with DeQueen, a point on the Kansas City Southern Railroad in Arkansas. This line passes through Eagletown, Broken Bow, and Wright City, all of which are in central McCurtain County.

There are also numerous automobile roads in southeastern Oklahoma. Thus, one may approach from the north via. McAlester or Poteau to the small town of Victor, by automobile, thence south over the mountains to Talihina, Albion, Tuskahoma, Finley, Antlers, and Hugo; or one may enter the region from the west, coming in from Ada via. Atoka and Durant, or from Ardmore to Durant, thence to Hugo. The region is easily accessible from the south over the Red River bridge at Arthur's Bluff, Texas, south of Hugo; and from the east over good roads from De Queen, Arkansas, to Broken Bow, Oklahoma. One may also come in from Ashdown, Arkansas, to Idabel, thence north to Broken Bow, or proceed west from Idabel to Hugo.

TOPOGRAPHY AND DRAINAGE

The area of the Ouachita Mountains in Oklahoma, in which falls the northern half of Atoka County, practically all of Pushmataha County (all except the southern margin), and the northern half of McCurtain County, is for the most part one of high sandstone ridges and intervening wide flat valleys having an east-west direction, but locally there are considerable areas of flint hills. The sandstone ridges are steep sided, strewn with blocks of loose rock, and many of them are of mountainous dimensions, 20 to 50 miles in length and several miles broad. They range in height up to 2,900 feet above sea. The valleys between the principal ridges are established on broad belts of shale or slates, chiefly which, because of less resistant character, have been worn down by the streams. Some of the larger valleys are several miles broad and terminate abruptly against the flanks of the mountains. In these valleys, locally, are certain low ridges or rounded hills and knolls, and some rolling prairie lands, which are the result of the weathering of sandstones. The areas of flint, such as the Potato Hills in northern Pushmataha County, Pine Mountain, He Mountain, and numerous other (unnamed) mountains all in central McCurtain County, and the flint hills in central Atoka County, are composed of black, bluish, and gray to white flint. These hills are not as high as the sandstone ridges, but they are rough and rocky and have, generally, much steeper slopes; also the chert or flint, which is continually breaking away from the parent ledges in place, to form a loose, sharp, angular rubble, covers the surfaces and makes walking difficult.

The topography of the Gulf Coastal Plain, which includes southern Atoka County, the southern edge of Pushmataha County, southern McCurtain County, and all of Bryan and Choctaw counties, is a relatively featureless plain, compared to the Ouachita Mountains. As concerns southeast Oklahoma, the Coastal Plain consists of broad expanses of loose sand, extended areas of black land prairie, narrow strips of hilly limestone country and a few low, rounded, sandstone hills. No small part of it is the flood plain of Red River where river silt is deposited, and this, after drying, blows inland for many miles and locally is drifted into dunes.

The drainage is south and southeast, out of the mountains, across the plains, to Red River. Blue River flows southeast across central Bryan County and is the chief drainage in that area. Boggy Creek drains all of Atoka County, and Choctaw County west of Hugo. Kiamichi River gathers the waters from Pushmataha County, except the east edge, and from Choctaw County east of Hugo. The remainder of the area is drained by Little River and its tributaries.

The climate is hot and humid. The mean annual temperature is 62°, and the rainfall 43 inches per year. The mountainous parts are clothed in a forest of white and black oak, hickory, and yellow pine. In the valleys there is a great deal of red cedar together with brush and briars of all kinds. On the plains and prairies farther south are large areas of bois d' arc and thorn. There is also much scrubby oak and hickory. Cypress swamps abound along Little River and clumps of cypress may be found along the streams within the mountains in McCurtain County.

ACKNOWLEDGMENTS

The writer is under obligations to the Empire Gas and Fuel Company, for the logs of wells drilled in Bowie County, Texas, and in Miller and Little River counties, Arkansas; and to Frank Herald of Tulsa for logs and elevations of wells in the same area. The locations and total depths of the wells drilled in Fannin, Lamar, and Red River counties, Texas, were obtained from the offices of the Gulf Production Company, Texas. Information on the wells drilled in Oklahoma was obtained largely from the Gypsy Oil Company. Miss May Pepperdine of the Gypsy office has very kindly drafted the maps, and others of my colleagues have assisted with the typing and proofing of the manuscript. A liberal use has been made of the literature touching upon the general area, but credit is given to authors in the footnotes, which constitute a fairly complete bibliography.

GEOLOGY

GENERAL STATEMENT

The five counties here under review, namely: Atoka, Pushmataha, McCurtain, Bryan, and Choctaw, lie partly in a region of highly folded ancient (Paleozoic) sediments, and in part in an area of nearly flat-lying loosely consolidated sands and clays of more recent (Cretaceous) age. The outcrop of the old rocks lies north of a line joining the towns of Atoka, Antlers, and Broken Bow, (Fig. 2), and is known, physiographically, as the Ouachita Mountains. South of this line to Red River and beyond, the terrane belongs to the Coastal Plain. The area to be considered is just about equally divided, therefore, geologically. I shall discuss first the stratigraphy and structure of the Ouachita Mountains as it pertains to the particular area and problem, and take up second the stratigraphy and structure of the Coastal Plain, insofar as it concerns Bryan, Choctaw, and McCurtain counties in particular.

Ouachita Mountain Stratigraphy

The rocks exposed in the Ouachita Mountains are almost wholly of the non-calcareous types, consisting of shales (slates), sandstones, and flints or cherts. These have been described in detail, their thicknesses determined, and other facts about them made known largely through the labors of J. A. Taff[1], G. H. Girty[2], Hugh D. Miser[3], and C. W. Honess[4]. For present purposes it will not be necessary to repeat all of these details, and I shall give only such facts briefly as are of immediate interest. Following is the succession of formations in stratigraphic order from youngest (top) to oldest (bottom) as determined by the various geologists who have worked in the region.

STRATIGRAPHIC SECTION OF THE OUACHITA MOUNTAINS

Atoka formation (Pennsylvanian). The Atoka formation consists of blue and black shales, and dark brown sandstones of varying hardness, all generally thin bedded, and having a total thickness of 3,100 feet in Atoka County. In Pushmataha and McCurtain counties the Atoka has been largely removed by erosion, since the mountains were formed.

Wapanucka limestone (Pennsylvanian). The Wapanucka limestone is in part ōolitic and in part a cherty fossiliferous limestone, with dark sandy shales at the base, the total thickness being about 100 feet in Atoka County. Farther east this formation is locally present as a calcareous sandstone, but in general it has been cut away by erosion.

Caney shale (Pennsylvanian and Mississippian). The Caney is a mass of blue and black shales including limestone segregations and er-

1. Taff, J. A., U. S. Geol. Survey, Atoka Folio (No. 79), 1902. Grahamite deposits of southeastern Oklahoma: U. S. Geol. Survey, Bull. No. 380, pp. 286-297, 1909.
2. Girty, G. H., Fauna of the Caney shale of Oklahoma: U. S. Geol. Survey, Bull. No. 377, 1909.
3. Miser, H. D., Llanoria, the Paleozoic land area in Louisiana and eastern Texas: American Jour. Sci. 5th Series, Vol. 2, pp. 61-89, 1921; Geologic map of Oklahoma; U. S. Geol. Survey, 1926.
4. Honess, C. W., The Stanley shale of Oklahoma: Amer. Jour Sci. 5th Series, Vol. I, pp. 63-80, 1921; Geology of the southern Ouachita Mountains of Oklahoma: Okla. Geol. Survey Bull. No. 32, 1923; Geology of southern LeFlore and northwestern McCurtain counties, Oklahoma, Circular No. 3, Bureau of Geology, Norman, Okla., 1924.

ratic boulders of limestone and sandstone. It has a total thickness in Atoka County of 800 feet or more, but appears not to have been deposited in its typical phase farther east.

Jackfork sandstone (Mississippian). The Jackfork sandstone is a formation 6,600 feet in thickness consisting chiefly of massive beds of fine to medium grained sandstone interbedded with minor amounts of blue shale. It is exposed widely in Atoka, Pushmataha, and northwest McCurtain counties, and is responsible for all the highest mountains in this area.

Stanley shale (Mississippian). The Stanley is a formation of dark colored, thin bedded, ripple-marked sandstones and dark gray or black shales and slates interbedded in one vast series 6,000 to 10,000 feet thick. The sandstones are unusually hard, and in places they become quartzites. A bed of volcanic ash (tuff) 90 feet in thickness occurs near the bottom of the formation in McCurtain County, and a lentil of black chert up to 25 feet in thickness appears in the middle of the Stanley in this same region. The Stanley is widely exposed throughout the length and breadth of the Ouachita Mountains.

Arkansas novaculite (Devonian). The Arkansas novaculite may be subdivided into three parts: (1) a heavy bedded white novaculite (flint), carrying locally pockets of manganese ores, and composing the lower one-third of the formation; (2) thin bedded black novaculite (chert or flint) and black shales or slates forming the middle portion; and (3) a manganese-bearing white novaculite, 100 feet thick or less, occurring at the top. The total thickness of this rock ranges from 250 feet in western McCurtain County to 540 feet in eastern McCurtain County. In northern Pushmataha County and central Atoka County the upper part of the Talihina chert is the Arkansas novaculite and this part of the chert appears to have a thickness of about 250 feet here. The novaculite is exposed extensively in central McCurtain County and locally elsewhere.

Missouri Mountain slate (Silurian). This formation consists wholly of green and red shales or slates, weathering buff, their thickness being 60 to 100 feet. The outcrop appears only in central McCurtain County.

Blaylock sandstone (Silurian). The Blaylock is a formation of hard, quartzitic, thin bedded, green sandstones and hard, green slaty shales, 600 to 800 feet thick. Upon exposure the entire mass weathers red. The outcrop appears only in central McCurtain County.

Polk Creek shale (Ordovician). The Polk Creek shale is jet-black in color, richly graphitic or carbonaceous, soft, contains abundant graptolites, and is uniform in character throughout its geographic extent. It is about 100 feet thick. The main outcrop appears in central McCurtain County, but a portion of the Talihina chert in Atoka and Pushmataha counties resembles the typical Polk Creek, and is doubtless of the same age.

Bigfork chert (Ordovician). The Bigfork chert consists of wavy thin beds of black chert and black cherty limestone interbedded with minor amounts of black slaty shales, having a total thickness of approximately 800 feet. The outcrop appears in central McCurtain County where it covers many square miles, but the lower part of the Talihina chert in Atoka and Pushmataha counties has been identified as the Bigfork, which therefore must be present throughout the entire Ouachita region. The Bigfork chert is synchronous with the Viola limestone of the Arbuckle region.

Womble shale and sandstone (Ordovician). The Womble formation consists of soft, micaceous, argillaceous, fine grained, green sandstones and clay shales which have a total thickness of 1,000 feet more or less. These have been modified by folding and uplift, and by hydrothermal action. They have also suffered from quartz intrusions, with the result that the slates split readily across the bedding, and the sandstones have taken on a schistose character which is decidedly characteristic. Although green when fresh these rocks invariably weather red and finally brown. The outcrop is confined to central McCurtain County, but the Stringtown black shales which appear beneath the Bigfork in the Potato Hills in northern Pushmataha County and in the flint hills of central Atoka County are probably of the same age as the Womble.

Blakely sandstone (Ordovician). A dark gray quartzite composed of spherically rounded quartz sand grains and having numerous smoky quartz veins cutting across it has been called the Blakely. It is approximately 15 feet thick, and outcrops in central McCurtain County.

Mazarn shale (Ordovician). The Mazarn shale is a mass of dark colored carbonaceous shales, which split across the bedding. The thickness is estimated at 1,000 feet, but there is doubt about the identity and correlation of these Oklahoma deposits with the type Mazarn shale areas, which are in Arkansas. The Oklahoma "Mazarn" crops out typically along Glover Creek (sec. 15, T. 5 S., R. 23 E.) in central McCurtain County.

Crystal Mountain sandstone (Ordovician). The Crystal Mountain sandstone is composed essentially of coarse, spherically rounded quartz sand, now firmly cemented with silica. The rock is massive, without bedding, hard, and gray in color, but weathers brown, due to the presence in it of a ferruginous carbonate. At the base is a conglomerate 14 feet thick, which contains angular as well as rounded blocks of limestone and black chert up to eight inches in length. The total thickness of the Crystal Mountain sandstone is 500 feet, and it outcrops in central McCurtain County.

Collier shale (Ordovician). The Collier shale consists of dark colored metamorphosed shales and slates containing local minor developments of conglomerates and limestone. This is the oldest formation exposed in the region, and we see only the topmost 200 feet of it. Its total thickness is not known, and what lies beneath it is not known. The outcrops of the Collier appear in central McCurtain County.

Ouachita Mountain Structure

The structure of the Ouachita Mountain area is of that type commonly known as Appalachian. It resembles, that is to say, the well known structure of the Appalachian Mountains, which is essentially a series of tightly compressed, and in part, overturned folds (anticlines and synclines), accompanied by faulting. Viewed at large the Ouachita Mountains are clearly but a fragment of a former, extensive range, which indeed may have, at one time, connected with the Appalachian Mountains. There is a great deal of evidence in support of this supposition. It is also clear that the present mountains once did, and that the structures still do, continue far to the south and west into the State of Texas. We are describing, therefore, a type of structure which is not locally confined to the present mountains, but is more general, regionally larger, and deep seated.

The present Ouachita Mountains, extending from Atoka, Atoka County, Oklahoma, east into Arkansas, and occupying a belt 50 to 60 miles broad, is essentially a mass of complexly folded sandstones, shales and cherts (flints), which have been, since they were folded, subjected to erosion. During this interval of erosion the tops of the folds were gradually cut away, and one sees now only the roots of the former mountains, and only the jagged edges of the rock strata that compose the arches and troughs. The rocks were not folded into broad basins and domes, but for the most part were pushed together to form the isoclinal and recumbent types of folds, and these were packed tightly together, or inclined one upon the other, in a manner that left the strata all plunging in one direction for any single large area. The rocks were also broken in an infinite number of places, jointed, and the shales, which were softer, must have yielded much as putty in the hands of the glazier. In numerous places large masses of rock slipped past other large masses along definite lines of displacement which are many miles in length and thousands of feet deep in the ground; also there were slips (faults) of small dimension. The friction of these moving masses of rock, which, by the way, moved in a northerly and northwesterly direction, developed a great deal of heat, and heat, combined with the pressure which was brought to bear on this mountain mass, caused the rocks to be changed physically and chemically, from their original soft nature to harder materials. There is evidence that at greater depths this movement was accompanied by the intrusion of melted rock, for the sediments now exposed at the surface have suffered intrusions of thick masses of quartz and locally other igneous matters. All the olders rocks have been steamed in hot waters containing lime and iron carbonates and silica, which come from below.

One of the larger upfolded masses in the Ouachita Mountains is the Choctaw anticline, which occupies all of central McCurtain County, and extends southwest, without the shadow of a doubt, beneath the Coastal Plains sediments at least as far as Red River, and presumably much farther. This anticline is a region of general uplift, and it is extremely complicated structurally, for it carries on either flank as many as fifty minor thrust folds (anticlines and synclines) and numerous faults, yet the strata dip uniformly to the north (northeast on the east flank, and northwest on the west flank) throughout the mass. Half of the rocks in this structure are, therefore, upside down. (See areal maps and structure sections, Okla. Geol. Surv. Bull. 32, Pt. 1, Plates I, LXIX, and LXXXII, 1923).

Another large anticline appears in northern Pushmataha County and southern Latimer County. The rocks exposed along the central part of this axis form the Potato Hills, 15 miles long by six miles broad. The entire anticline may be thought of as extending roughly 35 miles, in an east-west direction. Like the Choctaw anticline the Potato Hills anticline is also extremely complicated, having many small folds on its back, but in this case the strata are tilted in various positions, mostly toward the south. The rocks dip to the south generally over all of northern Pushmataha County north of Kiamichi Mountain, and over all of southern LeFlore County, south of the Choctaw fault.

There are a number of large down folded areas or synclines in the Ouachita Mountains, and singularly enough, these are all simple troughs tilted up at one end, or both ends, and are never complicated in the sense that the large up-folded areas are. These troughts are 20 to 50 miles long by 6 to 10 miles broad *and are separated one from the other by huge thrust faults.* They are formed of the Stanley and Jackfork formations in some cases, but usually later sediments, up to and including the Atoka formation, are also caught in these basins. These synclines are sometimes over-turned. The strata dip from 30° to 60° toward the central axis in most cases, but frequently the dip is much less—sometimes more. Some of the more prominent of the synclines are: Bethel syncline and Boktukola syncline in northern McCurtain County; Lynn Mountain syncline in northern Pushmataha and southern LeFlore counties; and Caney basin in western Pushmataha County. There are ten or a dozen all told. These large basins and accompanying thrust faults all trend in a southerly or southwesterly direction, and the rocks of which they are composed form the foundation stones of southern Atoka, southern Pushmataha, most of Choctaw, and a part of Bryan counties, i. e., it is on this type of structure and over this kind of rocks that the Coastal Plains deposits were laid in the Red River region. Southern McCurtain County, as previously stated, is underlain by the hard standstones and especially by the flints and slates which compose the Choctaw anticline.

Coastal Plains Stratigraphy

Lying on top and across the steeply dipping, eroded edges of the Ouachita Mountain rocks in southern Atoka, southern Pushmataha, and southern McCurtain counties, and farther south, are thick deposits of yellow sand, red and yellow clays, chalky limestones, and shell beds; also black gumbo clays and marls, which dip toward the Gulf at the

rate of 40 to 70 feet per mile. This group of rocks, 1,000 feet in thickness or more in its entirety, comprises the lower Cretaceous (Comanchean) group, and the basal part of the Upper Cretaceous group, of sediments. Much has been written concerning the character, thickness, and age of these formations, very largely by J. A. Taff[5], but Stephenson[6], Hopkins, Powers and Robinson[7], Ellisor[8], Miser[9], and Dane[9a], have also made notable contributions to our understanding of this area. For present purposes only brief descriptions of the several formations need be given. In order from the top downward or from youngest to oldest these are as follows:

STRATIGRAPHIC SECTION OF THE RED RIVER PLAIN

Pecan Gap Chalk (Upper Cretaceous). Although at present concealed from view beneath a thin covering of river silt and sand, the Pecan Gap chalk and associated shales and sands unquestionably lie across the southern tip of McCurtain County, and are the uppermost beds of the Cretaceous in this region in Oklahoma. The chalk has a thickness of 400 feet in Bowie County, Texas, where it has been identified in wells drilled there, and doubtless will be found to have a like thickness in the southern end of McCurtain County, Oklahoma (T. 10 S., Rs. 26 and 27 E.). The chalk is exposed at Rocky Comfort, 1½ miles southwest of Foreman, Little River County, Arkansas, just east of the Oklahoma-Arkansas State line. Here it consists of massive beds of pale blue chalk weathering white, and is fossiliferous.

Brownstown beds (Upper Cretaceous). The Brownstown is essentially "a blue or gray calcareous clay containing many fossil oysters, and is characterized by the presence of the large oyster, *Exogyra ponderosa,* whence it has been called the *Exogyra ponderosa* marl," but there are beds of glauconite, lenses of quartz sand and some sandy shales as well as blue-gray calcereous clays, in this formation. At the top there is a glauconitic, fossiliferous, sandy zone, 100 feet thick, to which the name Wolf City has been applied. It has been recognized in northeast Texas, including Bowie County, and should also be found immediately beneath the chalk in Oklahoma. The clays of the lower portion of the Brownstown weather dark olive green, which is character-

5. Taff, J. A., U. S. Geol. Survey, Atoka Folio (No. 79), 1902; and U. S. Geol. Survey, Tishomingo Folio No. 98, 1903.
6. Stephenson, L. W., A contribution to the geology of northeastern Texas and southern Oklahoma: U. S. Geol. Survey, Prof. Paper No. 120-H. 1918; and notes on the stratigraphy of the Upper Cretaceous formations of Texas and Arkansas: Bull. Amer. Assn. Pet. Geol., Vol. 11, pp. 1-17, 1927.
7. Hopkins, O. B., Powers, S., and Robinson, H. M., The structure of the Madill-Denison area, Oklahoma and Texas, with notes on the oil and gas development: U. S. Geol. Survey, Bull. No. 736-A, 1922.
8. Ellisor, A. C., The age and correlation of the chalk at White Cliffs, Arkansas, with notes on the subsurface correlations of northeast Texas: Bull. Amer. Assn. Pet. Geol., Vol. 9, pp. 1152-1164, 1925.
9. Miser, H. D., Lower Cretaceous (Comanche) rocks of southeastern Oklahoma and southwestern Arkansas: Bull. Amer. Assn. Pet. Geol. Vol. 11, pp. 443-453, 1927; and geologic map of Oklahoma, U. S. Geol. Survey, 1926.

9a. Dane, C. H., et al, Oil-bearing formations of southwestern Arkansas: U. S. Geol. Survey Press Notice, No. 8823, Sept. 10, 1926.

istic of this part of the formation. The total thickness of the Brownstown ranges from 300 to 600 feet. Westward in Texas it grades into the Taylor marl and Austin chalk. In Arkansas the Browntown beds have been subdivided recently by Dane et al into: (1) Brownstown marl (restricted), below, and (2) Ozan formation, above. The subdivision was made because of the discovery in the middle of the formation of an unconformity and a change in lithology.

Eagle Ford shales (Upper Cretaceous). Below the Brownstown in the wells drilled in Bowie County and west, in Texas, there is found the same type of sand and associated shales as found in the upper part of the Eagle Ford farther west. These strata have a thickness of 250 or more feet, at the top of which is a sand (sub-Clarksville sand). Ordinarily, the Eagle Ford consists of dark bluish or black shaly clay which is gypsiferous and more or less bituminous, but the typical black, bituminous phase of the Eagle Ford shales is missing in this area, according to A. C. Ellisor, and the sub-Clarksville sand and underlying shales grade into the Woodbine (Bingen) below. But, according to L. W. Stephenson[10], there are no rocks at all of Eagle Ford age in this locality, southwest Arkansas in particular, and a break in the Bingen sand represents Eagle Ford time. In McCurtain County, Oklahoma, the upper Eagle Ford section, if present, should crop out as a narrow east-west band at about the latitude of Haworth or Bokohoma, and dip south. Southeast of Durant in Bryan County, Eagle Ford shales occupy an area of approximately 50 square miles and dip southeast. They apparently occupy the trough of a syncline in this locality.

Woodbine sand (Upper Cretaceous). The Woodbine sand or "Silo sand" which crops out in southern Bryan and southern Choctaw counties, comprises farther east, in southern McCurtain County, the lower part of the Bingen formation.[11] It is the basal formation of the Upper Cretaceous and consists of fine brown sand and sandy clays interstratified. The total thickness is about 500 feet, but erosion has removed much of the upper part from the outcrop, the north edge of which strikes through Silo, Durant, and Bennington in Bryan County; through Duland and Grant in Choctaw County; and through Idabel and Odell in McCurtain County. It lies in an unconformable position upon the Lower Cretaceous strata beneath, with overlap in a northeasterly direction, so that it is in contact with the Bennington limestone below, in Bryan County and western Choctaw County, but overlaps the Goodland limestone at the east margin of McCurtain County.

Bennington limestone (Lower Cretaceous). The Bennington limestone in the Texas region is represented by from 80 to 100 feet of calcareous, fossiliferous clays according to Taff. Coming northward into Oklahoma they change gradually to a hard dull-blue limestone, the Bennington limestone, 10 feet in thickness, which carries an abundance of small shells, (*Exogyra arientina*). Because of the overlap of the succeeding Bingen, the Bennington might not be found in wells drilled along the north edge of the Bingen in parts of Choctaw and southern McCurtain counties. It should be present in Bryan County.

10. Stephenson, L. W., Notes on the stratigraphy of the Upper Cretaceous formations of Texas and Arkansas; Bull. Amer. Assoc. Pet. Geol. Vol. 11, p. 4, Jan. 1927.

11. The upper part of the Bingen has been given a new name by H. D. Miser (U. S. Geol. Survey Bull. No. 690) because of the discovery in the Bingen of an unconformity. The upper Bingen, 300 feet thick, accordingly, is known as the Tokio formation, which is present in McCurtain County, and east, but has no counterpart in the section farther west.

Bokchito formation (Lower Cretaceous). The Bokchito is a formation composed chiefly of clay and sandy clay with beds of friable sandstone, shell limestone, and ironstone concretions, aggregating approximately 140 feet. The sandstones are 20 to 30 feet in thickness locally. Because of the overlap of the Bingen to eastward the Bokchito formation might not be present in wells drilled in parts of Choctaw and southern McCurtain counties.

Caddo limestone (Lower Cretaceous). This formation consists of clay and calcareous marls interstratified with white marly limestone and semi-crystalline limestone making a section about 150 feet thick. Oyster shell beds are found at the top similar to those occurring below, at the top of the Kiamichi formation. The Caddo limestone is doubtless present in its proper sequence throughout southern Bryan, southern Choctaw, and southern McCurtain counties.

Kiamichi formation (Lower Cretaceous). The Kiamichi formation includes a few feet of siliceous limestone and shale marl overlaid by 50 feet of blue clay marl with oyster shell beds in the upper part. The oyster shells are large, up to 3 inches in length, and are cemented into firm ledges, one foot thick, by marly lime. This formation crops out south of the Goodland limestone and adjacent to it all across the southern counties.

Goodland limestone (Lower Cretaceous). The Goodland is a massive white limestone 25 to 50 feet thick, and crops out in a slightly south of east direction from the northwest corner of Bryan County to the place where Little River leaves the State in southeast McCurtain County. It is a good marker in well logs, and is prominent in the field as a maker of cliffs and terraces where it comes to the surface. It should be encountered in all wells drilled south of its outcrop at successively lower and lower depths toward the south.

Trinity sand (Lower Cretaceous). The Trinity sand is the basal member of the Lower Cretaceous group of rocks, and is the beach and near shore deposit of the Lower Cretaceous sea, which encroached upon the land from the south and east. The progress of this ancient sea upon the subsiding land to the north was so slow and its work so complete that all of the Paleozoic rocks: shales, sandstones, cherts, etc., hard and soft alike, were worn down to a nearly level base. Upon this plain, across the eroded edges of the hard rocks, the Trinity was laid down in much the same condition and relative position to the older rocks as we now find it. It consists of local, coarse conglomerates or boulder and gravel beds at the base, covered with from 400 to 600 feet of the fine pack sands, red and yellow clays and, in the east, certain

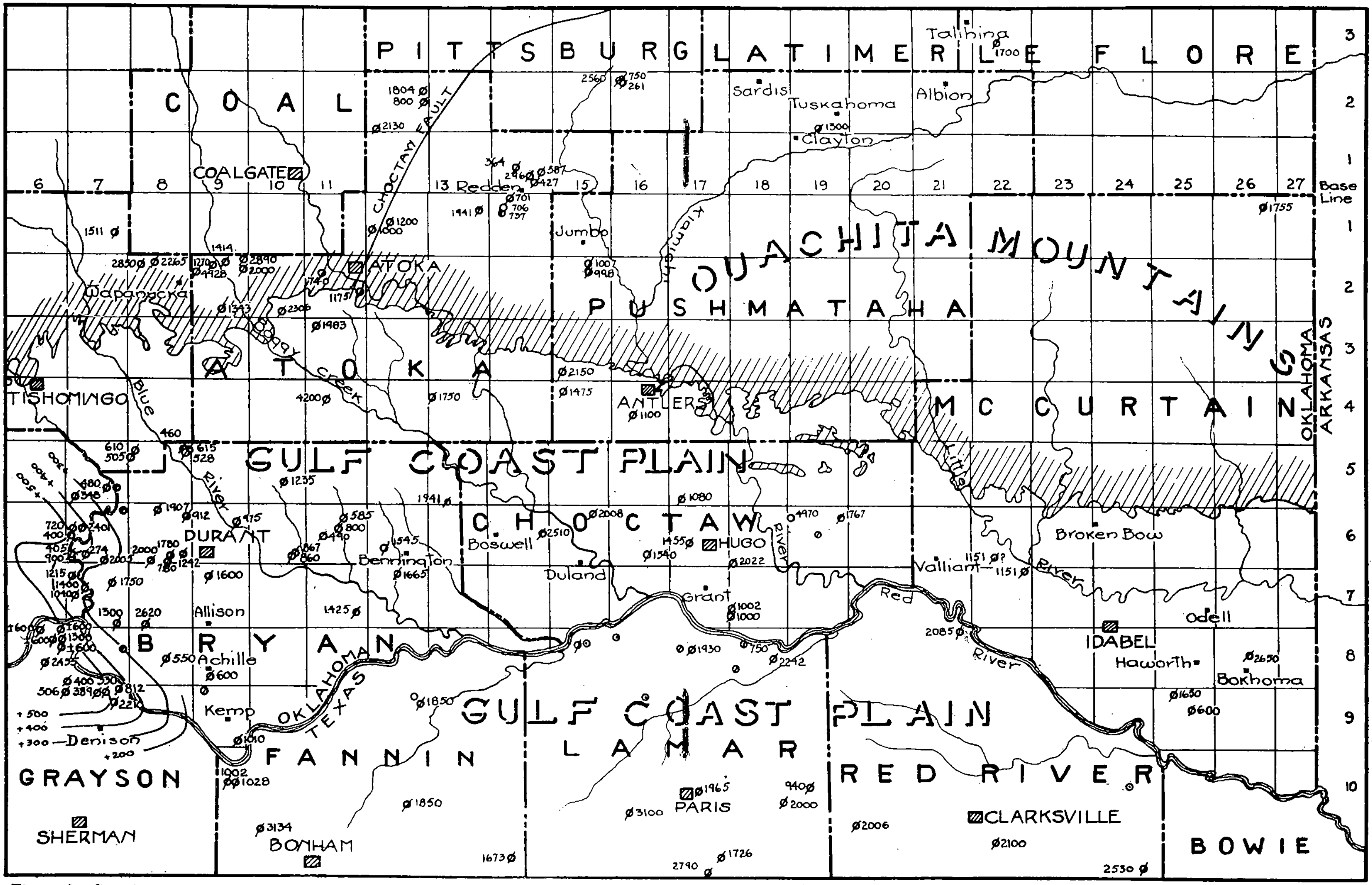

Figure 2. Showing the location and total depths of wells drilled in southeastern Oklahoma and a part of northern Texas. The structure contours in western Bryan County are from U. S. Geological Survey Bull. 736, Pt. 2, Pl. IV.

thin layers of limestone. The gravel beds may be 50 feet thick in central McCurtain County and central Atoka County, or wanting entirely in some places elsewhere. The gravels are composed of chert or flint largely, where thickest. The overlying sand is soft, poorly cemented, and upon exposure yields great quantities of loose sandy soil. Occasionally silicified fragments of wood and thin layers of lignite or carbonized wood are found in the Trinity sand. This material is drift wood which floated in the Trinity sea for a time, but was finally buried. The Trinity formation crops out in a belt about 10 miles broad, covering southern Atoka County, southern Pushmataha County, northern Choctaw County, and a portion of central McCurtain County. It should be found in all wells drilled south of the outcrop at progressively lower and lower depths in a southerly direction.

Coastal Plains Structure

It has been pointed out that the Ouachita Mountain rocks and structures extend beneath the Cretaceous cover in a southerly direction and that the Cretaceous rocks have been deposited across the upturned eroded edges of these old rocks. It has also been said that the Cretaceous sediments dip to the south and southeast at an average rate of 40 to 70 feet per mile, which is approximately the rate of dip of the old sea floor. It remains to call attention to some of the details of this general structure.

The most prominent anticline in all the Gulf Coast area of southeast Oklahoma is the Preston anticline, the axis of which strikes southeast diagonally across Marshall County, Oklahoma, and continues southeast into Grayson and Fannin counties, Texas. This is a very large, plunging structure, plunging southeast, and has been fully described by Stephenson, Hopkins, Powers, and Robinson, whose works have been referred to above. The axis passes down Red River, in the southwest part of Bryan County, after it leaves Marshall County, and continues on as far as the big bend south of the village of Kemp, where the river turns northeast. The Cretaceous strata dip sharply south, (approximately 100 feet per mile) south of this axis, and almost as sharply northeast (95 feet per mile) north of the axis. The northeast dip prevails as far out as the village of Achille, in Bryan County, then flattens out in the bottom of a syncline.

There is another anticline in Marshall County, known as the Madill anticline, which also has a trend in a southeast direction and plunges southeast.[11a] This anticline enters Bryan County at the middle west line of the county, west of Durant, but it is a very much smaller structure than the Preston anticline, and probably does not extend farther east and south than some point near Allison, south of Durant. The surface rocks dip away from the Madill axis south and northeast, as

11a. Hopkins, O. B., Powers, S., and Robinson, H. M., The structure of the Madill-Denison area, Oklahoma and Texas, with notes on oil and gas development: U. S. Geol. Survey, Bull. No. 736, map Plate IV, 1922.

in the case of the Preston anticline, but at a less rapid rate,—about 50 feet per mile.

The axis of the syncline, which lies between the Preston anticline and the Madill anticline, passes north of the village of Colbert to about the position of Achille. This syncline, of course, also plunges southeast. On the map, Fig. 2, the structure contours, copied from Hopkins, Powers, and Robinson, indicate the position of the Preston and Madill anticlines and the intervening syncline in western Bryan County. The presence of these structures is also indicated by the outcrop of the Goodland limestone in Marshall County (See map of Marshall County). North of the Madill anticlinal axis the strata dip northeast for a short distance (possibly five miles) and are then reversed and rise gradually to the outcrop still farther north. Judging from the strike of the Goodland limestone Durant lies in a shallow plunging syncline, plunging southeast, and the rocks farther north all dip south into it.

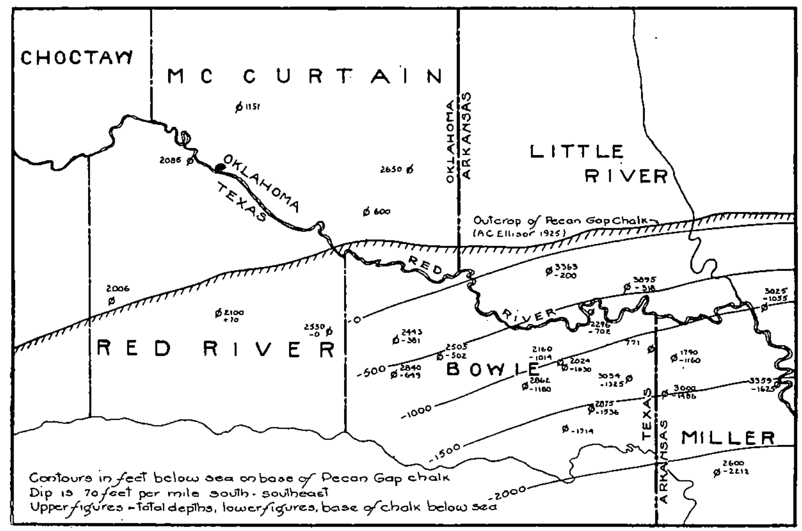

Figure 3.

The details of the structure in eastern Bryan County are not known, but there are probably no important flexures in the general area, else they would be indicated by curves in the outcrop of the Goodland limestone. The outcrop is straight, except for minor irregularities, due to drainage. Neither are the details of the structure in Choctaw and southern McCurtain counties known. The outcrop of the Goodland limestone, which is fairly straight, however, shows no pronounced irregularities in the general south dip of the rocks, and the depths at which the Goodland limestone is reached in the wells drilled indicate only minor wrinkling, so far as can be determined. In southern Atoka and southern Pushmataha counties there is every indication that the Trinity sand dips directly south and merges into the structure as outlined for Bryan and Choctaw counties.

No attempt has been made to assemble the data in northern Fannin, Lamar, and Red River counties, Texas, from which it might be possible to tell something about the structure there, but there is included on the map, Fig. 2, the locations of all the wells that have been drilled and are drilling in this region, and their total depths are recorded. The logs of these wells show a gradual south dip of the rocks, but data are lacking upon which to base any further statement.

In Bowie County, Texas, and in southern Little River County and Miller County, Arkansas, the Pecan Gap chalk serves as a convenient datum for structural mapping, and as the well records and elevations of the wells drilled there were available, a general structural map, Fig. 3, has been made of this region. In general the rocks dip slightly east of south at the rate of about 70 feet per mile over all of Bowie County and contiguous territory. Several wells in this area have penetrated the Goodland limestone, and two or three of them have probably reached the Paleozoic rocks, but in the absence of samples these horizons are difficult to recognize. However, in the Arden No. 1 well, drilled by Hermann L. Grote, in the NE. corner of sec. 2, T. 13 S., R. 31 W., eight miles west of Ashdown, Arkansas, the Goodland limestone was encountered at about 1,256 feet in depth; in the Taylor No. 1, drilled by the Tri-State Oil Company, at Whaley station, five miles east of New Boston, Bowie County, Texas, a gypsiferous limestone, which I presume is the Goodland, was found at a depth of 2,300 feet; in the Red River Petroleum Company's well drilled in the NW.¼, NW.¼, SE.¼ of sec. 15, T. 8 S., R. 26 E., McCurtain County, Oklahoma, the Goodland limestone was reached at 485 feet in depth; and in a well drilled on the Bromway farm in the edge of Texarkana, in sec. 31, T. 15 S., R. 28 W., Arkansas, the Goodland was reached at 2,650 feet. The location of the outcrop is also established. Using these data there is observed to be a uniform dip of 70 feet per mile south also on the Goodland in this general region. This evidence, so far as it goes, is counter to the possibility of finding any anticlines or synclines of importance here, and there probably are none.

ASPHALTS AND RELATED SUBSTANCES

That grahamite veins and oil saturated sandstones crop out in various places in southeastern Oklahoma is common knowledge. Some of these occurrences were described by Taff[12] in 1909, and others by Hutchinson[13] in 1911. Two or three of the larger deposits were known early in the nineties. Grahamite was mined, intermittently, for a number of years at Jumbo in Pushmataha County, beginning in 1891 and continuing until about the year 1915, when an explosion of gas in the mines killed several men. A fissure vein of grahamite at Sardis, near Tuskahoma, also in Pushmataha County, was opened in 1907 and operations continued there for about 15 years. Grahamite has been mined also at Daisy in Atoka County, and at Page in LeFlore County. Asphaltite has been dug and blasted from a pit at Valliant in McCurtain County, only very recently. There is an asphalt deposit north of Idabel on the banks of Little River, and others farther east in Arkansas. In the Chickasaw Creek country and in the valley of McGee Creek, around Stringtown and Redden, in Atoka County, there are extensive outcroppings of sandstones which are now saturated with heavy residues of black petroleum and some asphaltum. A number of shallow wells, 600 feet deep, have been drilled at Redden and near by. These, when drilled into the sandstones, partly filled with a heavy black oil, which was used by the farmers and ranchers in that neighborhood for various uses. There is asphalt in the Potato Hills, west of Talihina, and in the cherts at Stringtown, and doubtless in numerous other places, as yet undiscovered, in the Ouachita Mountains.

12. Taff, J. A., Grahamite deposits of southeastern Oklahoma: U. S. Geol. Survey, Bull. No. 380, pp. 286-297, 1909.
13. Hutchinson, L. L., Preliminary report on the rock asphalt, asphaltite, and natural gas in Oklahoma: Okla. Geol. Survey, Bull. No. 2, 1911.

The occurrences mentioned are of two general types: (1) fissure veins, and (2) impregnated sandstones. The veins have resulted from the solidification or drying up of liquid petroleum, which welled up from beneath, and for a time flowed from cracks or crevasses in the ground, but which eventually ceased to flow and that which remained in the cracks and near the surface became hard. The crevasses were widened by the flow of the oil and asphalt, locally up to 50 feet, but usually the width is from two to four feet, pinching out gradually to zero. The length of such veins may be one mile, as in the case of the Sardis occurrence, but any single, continuous body of grahamite or gilsonite ordinarily does not extend more than 100 yards or two hundred yards at the outcrop. The veins are vertical or nearly so and are usually parallel with the bedding of the shales and sandstones in which they occur. All the known veins of large size are found in the Stanley formation of Carboniferous (Mississippian) age. The Jumbo asphalt vein and the Sardis vein are typical of this class.

The asphaltites or impregnated sandstones, which make up the second class of the two general types of asphalt deposits, occur most conspicuously in the valley of McGee Creek near Redden, where ledges of sandstone, 4 to 6 feet thick, saturated with asphalt, come to the surface dipping at fairly steep angles, up to 45°. It is possible to follow these along the creeks and at intervals through the woods in places 100 yards or more. If continuous outcrops could be observed the actual length of the asphaltite deposits, in outcrop, presumably would be seen to be somewhat greater. As above mentioned the sandstones at a depth of 600 feet contain fluid oil, which indicates that the present dried out, exposed edges of the sand bodies were at one time the source of much exuding petroleum. (The grahamite veins are said also to become soft in depth). It is not known whether these sandstones are the original oil sands which have been tilted up and eroded, or whether they constitute a means of escape of the oil in other, deeper, broken strata—a subject to be taken up later on page 26. The exposed strata which include the asphaltites of McGee valley are Stanley sandstones and shales—the same rocks that contain the grahamite and gilsonite veins elsewhere.

The asphalt deposits at Valliant and Idabel are also of the second class, being sand or sandstone which has been saturated with petroleum, but the sands in these cases belong to the Trinity formation of lower Cretaceous age, and the oil has come up from below, accumulated beneath the overlying hard limestone (Goodland limestone), and there, after a long period of erosion and exposure, has partially evaporated. The oil is thought not to be indigenous to the Trinity sand, but to have come up from the older (Paleozoic) rocks which lie buried beneath.

The residues of petroleum in the Potato Hills, in northern Pushmataha County, and in the Talihina chert at Stringtown are accumulations in the jointed chert and are of minor importance quantitatively. That which is seen in the fresh, deep exposures in the quarry at Stringtown is in part a very fluid oil, and emits an odor.

We come now to the question of the origin of this asphalt, which, as has been pointed out, occurs as vertical fissure veins and as impregnations in sandstones in the Stanley (Mississippian) formation, as deposits in the cracks in the jointed Talihina (Ordovician to Devonian) chert; and as impregnations in the Trinity (Lower Cretaceous) sands and sandstones.

Origin of the Asphalt

Since the Trinity sand is largely non-fossiliferous, and contains practically no carbonaceous nor woody matter, and no bituminous black shales, which might be considered as sources for petroleum, the asphalt found in the Trinity sand is thought to have been derived from seepages from the Carboniferous rocks beneath. The Carboniferous rocks contain asphalt and oil-saturated sandstones, and are inclined with their broken edges tilted up against the bottom of the overlapping Trinity, which itself dips at a moderate rate. The situation is thus favorable for the migration of petroleum from the older rocks into the Trinity sand. This is the condition of the rocks in question all across the southern border of the Ouachita Mountains of southeast Oklahoma and southwest Arkansas, and is believed to be fundamental to the occurrence of the asphalt in the Trinity.

Taff and Reed[14], in discussing the probable source of the oil in the Madill oil pool of Marshall County, Oklahoma, state the case as it occurs to them as follows:

14. Taff, J. A., and Reed W. J., The Madill oil pool, Oklahoma: U. S. Geol. Survey, Bull. No. 381, p. 513, 1908.

> 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 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 desposit 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.

Miser and Purdue[15] have described seven asphalt deposits occurring in the Trinity sand in Pike and Sevier counties in southwest Arkansas, concerning the origin of which the following statement is made by them:

> The Trinity formation contains petroleum and asphalt at many places in northern Texas and southeastern Oklahoma. The asphalt in these two states and in Arkansas, as in other regions, is doubtless a residue of crude petroleum, whose lighter and more volatile parts have escaped by evaporation. The petroleum yielding the asphalt in Arkansas is believed by the writers to have been derived from the Carboniferous rocks underlying the Trinity formation, near the base of which the asphalt is found. In support of this belief is the fact that there are small amounts of asphalt in the sandstones of the Atoka formation of Carboniferous age, which crops out in two narrow belts with a north of east trend in Pike County, a few miles north of Pike and Murfreesboro. Asphalt is also found in Carboniferous and older rocks near Mena, Arkansas, and in southeastern Oklahoma. The Carboniferous rocks pass beneath the Trinity formation, and the beds are tilted in such a manner that their edges project against the base of the Trinity. Any oil in the Carboniferous beds, would, in the course of time, work its way upward into the Trinity. It could not go higher than the lower limestone of the Trinity, because of the impervious character of this limestone and the associated clays. As the Trinity has a gentle dip to the south, the oil would be conveyed up the dip to the surface. There is, however, no direct proof that some or all of the petroleum did not originate in the basal part of the Trinity formation, which contains some fossiliferous limesone.

15. Miser, Hugh D., and Purdue, A. H., Asphalt deposits and oil conditions in southwest Arkansas: U. S. Geol. Survey, Bull. No. 691, part II, p. 280, 1918.

Hopkins, Powers, and Robinson[16] in their discussion of the Madill and Preston anticlines, give a similar view of the origin of the oil and gas in these folds, when they say:

> The high grade of the oil now found in the Trinity, the absence of organic matter in the formation, and the distribution of the oil in it prove fairly conclusively that the oil has migrated into the Trinity from the underlying Paleozoic formations, either from the Caney shale or from the Glenn formation, both of which are believed to underlie this area. Thus, wherever the Trinity is in contact with either of these formations an adequate source of oil is probably available. But they are in contact with the Trinity only under abnormal structural conditions, where they have been folded or faulted and deeply eroded before the Trinity was deposited. Such a condition is not likely to exist in this area except near crests of major anticlines like the Preston, Madill and Oakland folds. Accordingly it is unlikely that oil will be found in paying quantities in the Trinity anywhere in this area except on these folds, a conclusion that is corroborated in a measure by the drilling that has been done.
>
> The Trinity has yielded prominent showings of oil and gas in this area only on these anticlines. Because of the intensity of the pre-Cretaceous folding and the depth to which these folds were eroded before the deposition of the Trinity, it is rather unlikely that much oil will be found in that formation even under favorable structural conditions. Over a broad area in Texas the Trinity constitutes an enormous reservoir of fresh potable water; in the area here considered the Trinity contains a large supply of water, but the water is more or less salty, doubtless owing to its stagnant character.

The asphalt and heavy residues of petroleum in the exposed Carboniferous rocks of the Ouachita Mountain area may also be thought of as having had a deeper seated origin, especially since there are so many fissure veins of large size in the lowermost formation of the Carboniferous, i. e., in the Stanley shale, and since a certain amount of these materials, asphalt and oil, is actually found in Ordovician to Devonian rocks, namely in the Talihina chert. The asphalt vein at Page in LeFlore County occurs in the Jackfork sandstone, above the Stanley, and there is one small deposit of asphalt in the Atoka formation above the Jackfork in the valley of McGee Creek, Atoka County, but both of these veins extend in depth, doubtless into the Stanley shale beneath. The bulk of the asphalt is seen to be in the Stanley.

The Stanley shale has been described[17] as a deposit of dark colored, fine grained sandstone, and dark, carbonaceous shales 6,000 to 10,000 feet thick; as being practically non-fossiliferous, except for plant remains; and as having been laid down in shallow water. The plants are pieces of *Lepidodendron,* fragments of *Calamites* and fern pinnules. All of the carbonaceous matters of microscopic sizes in the shales and sandstones seem to be macerated woody and other plant material which was

16. Hopkins, O. B., Powers, Sidney, and Robinson, H. M., The structure of the Madill-Denison area, Oklahoma and Texas, with notes on oil and gas development: U. S. Geol. Surv. Bull. No. 736, p. 29, 1922.

17. Honess, C. W., The Stanley shale of Oklahoma: Amer. Jour. Sci. 5th Series, Vol. I, pp. 63-80, 1921.

reduced to these fine particles by the work of waves. Because of the presence of the plants, and the almost total absence of marine fossils in this thick formation, and because also of its general lithologic character and limited geographic distribution, it has been further described as a delta deposit, which was laid down on the margin of the ocean near land, and at least partly in fresh water.

Geologists at present are not inclined to think of petroleum as originating in coaly or woody substances, nor as forming in marshes or delta deposits of fresh or brackish water accumulation. Thus, while the Stanley is carbonaceous it is not bituminous, hence not inherently petroliferous. The Jackfork sandstone, 6,600 feet thick, superimposed on the Stanley is also non-fossiliferous, except for plants, and has also been described as deltaic in origin. It is in fact the upper one-half of the same delta which was begun in Stanley times, and like the Stanley, was laid in fresh or brackish waters, apparently. At any rate there is nothing about the Jackfork sandstone that would indicate an accumulation in marine waters, and no part of it has, as an essential quality, a petroliferous nature. This cannot, however, be said of the Atoka formation, which is at least in part marine and which is locally petroliferous.

When the section of rocks beneath the Stanley shale is examined, flints and slates are found throughout central McCurtain County, in northern Pushmataha County, and in western Atoka County. Certainly these are not the source beds of the petroleum in question. There is, however, a formation known as the Caney shale lying on top of the Woodford chert and shale in northern Atoka County and in southern Pittsburg County in the Ouachita Mountains, and this formation is marine it its origin, fossiliferous, and may be considered as a likely source for petroleum. In central Atoka County, where there is much of the asphaltic sandstone, as well as veins of asphalt, in the Stanley, the Atoka formation lies adjacent to the west, separated from the Talihina-Stanley succession only by the Choctaw thrust fault. Beneath the Atoka lie the Wapanucka, Caney and older formations which normally make up the Arbuckle Mountain section. These rocks are all marine, in part petroliferous, and some of these may have furnished asphalt. The rocks east and west of the Choctaw fault are badly broken, and stand on edge, partly overturned, for two miles or more either side. The upthrow side of the fault is the east side, and the Talihina chert is at the surface in contact with the Atoka formation, which crops out along the west side of the fault. Under these circumstances, petroleum from the broken rocks of the Atoka formation, and possibly from older petroliferous rocks (Wapanucka, Caney) should find its way into the Talihina chert and Stanley shales and sandstones, which have been thrust against and upon the petroliferous series. But, granting that the asphalt in Atoka County could have originated in the manner suggested, it is still difficult to see how the Jumbo and Sardis asphalt veins and other veins still farther east could be derived from so distant a source.

THE OVERTHRUST THEORY

The rocks which are exposed in the Ouachita Mountains are very different from those of the same age which appear at the surface in the Arbuckle Mountains. This difference is so marked throughout that separate names have been used for the formations in these two areas, and up to the present time they have not been satisfactorily correlated. Because of the marked contrast in lithology in the two regions, lying adjacent to each other, it has been suggested, first by C. L. Dake[18], that "an enormous overthrust fault, the displacement measured in scores of miles, * * * may have crowded the Ouachita facies from the south or southeast far to the northwest, over the Arbuckle facies * * *."

The rocks of the Ouachita facies have been folded and thrust-faulted throughout the full length and breadth of the Ouachita Range, and this mountain mass has been crumpled and broken by a force that moved in a northerly and northwesterly direction. These facts are obvious from the areal geologic map of the region[19], but whether the Ouachita Mountain rocks have been shoved bodily scores of miles north and northwest into Oklahoma, from an adjoining territory outside, presumably from a region in Texas and Arkansas, as Dake has suggested might be the case, is difficult to prove. However, if such a force has operated to bring the Ouachita Mountain formations up and over the Arbuckle formations, then the Arbuckle limestone, Simpson formation, Viola limestone, and younger rocks of the Arbuckle facies may lie buried beneath the Talihina chert in the Ouachita Mountains, and these Arbuckle rocks may be considered as a source for the asphalt now found in the Talihina chert and in the Stanley and Jackfork formations. It may be assumed, of course, that the Arbuckle facies normally should extend some distance to the east of their present outcrop in the Arbuckle Mountains—at least as far east as the eastern boundary of Atoka County. There may be Carboniferous rocks (Atoka formation) beneath the Stanley and Jackfork or beneath the Talihina chert according to this theory, and the Atoka then could furnish petroleum for the dikes of asphalt in the Stanley and elsewhere.

The outcropping sandstone ledges in the vicinity of Redden above referred to (p. 22) which are saturated with asphalt and which at a depth of 600 feet carry fluid petroleum may be, thus, only a means of escape of oil which in reality is coming from the Atoka formation, buried beneath, or from the Hunton limestone or "Wilcox sand"!, and not *from* the formation in which the oil is found. If this condition exists the outcropping sandstones (Stanley), which dip at high angles, up to 45 degrees at the surface, may extend downward, possibly a mile or more, to a low-angle fault plane, and beneath the fault there might be present a petroleum-bearing formation of the Arbuckle facies, in contact with the faulted-off edges of the outcropping sandstones. Sandstones, structurally so related, should permit the escape of oil at the surface, in the same manner in which oil is supposed to escape from the Carboniferous rocks into the Trinity sand farther south, and as explained above. But, again, it is easier to think of these relationships of old rocks in the vicinity of Redden, in Atoka County, or even at the Jumbo asphalt mine in western Pushmataha County than farther east. Moreover it is not to be assumed that the Arbuckle facies was necessarily deposited as far east as the Sardis asphalt vein in northern Pushmataha County, certainly not necessarily as far east as the Page asphalt vein in southern LeFlore County. Nevertheless, carrying out the idea of a large overthrust fault, and recognizing that some of the Carboniferous rocks (the Atoka) are locally petroliferous, there is the possibility that the Sardis asphalt and the Page asphalt came up from an over-ridden mass of Atoka formation, if not from some older Paleozoic rock.

18. Dake, C. L., The problem of the St. Peter sandstone: Bull. Vol. 6, No. 1, Missouri School of Mines and Metallurgy, p. 55, 1921.

19. Miser, H. D., Geologic map of Oklahoma, U. S. Geol. Survey, 1926.

I do not propose here to discuss the possibility or impossibility of such an overthrust as suggested by Dake. The idea has been favorably received by all of several geologists with whom I have had occasion to discuss it. It is a subject as Dake has said, that is worth considering at least. Since there appears to be no adequate source for petroleum in the Stanley and Jackfork shales and sandstones and none in the Talhina chert, Arkansas novaculite, nor any of the older rocks in the Ouachita series, the idea is very welcome as a means to explain the presence of these large asphalt veins or dikes. Indeed the argument may be turned around, and we may say, that since there is no adequate source for petroleum in the Stanley-Jackfork sequence and none in the Talihina chert, Arkansas novaculite, nor any of the older rocks of the Ouachita series, these dikes and seepages of asphalt must be leakage from the over-ridden and deeply buried petroliferous beds of the Arbuckle facies. But, there are arguments touching upon the mechanics of such an overthrust, both for and against,—a presentation and discussion of which would be entirely out of place in the present instance. I would state at this time, in conclusion, that if the asphalt in question is not derived from some deeply buried petroliferous rocks of the Arbuckle facies, I see no reasonable explanation for it. So far as asphalt is concerned it is not necessary to assume that the overthrust extends farther south than approximately the valley of Kiamichi River above the town of Antlers, for any asphalt south of that latitude, so far as known, in Oklahoma, occurs in the Atoka formation where it might be indigenous, or is found in the Trinity sand derived as seepages, presumably from the Atoka.

DEVELOPMENT

There have been, up to the present time, about 80 wells drilled in the five counties of southeast Oklahoma (Atoka, Pushmataha, McCurtain, Bryan, and Choctaw counties); and there have been drilled about 40 others which might be considered border wells, bordering this area, (Fig. 2). Most of these are located in the Red River Plains area, but in Atoka County most of them were drilled in the mountains. Many of the wells encountered "shows" of oil, gas and asphalt, but none, including the nearby wells in Arkansas and Texas, has found production in paying quantitites.

The discovery of the Madill oil pool and the Lark and Enos gas fields, in Marshall County, in 1906 and later, led to the drilling of wells in Bryan County, where it was hoped other fields might be found. In Atoka County it was the asphalt that attracted the prospector, and the wells drilled there are located near the asphalt. Elsewhere wells were located on anticlines, or what were reported to be favorable structures, or were located for no reason at all, except that the country looked like oil country, or appeared to be worth a test for oil.

By reference to the map (Fig. 2) it will be seen that very few of these holes are more than 2,000 feet deep, and that most of them range from a few hundred feet to around 1,700 feet. In the Ouachita Mountains the sandstones are so hard that it is impossible, with standard equipment, to drill much below 1,700 feet, and this at great cost of time and money. In the Plains regions, south of the Mountains, drilling is fairly easy in the Cretaceous sediments, but as soon as the older rocks are reached difficulties commence, and the wells are then abandoned.

There are only three very deep holes in the entire region. One of these is in the SW.¼, NE.¼, NW.¼, sec. 7, T. 2 S., R. 9 E., and was drilled by the Wapanucka Oil and Gas Company to a depth of 4,928 feet. It was begun in May, 1922, and completed in May, 1926. At the top, in this hole, there were 1,417 feet of Atoka sandstones and shales, below which were found the Wapanucka limestone and older rocks of the Arbuckle facies, all of which could be drilled, whereas hard sandstones of the Ouachita Mountains facies, had they been encountered, could not have been drilled by the ordinary drilling equipment.

A second deep hole was drilled in the SE.¼, NW.¼ of sec. 17, T. 4 S., R. 11 E., by Ed. Hansen, et al., to a depth of 4,065 feet. There were rocks of the Arbuckle facies encountered in this well also, from comparatively shallow depths to the bottom of the hole.

The other very deep hole is located in the SW.¼, SE.¼, NW.¼ of sec. 7, T. 6 S., R. 19 E., drilled by the Oklahoma-Colorado Oil and Gas Company, with standard tools to 2,615 feet and completed with a diamond drill to a total depth of 4,970 feet.

In the northern part of Grayson, Fannin, Lamar, Red River, and Bowie counties, Texas, few attempts have been made to go below the Woodbine sand. So far as known, none has reached the Paleozoic rocks. In southern Little River County, Arkansas, two fairly deep tests have been drilled and both seem to have reached Paleozoic rocks. These are: (1) The H. L. Grote test in the NE.¼, NE.¼ of sec. 2, T. 13 S., R. 31 W., Arkansas, drilled to a total depth of 3,363 feet: and (2) The Goodrun Trust Company's test in the NW.¼, NW.¼ of sec. 15, T. 13 S., R. 29 W., Arkansas, drilled to a total depth of 3,895 feet.

As a rule, in southeast Oklahoma, the logs of the wells drilled are fragmentary and, in the absence of samples, unreliable. Few samples have been saved. No attempt has been made, therefore, to identify

the Paleozoic formations in any of the deeper tests. Except for the attempted identification of the Goodland limestone of the Lower Cretaceous and the Pecan Gap chalk of the Upper Cretaceous (Bowie County, Texas), no satisfactory correlation of the logs is possible. From the rate of dip of the Goodland limestone and the chalk, we may assume, however, that the Paleozoic rocks drop rapidly south from their outcrop in the mountains to Red River and beyond.

RECOMMENDATIONS

The authors of all the early reports on oil and gas in Oklahoma wrote favorably of the southern Oklahoma Cretaceous area, which includes southern Atoka, southern Pushmataha, southern McCurtain, and all of Bryan and Choctaw counties. Hutchinson[20], who was one of the earliest to go into this region and to write about it, refers to it as "possible" oil field territory. All the maps and reports of the Oklahoma Geological Survey, up to and including Bulletin 19[21], show the Cretaceous area as "likely" or "probable" oil territory.

The Ouachita Mountains, on the other hand, have always been regarded as too sharply folded and faulted to produce oil or gas in economic quantities, and this area was therefore described by Hutchison and by all later workers up to 1917, as non-productive, or was left blank on the maps with the understanding that it was not in an oil country.

In 1923, after spending several years studying the general geology of the Ouachita Mountains, C. W. Honess came to the conclusion[22] that it was "useless to drill into the Paleozoics anywhere in the eastern half of Choctaw County, or anywhere in the southern half of McCurtain County, Oklahoma, excepting an area of about 300 square miles in the extreme southern part of McCurtain County,—and that very little oil indeed would be found in the Comanchean sediments (of eastern Choctaw County and southern McCurtain County) excepting in the 300 square miles or so of country in the extreme southeastern part of McCurtain County * * *." A part of the territory of southeastern Oklahoma formerly regarded as in an oil country was thus transferred to a region designated as impossible of production. Nothing was said of western Choctaw County and the territory farther west, but a corner of southeast McCurtain County was left in the original classification as "possible of production." At the same time, on the other hand, Honess partially recommended the Smithville anticline in northeast McCurtain County, in the Ouachita Mountains proper as "possible of production." At any rate he was unwilling to classify the ground covered by the Smithville structure along with the rest of the southern part of the

20. Hutchison, L. L., Oklahoma Geol. Survey, Bull. 2, map, p. 145, published in 1911.

21. Okla. Geol. Survey, Bull. 19, Pt. I, p. 27, 1915 and Bull. 19, Pt. II, Plate IV, Fig. 2, 1917.

22. Honess, C. W., Geology of the southern Ouachita Mountains: Okla. Geol. Survey Bull. No. 32, Part II, 1923, pp. 48-52, and map Pl. XIII.

Ouachita Mountains, as entirely impossible of production, and thus removed a small strip of country from an area which had always been thought of as one "impossible of production" to a classification of "possible of production."

During the past five years several reports have come from the press dealing with the stratigraphy and structure of parts of this area and adjacent areas, and numerous wells have been drilled in the region and bordering it. Two wells of moderate depth have been drilled in southeast McCurtain County in the area described as "possible of production," and a shallow (1,755 feet) test has been made of the Smithville anticline. But, as yet, no production has been found in the general region nor near it. "Shows" of gas and oil are commonly found in both Paleozoic rocks and Cretaceous strata, but in all cases these seem to be small residues of former pools of oil which have escaped, for the most part, to the surface, and no longer exist as pools.

Most of the oil which is found is black and of a low grade. It is sometimes described as "dead oil," which indicates that it is not found under pressure, and does not have a sustained flow. Gas, when found, is usually in small amounts, and soon exhausted. One exception, however, is the one-quarter million feet of gas found in the well in sec. 16, T. 3 N., R. 22 E., in LeFlore County, Oklahoma, in a sand 1,128 to 1,178 feet deep, and with a rock pressure of 175 pounds per square inch. This well, drilled in 1920, was allowed to flow for several months, but was later shut in. Gas was escaping through the valve in March, 1927. In all probability the well would still produce if opened.

When one considers that there are large asphalt dikes, residues of heavy black oil, and gas in widely separated areas in the Ouachita Mountains and south in the Red River Plain one hesitates in condemning this territory as an oil producing territory. In spite of the facts that in the mountains the rocks are thrust-faulted, partly overturned, and metamorphosed, and supposedly lie in a region of high carbon ratio, if there be any truth in the theory of overthrust, there may still be oil pools below the overthrust sheet, and if the thickness of the mass which was thrust over the Arbuckle facies is not too thick, there may yet be Hunton and Simpson production found in certain areas in the Ouachita Mountains. The most likely places to look for the Arbuckle section would be, of course, nearest the Arbuckle exposures, and the shallowest depths at which the Arbuckle facies may be expected should be where the Ouachita facies is known to be thinnest, i. e., where the Talihina chert is exposed. Possibly some of the areas of Stanley shale are not too thick to be pierced by the drill. Conditions of subsurface structure also should be considered, for where the overthrust mass is thinnest, granting there is an overthrust mass, there may be Tishomingo granite, or some other non-petroliferous rock beneath. In this matter it would be logical to prospect in the localities where asphalt and oil seeps occur, because at those places there must be a source of some kind, the most likely being, in the absence of the Glenn formation, the Hunton or Simpson.

Referring to the new map of the State of Oklahoma, compiled by H. D. Miser of the U. S. Geological Survey, and published by the United States Geological Survey, it will be seen that certain areas of eastern and northern Atoka County and a part of northern Pushmataha County appear attractive. The region of the Jumbo asphalt deposit, and the valley of Kiamichi River, north of Kosoma, in western Pushmataha County, may also be considered. There are numerous localities in the general region farther north, in southern Latimer and southern Pittsburg counties, which, if there has been an overthrust, may be considered favorable or prospective oil and gas regions. But, has there been an overthrust? If so, is it possible to drill through the overthrust sheet? What are the chances of hitting upon an oil pool beneath, granting there has been an overthrust, and granting that it can be pierced by the drill? Also, what should be the degree of metamorphism of the buried Arbuckle facies in this region? It is not possible for the writer to answer any of these questions. This much has been said on the subject that the reader may know why it is not possible to classify the Ouachita Mountains of Oklahoma definitely and conclusively as lands impossible of oil production. In regard to that part of the Ouachita Mountains east and south of Kiamichi River (except the Smithville anticline) this can be done with a much greater margin of safety, than for the country west and north of Kiamichi River, in the Ouachita Mountains. It would be well to state also that while the Ouachita Mountains west and north of Kiamichi River cannot be condemned as an oil producing country, because of the theory of overthrust, neither can this region be highly recommended, or even recommended at all, to anyone who has not large sums of money to squander, and in the event of failure can nevertheless go on rejoicing.[23]

Any drilling operations whatsoever that may be undertaken in the Ouachita Mountains should be preceded by thorough and exhaustive field studies over wide areas, for it may be that after such studies have been completed it will not be necessary to drill at all. The entire situation hinges on the question of overthrust, which at the present writing is only a theory.

Finally, as a warning to the inexperienced, and as giving the writer's own personal opinion, it seems that the Ouachita Mountains is one of the last places in the United States where one may expect to find petroleum in commercial quantities. As a last resource, sometime in the future, when gasoline is selling for 50 cents a gallon it might be worth while to study the Ouachita Mountains. Meantime there are too many other places and better places in which to drill prospect holes.

Much of what has been said in regard to the Ouachita Mountains applies also to the Red River area (including Bryan and Choctaw coun-

23. The Smithville anticline in northeast McCurtain County, which is south of Kiamichi River, may be considered, at present, as in the same category and as having the same prospects as the lands north of Kiamichi River. This particular structure was originally described as an area having some slight possibilities. At this writing, and with all the facts considered, it is still impossible to absolutely condemn it.

ties and the southern parts of Atoka, Pushmataha, and McCurtain counties, because the old (Paleozoic) rocks of the mountains extend in depth, beneath this area. It is recommended, therefore, without further discussion, that wells be not drilled into the old rocks beneath the Cretaceous sediments at any place in the area discussed in this paper.

In the Cretaceous rocks of southeast Oklahoma only two anticlines are known. These are the Preston anticline and the Madill anticline, both of which are productive of oil or gas in Marshall County, but have been proved unproductive farther east. These anticlines have been described above and are shown on the map, Fig. 2. They are plunging structures, plunging southeast, and it is to be expected that they should produce from the higher westward portions if at all. These structures probably have by now been fully exploited.

In the remaining Cretaceous area of southeast Oklahoma, which includes eastern Bryan County, all of Choctaw County, southern McCurtain County, and the southern parts of Atoka and Pushmataha counties, the structure is unfavorable to oil and gas accumulation so far as known. The rocks dip uniformly south or slightly east of south throughout this region—a type of structure which should permit the escape of any oil or gas which might otherwise accumulate here. Apparently then, there is not a single attractive locality to be found in this region. Indeed there is no place anywhere in the five counties of southeast Oklahoma that can be recommended with any assurance that oil may be found in commercial quantities.