OKLAHOMA GEOLOGICAL SURVEY
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GEOLOGY OF EAST CENTRAL OKLAHOMA.

By L. C. SNIDER.

With Descriptions of Structure of the McAlester-Lehigh Coal Field from Report of J. A. Taff.

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LOCATION AND AREA.

The area considered in this paper lies in the east-central portion of the state. The Arkansas-Oklahoma state line forms the eastern boundary; the Choctaw fault, the southern boundary; the meridian of 95° 30′ West Longitude, the western boundary; and the parallel of 35° 30′ North Latitude and Arkansas River the northern boundary.

There is thus included all of Haskell County, southeastern Mus-

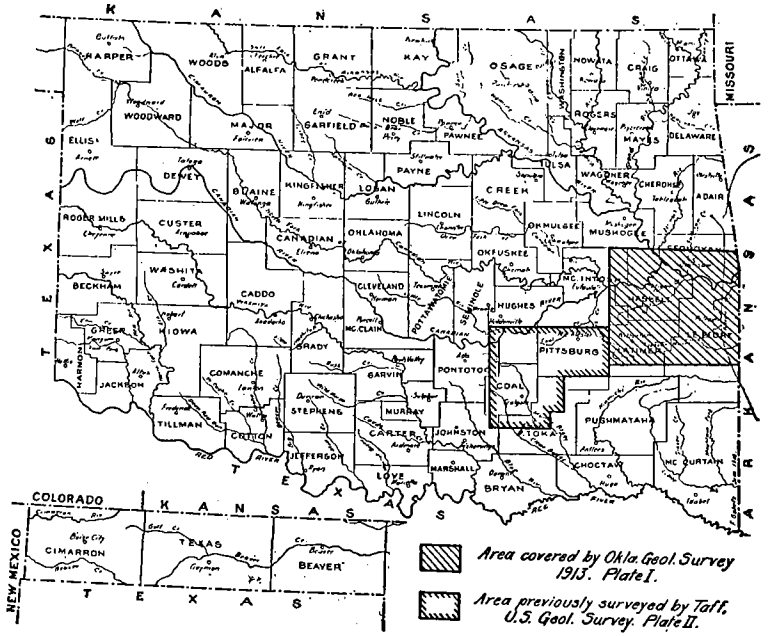


Fig. 1. Sketch map of Oklahoma showing the areas covered by this report.

kogee County, eastern McIntosh County, a small portion of northeastern Pittsburg County, northern Latimer County, and northern

LeFlore County. The region has all been mapped topographically by the United States Geological Survey, and is included in the Sans Bois quadrangle, the portion south of Arkansas River (about three-fourths) of the Sallisaw quadrangle, and a strip from 6 to 15 miles wide along the north end of the Winding Stair and Tuskahoma quadrangles. The portion of the state covered by the report is indicated on the small map (fig. 1). It includes approximately 2,200 square miles.

PREVIOUS WORK.

This area lies in the coal fields of eastern Oklahoma, and most of the geologic work which has been done previously has been with particular reference to the coal deposits. The earlier workers in the region were Dr. H. M. Chance, Robert T. Hill, Dr. J. J. Stevenson, and Dr. N. F. Drake. Their work was principally of a reconnaissance nature, and the area has been covered in a more detailed manner by Joseph A. Taff of the United States Geological Survey. The only published results of his work in this area are found in a paper entitled "The Geology of the Eastern Choctaw Coal Field," by Joseph A. Taff and George I. Adams, in the Twenty-first Annual Report of the United States Geological Survey, Part II, published in 1900. The area covered by Taff's and Adams' report includes only the southern and eastern parts of the area considered in the present paper. Taff, however, mapped the Tuskahoma, Winding Stair, Sallisaw and Sans Bois quadrangles for folio publication. He resigned from the Survey before the folios were written, and the results of his work have not been available. At present, the results of the survey of the Sallisaw and Sans Bois quadrangles are being prepared for publication by Carl D. Smith of the United States Geological Survey, who was Taff's assistant when the field work was done. These two quadrangles include the greater part of the area discussed in this paper.

The geology of a small portion of the area has recently been described by Smith in a paper on the Poteau gas field in Bulletin 541-B of the United States Geological Survey.

WORK FOR THIS REPORT.

The field work for the present report was done during the field season of 1913. The writer was assisted throughout the season by Wm. A. Buttram and Geo. D. Morgan, and during the early part of the season by Glenn C. Clark. The work consisted almost entirely in the determination of the structure, especial attention being paid to the location of the anticlines. In the greater part of the area the folds are sharp and the dips sufficiently steep to be read with an ordinary clinometer. In the northwestern part of the area it was necessary to do some areal mapping and to take aneroid readings to determine the structure. In general, the outcrops are sufficiently numerous to permit the axes of the folds to be located with a considerable degree of accuracy, but in some cases the distances between observed outcrops of different dip are considerable and the location of the axis must be approximated. No especial attention was paid to the details of the stratigraphy, except in vicinities where the dips were too small to make clinometer readings sufficiently accurate to determine the dip.

PHYSIOGRAPHY.

The region lies in the drainage basin of Arkansas River. The lowlands in the valley of the river and its tributaries are very flat, and the natural drainage is rather poor. The tops of the majority of the hills are broad and flat-topped, and are at nearly the same level. Their tops, then, can be considered as forming a highland plain into which the streams have cut rather broad, deep valleys. A few isolated peaks rise above the level of the highland plain to heights of 1,500 feet or more. The larger of these peaks are known as mountains, and are named. The principal ones are Sugarloaf, Poteau, Backbone, Cavanal, Potato Peaks, Pigeon, Sans Bois, Tucker Knob, Panther, Beaver, Brooken, and Short mountains.

In general the relation of the structure to the topography is intimate. All of the larger hills or mountains are synclinal, and many of the smaller features are also related to the structure.

The drainage of the area is entirely into Arkansas River. Poteau River carries the drainage of the eastern part of the area northward into the Arkansas, and the principal tributary of the Poteau, Fourche Maline Creek, drains a long, narrow strip along the southern border of the area. Another important tributary of the Poteau from the west is Brazil Creek, which drains a considerable territory in northeastern Latimer, southeastern Haskell, and northwestern LeFlore County. Sugar Loaf, Nail and Gap creeks, and James Fork flow into Poteau River from the east. Canadian River flows through the northwestern part of the area, but it has no very important tributaries within the area, and drains a comparatively small portion of it. The portion of the area between the drainage basins of Poteau and Canadian rivers is drained directly into the Arkansas through Cache and Sans Bois creeks.

STRATIGRAPHY.

The rocks exposed in the area consist entirely of sandstones and shales, with some beds of coal, of the lower part of the Pennsylvanian system. The stratigraphy of these rocks in the southern part, was studied carefully by Taff,* and is given in the paper pre-

*Taff, Joseph A., and Adams, Geo. I., Geology of the Eastern Choctaw Coal Field, Indian Territory; Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 271-279.

viously cited. The following descriptions of the formations exposed are summarized from his more detailed descriptions. The formations exposed are as follows, named from the lowest upwards: Atoka formation, Hartshorne sandstone, McAlester shale, Savanna formation, and Boggy shale.

Atoka formation.—This formation outcrops in a belt varying from 1 to 18 miles wide along the southern border of the area, and also in a belt from 1 to 3 miles wide in the northeastern part of the area. The formation has a thickness of between 6,000 and 7,000 feet, but along most of the outcrop only the upper part of the formation is exposed, the lower portion being cut out by the Choctaw fault to the south. The formation consists principally of shale with four sandstone groups, each about 100 feet thick at intervals of about 1,000 feet apart. The sandstones are brown or light gray in color, and are usually thin-bedded and platy, with the beds separated by shale partings. The shales are rarely exposed, but where they are shown they are bluish clay shales with occasional sandstone concretions. The sandstone groups usually give rise to pronounced ranges of hills, while the shale outcrops form flat plains between them. The Atoka formation contains the gas-producing sands in the Mansfield (Ft. Smith) gas field in Arkansas.

Hartshorne sandstone.—The Hartshorne sandstone is made up of sandstone, shaly sandstone, shale and coal. The thickness is estimated at from 100 to 200 feet. The lower part of the formation is thin-bedded and shaly, and grades into the shales of the underlying Atoka formation. The beds in the upper part of the formation are usually more massive, but in some places the sandstones of the whole formation are thin-bedded and shaly. In some localities there are three beds of sandstone separated by shales. The lower Hartshorne coal lies about 50 feet below the top of the formation, and the upper Hartshorne coal lies at the base of the McAlester shale immediately above the Hartshorne sandstone. The formation outcrops as a southward-facing ridge along the south side of the area. West of Heavener this ridge makes a pronounced loop to the east, around the end of the Heavener anticline. The Hartshorne sandstone also outcrops around the Backbone and Milton anticlines farther north. The Hartshorne sandstone is important on account of its connection with two workable coal beds, as well as on account of its being the gas-producing stratum in the Poteau field.

McAlester shale.—Lying above the Hartshorne sandstone is a formation estimated at 2,000 to 2,500 feet thick, consisting principally of shale, but with some lenticular sandstones, and coal beds of which two are of workable thickness. The outcrop of some of the sandstones can be traced for several miles, and the beds are of considerable thickness, but none of them can be mapped over sufficient area to permit the formation to be subdivided. The great mass of the

formation is of soft, clay shale which shows a blue black color in fresh exposures. Such exposures, however, are rare, for the softness of the formation causes it to weather easily. The outcrop is a flat plain, usually prairie land, between the hills of the Savanna sandstone, and the soil covering the shale is usually several feet in thickness. The flat lands of the McAlester shale area are poorly drained, and are characterized by peculiar, hummocky mounds which occur in great numbers. These are usually less than 100 feet in diameter, and do not stand more than 5 to 6 feet above the general level of the flats. The sandstones usually form low ridges. Two workable beds of coal, the McAlester beds, lie about 600 or 700 feet below the top of the formation. They are separated by about 70 feet of shale. The upper Hartshorne coal forms the lower limit of the formation.

Savanna formation.—This formation consists of three sandstone groups separated by shales. The upper sandstone division is about 200 feet thick while the others are thinner. In all three divisions the beds are more massive toward the top. The shale between the lower and middle sandstone is 300 to 450 feet thick and that between the middle and upper is 450 to 530 feet. The shales are usually more sandy than those of the McAlester and Atoka formations. The Savanna outcrops on the slopes of the principal mountains of the area and, in fact, the mountains are due to the resistant character of this formation, combined with the structure. Large areas in the foothills and lower slopes of Poteau, Sugar Loaf, Cavanal, Potato Peaks and Sans Bois mountains are underlaid by the Savanna. The formation varies in thickness from 1,200 to 1,500 feet in the southern part of the area, the greater thickness being towards the east. To the north the Savanna thins very rapidly and in the Muskogee quadrangle, only 25 miles north of Sans Bois Mountain, it could not be differentiated. It is very probable that the heavy sandstones in Beaver and Brooken mountains, in the hills west of Porum, and along Canadian River south of its junction with the Arkansas, belong to the Savanna, but these ledges are not definitely known north of Arkansas River.

Boggy shale.—Above the Savanna formation is a great thickness, about 3,000 feet, of shale with thin beds of sandstone irregularly distributed through it. The formation occurs well up on the slopes of Sugar Loaf, Poteau, Cavanal, and Sans Bois mountains, and over large areas to the west and northwest. While the shale greatly exceeds the sandstone in the formation, the upper slopes of the mountains mentioned are covered by sandstone bowlders residual from the sandstones, which give the impression that sandstone is extremely abundant in the formation. The sandstones are usually thin-bedded, brown in color and fine-grained. Exposures of the shale are rare but it appears to be very similar to that of the McAlester.

Winslow formation.—Under the description of the Savanna formation it was noticed that this formation disappears to the northward. The Hartshorne sandstone also disappears, or at least was not differentiated in the Muskogee and Tahlequah quadrangles immediately north of the area under consideration. There are thus no dividing lines in the lower Pennsylvanian shales in the extreme northern part of the area and farther north. All the Pennsylvanian rocks below the Boggy shale in this region are grouped into one formation, the Winslow, which is thus roughly the equivalent of the Atoka, Hartshorne, McAlester and Savanna formations to the south. The Winslow consists of shale and thin sandstones. It is much thinner than the equivalent rocks to the south, its thickness being about 1,000 feet while the combined maximum thicknesses of the Atoka, Hartshorne, McAlester, and Savanna are about 10,000 feet.

STRUCTURE.

General relations.—The area covered by this report lies in the Arkansas River Valley between the intensely faulted and folded Ouachita Mountain region on the south and the somewhat less folded and faulted Ozark Mountain region on the north. The area itself is characterized by broad low folds decreasing in intensity from south to north. In the southern part of the area the dips are usually steep, as high as 50° or even more, while in the northern part they are seldom over 5° and are usually less. The area is limited on the south by the great Choctaw fault, which enters the State from Arkansas almost straight east of Heavener and extends in a west and southwest direction to near Atoka, where it passes under the Cretaceous rocks. The older rocks on the south side of this fault have been thrust upward and northward over the younger rocks. In one other locality—along the Backbone anticline which extends north of east from Bokoshe into Arkansas—the force of folding has been sufficient to break the strata and force the rocks south of the break over those to the north. This anticline is thus faulted for a large part of its length. There are also many small local faults and displacements throughout the area.

In general, the synclines are broader than the anticlines. The general course of the folds is from east to west in the southern part of the area and from northeast to southwest in the northern part. In the south portion of the area the folds are usually unsymmetrical with the north sides of the anticlines and south sides of the synclines having the steeper dips.

In the following paragraphs each of the folds are described in turn in as much detail as possible. Reference to the accompanying map (Pl. I.) is continually necessary in tracing the axes of the folds and in following the descriptions. For the folds in the southern part of the area, Taff's work, the results of which were published in the Twenty-first Annual Report, Part II of the United States Geological Survey, is used as a basis and the axes of the folds as shown on the map are not changed appreciably from the location shown on his original map. In Haskell and southeastern Muskogee counties the work is largely original.

Since the work was undertaken with a view of determining the probabilities for oil and gas, more attention was paid to determining the axes of the anticlines than those of the synclines. One great difficulty in locating the axes of the anticlines with any great degree of accuracy is that the anticlinal areas are usually located in the valleys which are eroded in the McAlester shale and that in these valleys exposures are rather rare. So while the presence of an anticline is easily determined, the locating of the axis with exactness is often difficult or impossible. The locations given on the map are believed to be sufficiently accurate to be valuable as a guide for prospecting. It is urged, however, that before any locations for drilling be decided on that a thorough examination of the immediate vicinity of the proposed location be made, since a careful search is likely to show small exposures which were overlooked in the comparatively rapid work done in the preparation of this report. Naturally, the greater number of exposures which show reliable dips, the more accurately can the axis of the fold be located.

In the following paragraphs the folds are described in turn beginning at the southeast part of the area and continuing to the north and west.

Poteau syncline.—This syncline is named from Poteau Mountains which lie in the syncline and extend from near Howe and Heavener eastward to the State line and for a considerable distance into Arkansas. West of the end of the mountains the axis of the syncline crosses the Kansas City Southern Railway between Heavener and Petros switch and soon turns a little to the north of west and continues across the southern part of T. 5 N., R. 25 E., and T. 5 N., R. 24 E. The syncline ends in a basin-shaped structure near the west line of the latter township.

Heavener anticline.—The Heavener anticline lies to the north of the western portion of the Poteau syncline. The axis extends eastward along Fourche Maline. From this point eastward the axis rises very rapidly for a distance of about 4 miles and then descends as rapidly to a point about 2 miles northwest of Heavener. The Hartshorne sandstone and coal outcrop around the north side and east end of the anticline and make a pronounced loop to the westward on the south side. The rocks exposed in the anticline, therefore, belong to the Atoka formation. Measurements across the upturned edges of the rocks indicate that a thickness of 6,000 to 7,000 feet of this formation have been removed from above the axis of the anticline and the bottom of the formation is not yet exposed. The

dips from the axis of the Heavener anticline are quite steep. The general dip to the south is about 30° and to the north and east is from 20° to 40°. The steepest dip observed is about 1 mile south of Glendale Postoffice where there is a dip of about 65° almost directly south. This is very near the axis of the anticline since one-fourth mile to the north there is a dip of 40° to the north. The rocks exposed in the axis of this anticline are the lowest in the entire area under consideration.

Howe anticline.—An anticline, called by Taff the Howe anticline, branches from the east end of the Heavener anticline and extends northeast past Howe. Near the Chicago, Rock Island & Pacific Railway east of Howe this anticline branches, one branch continuing to the east past Hartford, Ark., and one continuing to the north to a point about 5 miles east of Poteau where it turns to the northeast and continues across the state line. The name Howe anticline was applied by Taff to the fold near Howe and to both branches as well. The eastward branch of the Howe anticline has been described by Collier* and by Smith** as the Hartford anticline and the northward branch by Smith as the Poteau anticline. These names will be accepted in this report and the name Howe anticline will be retained for the portion between the Heavener anticline and the junction of the Hartford and Poteau branches. Taff's description of the Howe anticline is as follows:***

> On the northeastern side of the Heavener anticline an anticlinal fold, which may be considered as a branch of the Heavener anticline, bears northeastward through the vicinity of Howe. From the location of Howe, nearly upon its axis, this anticline is known as the Howe anticline. A peculiar relation of the Howe to the Heavener anticline is that their axes do not join, yet the folds are not separated by any indication even of a syncline. * * * The crop of the Hartshorne sandstone southwest of Howe does not bear any indication of the effect of a branch fold. The next sandstone above the Hartshorne, however, diverges from the Heavener anticline near Poteau River and bears northeastward beyond Howe, where it crosses the axis of the Howe anticline and turns southward in the Poteau syncline. Between Howe and Monroe the Howe anticline divides into two folds, one of which bears due east between Poteau and Sugarloaf mountains, while the other turns north between Sugarloaf and Cavanal mountains and then east into Arkansas, north of Sugarloaf mountain. Both branches of this fold are wide and flat. The valleys occupied by the Howe anticline are eroded in McAlester shale. The grades of the streams are very low and the valleys are practically level planes stretching between the mountains from base to base.

Hartford anticline.—As has been said, the east branch of the Howe anticline is known as the Hartford anticline from Hartford, Ark. This anticline is eroded into a valley in the McAlester shale

*Collier, A. J., The Arkansas Coal Field; Bull. No. 326, U. S. Geol. Survey, 1907.

**Smith, Carl D., Structure of the Fort Smith-Poteau Gas Field, Arkansas and Oklahoma; Bull. No. 541B, U. S. Geological Survey, 1913.

***Taff, J. A., Nineteenth Ann. Rept. U. S. Geol. Survey, Part II, pp. 281-282.

so that it is difficult to locate the axis accurately but it is almost coincident in Oklahoma with the course of Sugar Loaf Creek. Farther east in Arkansas the Atoka formation is exposed near the axis of this anticline and gas has been produced from sands in the Atoka near Mansfield. No drilling has been done on this anticline in Oklahoma.

Poteau anticline.—From its junction with the Hartford anticline the Poteau aticline extends almost northeast to a point about due east of Poteau where it gradually turns more nearly to east and crosses the State line into Arkansas in an almost straight east-west direction. It continues into Arkansas for about 12 miles. As is the case with the Hartford anticline the rocks in the Poteau anticline are those of the McAlester shale. Exposures near the country town of Gilmore indicate that the axis passes very near that place, from which fact the anticline has been called by some the Gilmore anticline. The name Gilmore in some respects is preferable to Poteau, since Poteau is well down on the western limb of the anticline and is as near the axis of the syncline (Cavanal) as it is to the axis of the anticline. The dip of the rocks away from the axis of the Poteau anticline is not very steep; the dip to the northwest being 3° to 5° and that to the southeast less than that. Gas in considerable quantities has been found in this anticline east of Poteau in the Hartshorne sandstone. The development will be discussed in a later paragraph.

Sugarloaf syncline.—This syncline lies between the Hartford and Poteau anticlines and is named from Sugarloaf Mountains which are very conspicuous topographic features occupying the portion of the syncline near the axis. The mountains are composed principally of the Savanna formation and are topped by Boggy shale. The dip of the rocks into the syncline is low, not exceeding 5° and usually considerably less than that. The strata in the mountains near the axis are practically level. The syncline extends from near the junction of the Hartford and Poteau anticlines northeastward across the State line and for several miles into Arkansas.

Cavanal syncline.—The Cavanal syncline is a broad trough which extends from the vicinity of Red Oak eastward and northeastward across the State line and for many miles into Arkansas. Potato Peaks and Cavanal Mountain lie in this syncline.

Brazil anticline.—The Brazil anticline extends from the head waters of Brazil Creek northeastward to the vicinity of Walls. Taff describes the fold as rising again and continuing as far as the neighborhood of Bokoshe but a careful search by the writer and his assistants failed to find any north dips in the territory between the Ft. Smith & Western Railway and Brazil Creek in this vicinity while a large number of undoubted southward dips were found. So far as our examinations show the axis of the anticline plunges within

2 or 3 miles of Walls and the rocks in the region south of Bokoshe all dip to the south under Cavanal Mountain. The lowest formation exposed in the anticline is the McAlester shale. The dip of the southeastern limb of the Brazil anticline is from 5° to 8° and that of the northwestern limb from 12° to 18°. The Latimer County Oil and Gas Company has a gas well near the axis of this anticline about four miles north of Red Oak. The town is supplied with gas from the well.

Backbone fault and anticline.—The Backbone anticline extends eastward from a point about two miles south of Bokoshe, eastward past Panama and north of east as far as Greenwood, Arkansas. The anticline is faulted for a considerable portion of its length, the beds on the south side of the fault being thrust over younger beds to the north. The Atoka formation is brought to the surface in the axial portion of the anticline, and the Hartshorne sandstone and coal outcrop around it. The dips in both directions from the axis of this anticline (or the fault) are rather steep, ranging from 12° to 20° or even more.

Bokoshe syncline.—This syncline extends north of east from Bokoshe to Spiro. From Spiro eastward and northeastward to Arkansas River the country is sand-covered and the axis of the syncline cannot be definitely located.

Milton anticline.— Beginning near Lequire, the Milton anticline extends east and northeast, passing through or near Lequire, McCurtain, Milton, and Bokoshe, and to Arkansas River near Redland. Near McCurtain this fold rises in a dome around which the Hartshorne (Panama) coal outcrops. In this dome the rocks are considerably disturbed and there are several local faults which are shown by the displacement of the coal in the mines, but which are seldom noticeable on the surface. For a short distance west of Lequire the Ft. Smith & Western Railway lies practically on the axis of the anticline. East of Lequire the railroad swings to the north of the axis, but crosses it again about two miles west of McCurtain. From this place to Milton the railroad is approximately one-half mile south of the axis. At Milton the axis swings somewhat to the north and passes nearly midway between the old and new towns of Bokoshe, and extends northeastward about one-half mile west of Redbank Creek to the confluence of that stream with Cache Creek, and on to the Arkansas.

Siloam syncline.—The short syncline lying between the southwestern portion of the Milton anticline, and the northeastern part of the Kinta anticline, is called the Siloam from the church of that name in sec. 14, T. 8 N., R. 21 E. The axis lies in the range of hills on the southeast side of Sans Bois Creek between Sans Bois and Ironbridge.

Kinta anticline.—The Kinta anticline enters the area from the west at Featherston and extends eastward in the valley of Sans Bois Creek past Quinton to near Kinta, turns somewhat to the north and crosses the Ft. Smith & Western Railroad between Lewisville and Kinta. It then continues to the northeast in a somewhat curved course, passing through Shropshire valley, and dies out opposite the northeastern end of the Siloam syncline near Ironbridge. The dips are low, usually less than 5 degrees. Some local disturbances give westward dips near the axis between Quinton and Featherston.

Cowlington syncline.—The axis of this fold passes through the hills north of Quinton, through Beaver Mountain, then to the east and northeast through the hills between Pruitt and Shropshire valleys, across Sans Bois Creek and through the hills northwest of Keota, then curves to the east passing a short distance northwest of Cowlington and through Short Mountain.

Enterprise anticline.—This fold enters the area from the west, where House Creek crosses the western boundary and extends northeast across Longtown Creek, passing about a mile southeast of Enterprise, and continues to a point about two miles southwest of Whitefield, where it apparently forks. The exposures in this vicinity are not numerous, and it is possible that the eastern branch does not quite join the main anticline, but the exposures found indicate that such a junction does take place, and it is so considered in this report. The dip to the northwest from the axis is 6° or less, and to the southeast is about 8° at the maximum. The name Enterprise is applied only to the fold southwest of Whitefield. The northern branch is called the Vian anticline, and the eastern the Kanima anticline. The syncline between them is named the Stigler syncline.

Kanima anticline.—Branching from the Enterprise anticline southwest of Whitefield, the Kanima anticline extends almost east to a point 3 miles south of Stigler, where it turns to the northeast passing about a mile east of the Antioch school house, about one-half mile west of Kanima, and on to the Arkansas along the west side of Sans Bois Creek. The dips are about the same as those on the Enterprise anticline.

Stigler syncline.—The axis of the Stigler syncline extends north of northeast from Whitefield, passing about 2 miles northwest of Stigler, through the range of hills on the east side of Canadian River, and to the Arkansas, between Tamaha and Hisaw. The Stigler coal, equivalent to the McAlester coal, outcrops around this syncline.

Vian anticline.—The name Vian is applied to the anticline that forms the northern branch of the Enterprise anticline. It passes near Whitefield, and continues along Canadian River to the confluence of that stream with the Arkansas, crosses the latter stream and continues to the northeast, passing west of Vian. This anticline is

almost certainly responsible for the Canadian's abrupt turn from an easterly to a northeasterly direction at Whitefield. From this turn of the river northeast to the Arkansas the axis of the anticline lies in the alluvium-covered river valley and its exact location can not be determined. All that can be done is to draw the line about midway between the bluffs on the opposite sides of the river. The dips from this anticline are rather gentle, the majority of the recorded dips being 3 to 5 degrees.

Porum syncline.—From the crest of the Vian anticline, the rocks dip gently to the west for 6 or 8 miles into the Porum syncline. The axis of this fold is well defined in the hills west of Porum and it extends to the southwest through Brooken Mountain. To the north of the hills west of Porum the country is almost flat and exposures are few. The axis can not be very definitely located but some small hills extending north and slightly east from the large hills are believed to be very near the axis.

Warner anticline.—This fold occurs in the extreme northwestern part of the area examined by the writer. It rises near the Muskogee-McIntosh county line about 4 miles north of Canadian River and extends northeast through Gap Prairie. Farther north there are very few exposures and the axis can not be definitely located. However, it is believed to extend almost directly north and to pass very near the town of Warner. From near Warner a branch extends southwest along the head waters of Georges Fork. This branch appears to end near the Pleasant View School in sec. 8, T. 11 N., R. 18 E.

STRUCTURE IN THE McALESTER-LEHIGH COAL FIELDS

A considerable area to the west and southwest of that just described has been studied and mapped in considerable detail by Joseph A. Taff for the United States Geological Survey and has not been subsequently studied by any one connected with the Oklahoma Geological Survey. In order to present as complete a report as possible, these folds have been shown on Plate II as mapped by Taff, and his descriptions of them are given in full. These descriptions are from the paper entitled "The McAlester-Lehigh Coal Field, Indian Territory," in the Nineteenth Annual Report of the United States Geological Survey, Part III. The stratigraphy, except for minor changes, is the same as in the area to the east which has been described.

STRUCTURE.

General relations.—At the eastern border of the McAlester quadrangle the general strike of the rocks is east and west. This structure continues eastward to the Arkansas line, as shown by Dr. Chance, who examined these rocks and reported upon them in 1890. In Arkansas the same general strike of the rocks prevails from the Arkansas line down the Arkansas River Valley to the Tertiary overlap of the Mississippi embayment, both in the Upper and Lower Coal Measures, as shown by the work of the Arkansas Geological Survey. From the eastern border of the McAlester quadrangle westward the strike of the rocks changes from west to southwest and then south to the Cretaceous border near Atoka, Indian Territory.

From the Chickasaw Nation eastward these rocks have the same general structure, which is that of wide canoe-shaped synclines lapping upon narrow, compressed, and often slightly overturned anticlines. This is also the typical structural character of the Northern Appalachian region. Like the structure in the Appalachian region, again, the folding here becomes less intense toward the north and west, nearer the interior of the coal field. The belt of folded coal-bearing strata varies from 10 to 15 miles in width. North and west of this folded belt the rocks are somewhat crumpled, but maintain a slight downward grade toward the north and west. The structure sections and accompanying map will illustrate the essential features of the rocks of this coal field.

The Kiowa syncline.—The Hartshorne sandstone is at the base of the Productive Coal Measures of this coal field. South of Hartshorne this sandstone is a ridge maker and is usually exposed at its crop, where it dips to the north at about 30°. The dip decreases northward, and is horizontal at the center of the basin, 3 miles distant, where the sandstone lies not more than 600 feet beneath the surface. At Gowen, 3 miles still farther north, it comes up on the north side of the basin, forming a prominent ridge. From Hartshorne it strikes westward and then southwestward to the limits of the quadrangle, with dips varying from 40° to 80° toward the north and northwest. From Gowen, on the north limb of the syncline, the rocks bear a little north of west to the vicinity of Alderson, where they turn toward the north and pass across the axis of the McAlester anticline. The axis of this syncline, as in a typical canoe basin, pitches abruptly westward at the east end, northeast of Hartshorne, for a short space, and then becomes nearly horizontal north of Hartshorne. Sandstones which cap the flat topped mesa of Belle Starr Mountain appear at the same elevation in the ridge northwest of Hartshorne, pitching 6° toward the west. From the vicinity of Hartshorne southwest this syncline becomes rapidly broader and deeper for 6 to 8 miles, and then grows narrower, with a gradually rising axis to the vicinity of Kiowa. Opposite Kiowa this synclinal basin is about 4 miles wide. From Kiowa toward the southwest the basin grows gradually broader to the limit of the McAlester quadrangle, where it divides into two synclines separated by a peculiar anticline; one of these extends nearly due south, ending in the Lehigh Basin, while the other bears southwestward into the southern part of the Coalgate quadrangle, where it becomes broad and flat.

The contraction of the Kiowa syncline near Kiowa appears to be due to a northwestward movement of the strata from the south side of the basin. The northwestward overthrust of the older rocks southeast of Kiowa corresponds in strike and movement with those of the coal-bearing beds on the south side of Kiowa basin.

The McAlester anticline.—The axis of the McAlester anticline enters the quadrangle upon the east side, in the valley of Gaines Creek, and bears very nearly west for 10 miles, where, at a point between Alderson and Cherryvale, it divides into two folds. One of these divisions of the fold bears southwest by way of Savanna to and beyond the border of the quadrangle. This south division of the anticline is called the Savanna anticlne. The other, a more direct continuation of the main fold, bears northwest from Cherryvale for nearly 3 miles and then west to McAlester, where it curves southwest and passes the limits of the quadrangle parallel with the Savanna anticline.

The strata involved in the McAlester anticline from the eastern border of the quadrangle to Cherryvale have been thrust over toward the north, so that the beds upon the north side are on edge in places. At other places, especially south of Cherryvale, the Hartshorne sandstone has been overturned and, it is believed, faulted.

Through its course from Cherryvale eastward the axis of the anticline is almost horizontal. From Chreryvale westward it pitches downward rather abruptly at from 16° to 20°. The Krebs syncline crosses the McAlester arch east of Krebs and depresses it as well as deflects it northward. North of Krebs, however, the McAlester arch regains its normal condition as an unsymmetrical fold, and continues westward, with nearly horizontal axis, to a pont about 6 miles southwest of McAlester, where it pitches rapidly for a short space, then becomes a low, wide symmetrical arch, and as such continues to the western limit of the McAlester quadrangle. Upon the south limb of the McAlester anticline, near the axis the rocks dip usually from 10° to 25°, while upon the north limb, except where the arch is low, and near the western border of the quadrangle, they dip from about 30° to 90°, and in a few places, as noted, are overturned and faulted, dipping southward nearly 90°.

The Savanna anticline.—This fold joins the McAlester anticline about 2 miles east of Krebs, and thence bears almost due southwest to the western border of the quadrangle. In the northeastern part of its course it is not a well defined fold. It is little more than a southwestward pitching swell upon the southern limb of the McAlester anticline. South of Krebs the ill-defined axis of this fold pitches southwest probably 10°, and south of McAlester it begins to rise. South of Savanna this axis rises rather abruptly at an angle of nearly 20°. From Savanna it continues southwestward almost level to a point northwest of Kiowa, where it begins to pitch downward, and so continues beyond the limit of the McAlester quadrangle.

Northeast from Savanna the rocks dip gradually away toward the northwest and southeast from the axis of the fold. South and southwest of Savanna the fold near the axis becomes sharply contracted and elevated, so that the rocks dip northwest 40° to 60° and southeast 55° to 90°. This fold between Savanna and Kiowa may be compared to an inverted and narrowly contracted canoe. The south side of this inverted canoe is so crushed near the northeast end that the rocks are vertical, while at the end near by the dip will not exceed 20°. The same is true near the southeast end,

northwest of Kiowa, except that there has been greater compression upon the northwest side of the fold.

The Krebs syncline.—Southwestward from the vicinity of South McAlester, for a distance of nearly 10 miles, the Krebs syncline is a normal canoe basin. Upon the sides and end of the canoe the rocks dip nearly equally—about 15°. Upon the southern side of the syncline farther southwest, opposite Savanna, the dips increase to 45° and from Savanna to the western border of the quadrangle this dip is generally maintained, though it is in places greater. From the southeast side of this basin the dip decreases rapidly toward the northwest from 45° to 10° within the space of a mile. For a wide space the rocks in the central part of this basin are nearly horizontal, and upon the north side of the basin, near the west side of the quadrangle, the beds rise gradually upon the low arch of the McAlester anticline.

The syncline from Krebs eastward across the McAlester anticline can not be easily defined. It is shallow and rises with a gradual upward incline to the axis of the McAlester anticline. From the same point on the McAlester anticline this syncline pitches at a low angle downward toward the east. Northeast of Cherryvale the axis bears northeastward and then east, crossing the side of the quadrangle about 2 miles south of the northeast corner. As is the case in the vicinity of Savanna, the rocks here in the south side of the basin dip steeply toward the north over about 1 mile, and then for a wide space the rocks are nearly horizontal. From the center of the basin northeast of Cherryvale the rocks rise at a low angle to the limit of the quadrangle.

Minor folding north of the McAlester anticline.—Nearly due north of Krebs a narrow and short anticlinal fold extends eastward from the McAlester anticline. Upon the north side the rocks are steeply upturned, while upon the south side the dips are very low. This local anticline is a well-defined structural feature for more than 3 miles from the McAlester anticline. The rocks upon the north side dip at contnually lower angles as they are followed eastward. Upon the south side they become horizontal near the axis for 3 or 4 miles, where the anticline becomes simply a swell upon the northern limb of the Krebs syncline and is lost as a structural feature.

An ill-defined shallow basin occurs north of the McAlester anticline west and northwest of McAlester. The axis of this basin lies 2 1-2 to 3 miles north of the McAlester anticlinal axis and is nearly parallel with it. North of the town of McAlester this basin takes a more northerly turn and passes beyond the limits of the quadrangle. Within 6 miles of the western border of the quadrangle the northern limb of this syncline is nearly horizontal, and further west the fold loses character as a structural feature, becoming simply a wide and very shallow depresson upon the northern limb of the McAlester anticline.

Local folding near Hartshorne.—From Hartshorne southwestward for nearly 6 miles the Hartshorne sandstone, with shale, minor sandstone beds, and coal overlying it, is crumpled in an unusual manner. This structure is upon the southern limb of the Kiowa syncline. South and west of Hartshorne

the Hartshorne sandstone dips north at 15° to 25°. One-half mile southwest of Hartshorne this sandstone strikes almost due north for nearly 1 mile with dips toward the east, then west for nearly a mile with dips toward the north, and then south nearly a mile with dips toward the west, where it takes a southwest bearing with steep dip toward the northwest. Thus a short and almost square anticlinal fold is indicated with axial trend almost perpendicular to the general structure of the Kiowa syncline. Six miles southwest of Hartshorne the same sandstone turns in strike from southwest to almost directly northwest, and continues for half a mile with dips toward the northeast. At this point it turns in strike nearly 90° and bears again southwest. Rocks which lie 600 to 1,200 feet above the Hartshorne sandstone show in their outcrop a local syncline and anticline, one lying above the other upon the south limb of the Kiowa syncline, between the structures noted one-half mile and 6 miles, respectively, southwest of Hartshorne. The axes of these folds are parallel with the trend of the Kiowa syncline.

The cause of this buckling of the Hartshorne sandstone and associated rocks may be suggested by the location of the structures in the obtuse angle at the junction of the major east-west and northeast-southwest trends of folding in this district.

Faults and shear zones.—The faulting in this coal field is of minor importance and local extent. The sandstone beds, which are exposed in ridges, curve back and forth across the field, so that faults of much magnitude may be easily detected. A fault that may be called the Cherryvale fault occurs on the north limb of the McAlester anticline with strike parallel to the folding. Its location could not be determined with precision, but it occurs between the mines in Cherryvale and the crest of the ridge about one-fourth of a mile south of the town. The fault is an overthrust from the south. It is believed to extend not far from Cherryvale toward the east, and but a few miles toward the west.

The local faulting occurs in the sandstone ridge in the town of South McAlester, as may be seen in the railroad cut north of the station. It is of small extent and does not displace the sandstone which forms the ridge to more than barely appreciable extent.

In the vicinity of Kiowa, where the beds in the south side of the Kiowa basin have been deflected toward the northwest, the sandstone beds have been broken by cross faults or zones of shearing in a number of places. This structure is especially prominent in the limestone ridge, below the coal-bearing beds, immediately south of Kiowa, where it has been thrust strongly over toward the northwest. Near the south side of sec. 25, T. 3 N., R. 13 E., the Hartshorne sandstone is broken and displaced laterally 200 feet. The sandstone on the east side is thrust toward the north with respect to the sandstone on the west side. This sandstone is inclosed in several hundred feet of shale, so that it is not possible to trace the displacement farther than the limit of the sandstone. Near the middle of section 3 and the north side of section 10, T. 2 N., R. 13 E., other shear zones or

cross faults occur in the Hartshorne sandstone. In the first instance the sandstone on the southwest side of the break is thrust northward and overturned, while that on the other side remains with normal northwest dip. In section 10 the displacement is in the opposite direction.

These features of structure are not of great importance of themselves, but a knowledge of their occurrence and character will be of much value to the prospector and miner who operate coal in their vicinity.

The Lehigh basin.—This basin is a southern prolongation, in part, of the Kiowa syncline. It is broad and deep in the central part, opposite Lehigh, and much contracted and elevated at the north end, where it joins the Kiowa syncline. The contraction at the north end is due to the eastward bearing and enlargement of the Coalgate anticline at its north end. The Lehigh basin in surface outline is elliptical. It is relatively deep and its axis lies near its eastern side. The Savanna sandstone series and other associated beds which outcrop on the east side of this basin are upturned until they are almost vertical. Along their outcrop they form a prominent ridge. As they extend around the south end of the basin, west of Atoka, these beds separate in outcrop as the dips become less, and the thick sandstone strata form low ridges which curve, one after the other, in gradually widening lines. From the vicinity of Lehigh on the west side for a distance of 6 miles inward toward the axis the beds dip about 4°. Beyond this the rocks increase in dip to nearly 10° toward the center of the basin. It will be seen by this description and by reference to the section and map that the Lehigh basin is structurally unsymmetrical. Extensive westward overthrusting and faulting of the beds lying beneath the coal-bearing strata, between Limestone Gap and Atoka, immediately east of the Lehigh basin, have pressed the coal-bearing rocks westward and upward, while the same beds on the west side of the basin have been but little disturbed. The basin is canoe-shaped, its axis rising at both the north and the south end.

The Coalgate anticline.—This anticline is a peculiar structural feature. From Coalgate southwestward this fold is broad and very obtuse. The strata below the Lehigh coal bear westward around the south end of the Lehigh basin and then northward toward Coalgate. Southwest of Coalgate these beds curve gradually westward and then southwestward into the swamps of Clear Boggy Creek. The Lehigh coal bed in its outcrop emphasizes the character of this anticlinal structure more strongly. From Lehigh the strike of the coal bears nearly due north, with low east dip to Coalgate, where it turns abruptly southwestward. One mile northeast of Coalgate this coal rises and is exposed for nearly 8 miles in an elongated dome bearing northeastward. The Lehigh coal and the sandstones and shales for several hundred feet above the coal dip 10° to 15° from the axis of this dome. From a point about 7 miles northeast of Coalgate the rocks upon the axis of the Coalgate anticline pitch rapidly northeastward. This pitch gradually grows less until the anticline is lost as a structural feature in the center of the Kiowa syncline near the west end of the Kiowa Hills, southwest of Kiowa.

Three to five miles northwest of the axis of the Coalgate anticline there

is a parallel shallow syncline whose axis is nearly parallel to that of the Coalgate. The axis of this syncline rises toward the northeast and the syncline dies out or coalesces with the Kiowa syncline opposite the northeast end of the Coalgate anticline.

The axes of the folds according to Taff's mapping are shown on Plate II.

PROSPECTS FOR PETROLEUM AND NATURAL GAS IN EAST-CENTRAL OKLAHOMA.

The rocks of this entire region are sandstones and shales of the Pennsylvanian system, and are of the same general age and character as the oil and gas-bearing rocks in the main field farther to the northwest. The rocks are folded into structures suitable for accumulation and the sandstones are of such a nature to afford good reservoirs. The shales with which the sandstones are interstratified are dense enough to form efficient cap rocks. In some parts of the region the structure is sharp, that is, the rocks have been thrown into very steep folds and there is some local faulting. In these places it is possible that the rocks have been broken so that any oil or gas contained in them could have found a way to the surface and escaped. In a very steep fold the belt of oil or gas is probably very narrow and the chances for striking the deposit are less than on gentle folds.

In general the rocks exposed in the anticlines in this region are the lower part of the McAlester shale, the Hartshorne sandstone and the Atoka formation. These rocks have so far proved to be productive only of gas. Considerable quantities of gas have been found in the Hartshorne sandstone at Poteau in LeFlore County, and in either the Hartshorne sandstone or sandstones near it in the McAlester shale at Wardville in Coal and Pittsburg counties. Gas has also been found at about the same horizon north of Red Oak and at Kinta. The Atoka formation produces gas from near Mansfield and Ft. Smith, Ark. From the development so far it seems that the whole thickness of the Atoka—6,000 to 7,000 feet in the eastern part of the area and 3,000 to 4,000 feet in the vicinity of Coalgate—is liable to contain productive gas sands. So far there has been scarcely a showing of oil found in the region covered by this report. It is, of course, entirely possible that considerable bodies of oil may yet be found, but the fact that several holes have been drilled in favorable localities at widely separated points, and that only gas has been found does not make the prospects for oil very flattering at present.

On all of the anticlines there is a sufficient thickness of probable gas-bearing rocks beneath the surface to make prospecting for gas

advisable where the structure is not too steep. The degree of dip has been given under the description of the individual folds and need not be repeated here.

DEVELOPMENT.*

The development in the region consists of a number of wells in Coal and Pittsburg counties near Wardville and near Poteau in LeFlore County. There are also several isolated wells which will be briefly noted.

The development in Coal County to the middle of 1913 is as follows:

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

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

Poteau.—So far ten wells have been drilled in the vicinity of Poteau as follows:

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

*Snider, L. C., Petroleum and Natural Gas in Oklahoma.

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

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

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

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

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

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

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

In the fall of 1913 a well was drilled in SE 1-4 sec. 21, T. 7 N., R. 26 E., to a depth of 2,600 feet. A flow of 200,000 cubic feet of gas was found in the Hartshorne sandstone but the well caved badly and was plugged.

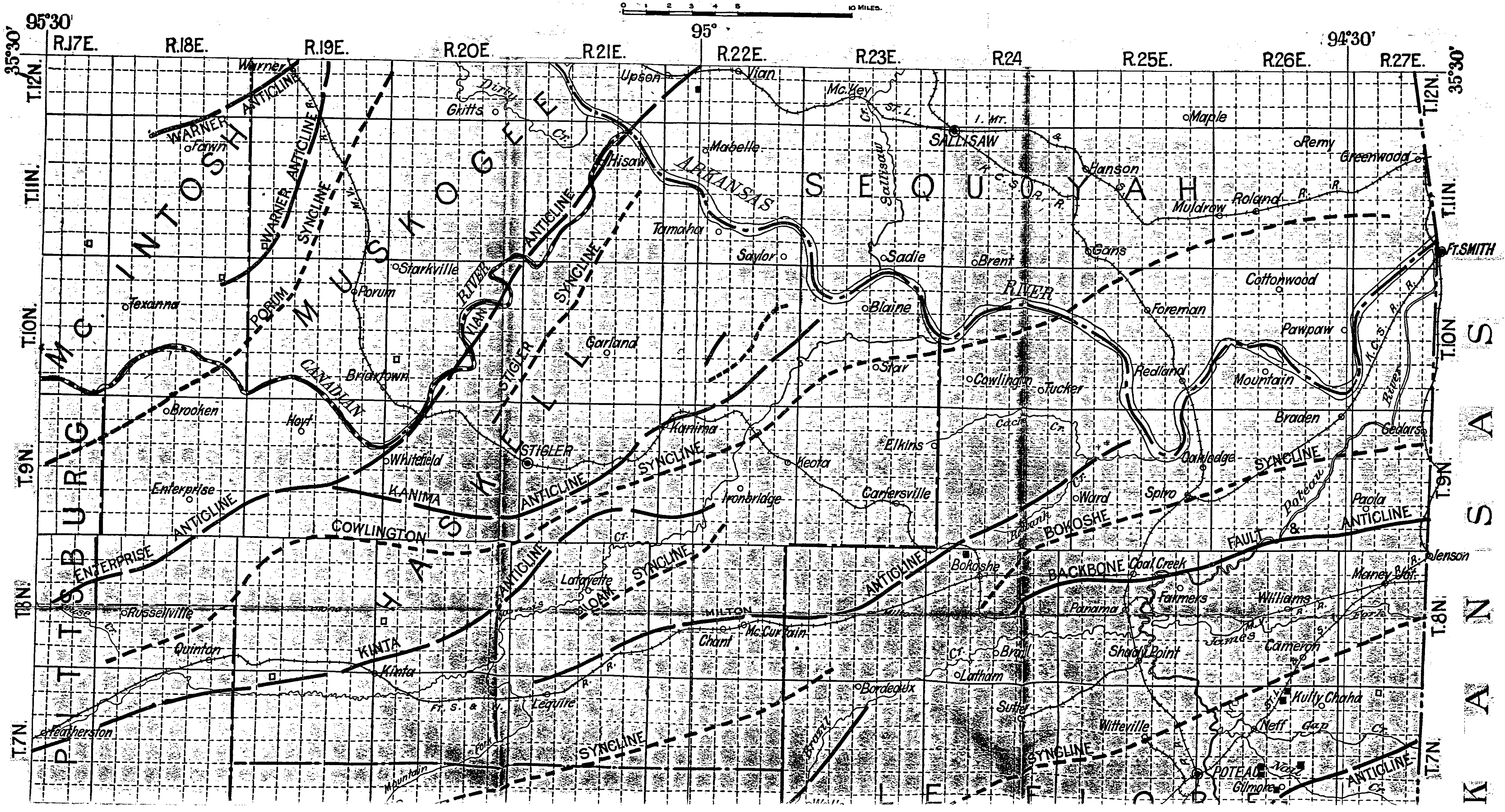
A well reported as yielding 10,000,000 cubic feet of gas per day was brought in during May, 1914.

The sand in the gas wells is reported as being about 220 feet

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

Other wells.—In addition to the development noted there are a few wells which have proven productive of gas at other localities in this region. Gas is reported in a well about 1,000 feet deep at Vian in southwestern Sequoyah County. This well is probably located on the Enterprise anticline. Four wells have been drilled at or near Spiro in northern LeFlore County, two wells were gas producers and two dry holes. The capacities of the gas wells are reported at from 750,000 to 3,000,000 cubic feet per day. A well 4 miles north of Red Oak in Latimer County is reported to have a capacity of 4,000,000 cubic feet per day. A well at Kinta in southern Haskell County is reported to have a capacity of 2,000,000 cubic feet at a depth of 1,700 feet. At Bokoshe a well was recently completed. Some gas was encountered but the quantity is not known. No oil was found. A well was drilled near Briartown in Southeastern Muskogee County, some distance from the axis of the Vian anticline without results. Some gas was found in a well about 4 miles west of Porum on the south branch of the Warner anticline. A well farther west, about 2 1-2 miles north of Texanna was dry.

Map showing the axes of the PRINCIPAL FOLDS in EAST CENTRAL OKLAHOMA.



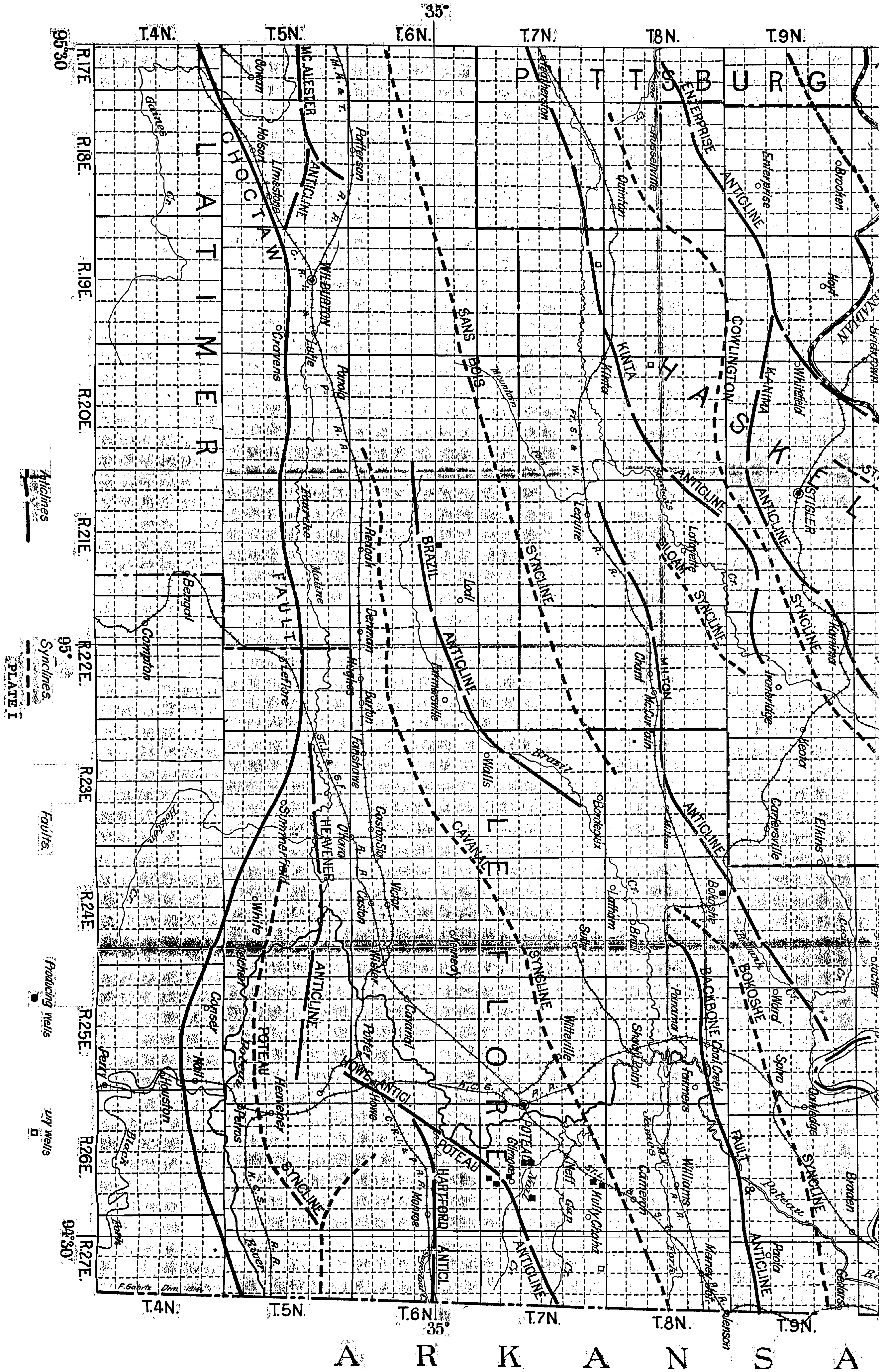
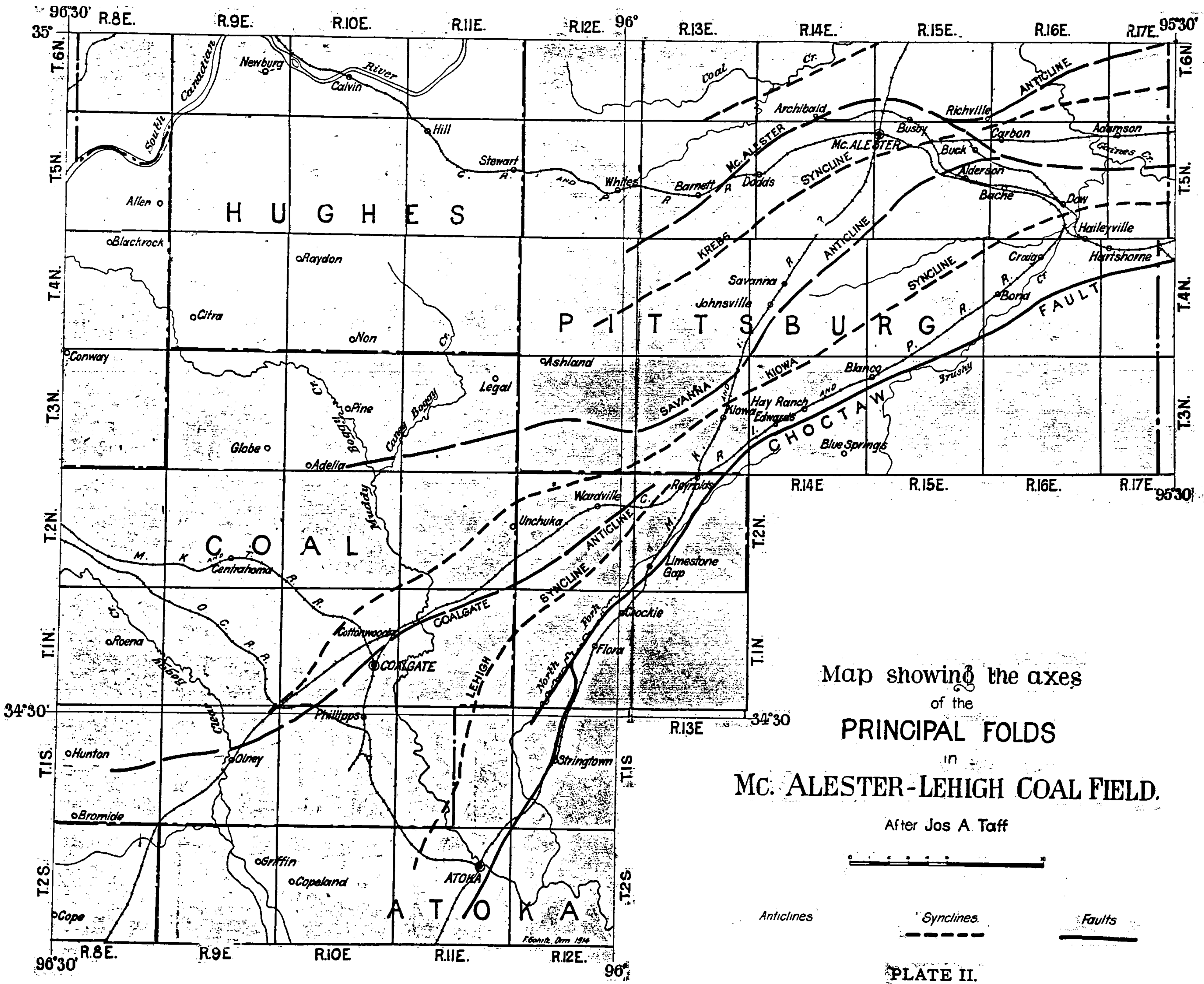


PLATE I
Anticlines
Synclines
Faults
Producing wells
Dry wells
T.4N.
T.5N.
T.6N.
T.7N.
T.8N.
T.9N.
35°
95°30'
95°
94°30'
R.17E.
R.18E.
R.19E.
R.20E.
R.21E.
R.22E.
R.23E.
R.24E.
R.25E.
R.26E.
R.27E.
PITTSBURG
HASKELL
LATIMER
LE FLORE
ARKANSAS
CHOCTAW FAULT
MC ALESTER ANTICLINE
SANS BOIS SYNCLINE
KINTA ANTICLINE
ENTERPRISE ANTICLINE
COWLINGTON ANTICLINE
KANIMA ANTICLINE
SLOAN SYNCLINE
STIGLER
BRAZIL ANTICLINE
CAVANAL SYNCLINE
MILTON ANTICLINE
HEAVENER ANTICLINE
POTEAU SYNCLINE
HOWE ANTICL
POTEAU
HARTFORD ANTICL
POTEAU ANTICLINE
BACKBONE FAULT & ANTICLINE
BOKOSHE SYNCLINE
WILBURTON
F. Gabritz Dim. 1914.



Map showing the axes of the PRINCIPAL FOLDS in Mc. ALESTER-LEHIGH COAL FIELD.

After Jos A Taff

PLATE II.