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# GEOLOGY AND COAL AND NATURAL GAS RESOURCES OF NORTHERN LE FLORE COUNTY, OKLAHOMA

BY

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Investigation conducted under cooperative agreement between the Oklahoma Geological Survey and the Geological Survey of the United States Department of the Interior

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## ABSTRACT

Northern Le Flore County contains substantial resources of low-volatile bituminous coal, which, when blended with other coals, make satisfactory metallurgical coke for blast furnace use. In addition, it has other types of coal, and important natural gas fields.

The area is part of the Arkansas Valley, lying between the Ozark Plateau on the north, and the Ouachita Mountains on the south. The altitude ranges from 400 feet above sea level along the Arkansas River, to 2,369 feet on Cavanal Mountain, and 2,564 feet on Sugarloaf Mountain.

Bedrock exposed belongs to the Pennsylvanian system and consists in ascending order of the Atoka formation, the Hartshorne sandstone, and the McAlester, Savanna, and Boggy formations. These formations are predominately shale, but include relatively thin and more or less widely spaced units of sandstone and siltstone; coal beds occur in all but the Atoka.

The strata are thickest beneath Cavanal Mountain, where correlatives of all the rocks exposed in the area are believed to total at least 12,000 feet. The units are markedly thinner northward seemingly as a result of (1) increasing distance from a southerly source of sediments, (2) greater subsidence in the southern part of the county during deposition, and (3) possibly to minor unconformities. More than 1,000 feet of strata ranging in age from Pennsylvanian to Ordovician, and in large part equivalent to rocks exposed in the Arbuckle Mountains, were penetrated beneath the Atoka formation in a gas well.

Northern LeFlore County lies within a belt of moderately deformed Paleozoic rocks north of the strongly deformed rocks of the Ouachita Mountains. Structural features comprise many synclines and anticlines whose axes trend chiefly easterly and northeasterly. There are also many faults both thrust and normal. Some are related to a system of sub-parallel fractures that trend in general east-northeastward in several counties on the southern and western flanks of the Ozark dome. Both faulting and folding occurred in late- or post-Boggy time, resulting from compressive forces that were exerted from a southerly direction.

The most valuable coal beds are the Lower and Upper Hartshorne beds within and at the top of the Hartshorne sandstone respectively, which have been mined in many places. The Stigler bed, in the McAlester formation, the Cavanal and other beds in the Savanna formation, and the lower Witteville and Secor beds in the Boggy formation are also minable in many places. The coal beds dip more than 5° at most places and are therefore mined chiefly by underground methods. The room and pillar method is generally employed, but a few mines at and near Poteau are worked by the long-wall method, and there have been some small stripping operations. Much of the minable coal lies beneath land formerly segregated for the benefit of the Choctaw and Chickasaw Indian Nations. These lands were purchased by the Federal Government in 1949, and are now administered by the Bureau of Land Management, Department of the Interior, under operational supervision by the United States Geological Survey.

Production of coal recorded in Le Flore County from 1908 to 1943, inclusive, was 11,353,628 tons, most of it from the northern part and mainly from the Hartshorne coal beds. The coal is low- to medium-volatile bituminous in rank, with heating values between 13,000 and 15,000 B.t.u. on an air-dried basis.

The coal of the Upper and Lower Hartshorne beds generally is low in ash and sulfur, and this probably also is true of the Stigler bed; whereas the coal of the Secor, Lower Witteville, and Cavanal beds generally contains more sulfur and ash. The Hartshorne coal has been blended with other coals for making metallurgical coke in byproduct ovens. It also is shipped to northern markets for use as "smokeless" fuel.

Natural gas fields of northern Le Flore County include the Cartersville and Poteau-Gilmore fields, which are the largest, and the Spiro, Cameron, Rock Island, and Cedars fields. All of the gas is dry, and the average calorific value is about 986 B.t.u.

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## INTRODUCTION

The geology and coal and natural gas resources of an area of about 500 square miles in northern Le Flore County, Oklahoma (Plate I), have been studied by the writer in pursuance of a cooperative agreement with the Oklahoma Geological Survey and the Geological Survey of the United States Department of the Interior. The study was undertaken primarily for the purpose of gathering geologic information that will aid in the development of the coal deposits of the county for different uses, including especially the manufacture of metallurgical coke. The field work in Le Flore County was carried out by the writer over a total period of six months in the autumn and winter of 1942-1943 and the summer of 1943. In this work he was assisted for 3 months by W. J. Souder and for one month by W. E. Ham.


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

The area studied (Fig. 1) lies north of Cavanal Mountain and is bounded on the west by Haskell County, on the north by the Arkansas River, and on the east by the State of Arkansas. The area is traversed by U. S. Highways 59 and 271, by Oklahoma State Highway No. 9, and by the Kansas City Southern, St. Louis and San Francisco, and Midland Valley Railroads.

The largest town is Poteau, the county seat, with a population of about 4,000. At the northeast corner of the county are the city of Fort Smith, Arkansas, and its suburb Arkoma, Oklahoma; other centers of population are Cameron, Spiro, Panama and Bokoshe.

Aerial photographs furnished by the Agricultural Adjustment Administration served as base maps and, as the field work progressed, were studied stereoscopically as an aid to interpretation of the geologic features. The geologic mapping, drainage, and cultural features were traced with black crayon directly from the photographs onto township diagrams drawn on sheets of transparent cellulose acetate to a scale closely approximating that of the photographs, which is nearly 1:20,000. These diagrams were then assembled and redrawn, as Plate I of the present report, on a base map prepared from township plats furnished by the Bureau of Land Management of the United States Department of the Interior. The area studied is well suited to application of this method of mapping, as most of the photographs clearly express the survey of the General Land Office as represented in the network of roads, which run chiefly along section and half-section lines, and in the outlines of cultivated fields. The photographs, moreover, are fairly uniform in scale, owing to the relatively low relief prevalent in the area. Altitude data for use in interpretation of the geology were obtained by aneroid traverses based on official bench marks and corrected for atmospheric pressure in relation to time by means of barograph charts furnished by the Fort Smith office of the U. S. Weather Bureau.

*Previous investigations.* The earliest geologic investigation known to have been conducted in northern Le Flore County was that of Drake[1] which formed part of a general reconnaissance of the Indian Territory. Results of later investigations, by Taff and his associates, were described in four published reports;[2] other publications include a brief description of the geology with reference to oil and gas by Stone and Cooper,[3] a compilation of analyses

1. Drake, N. F., "A Geological Reconnaissance of the Coal Fields of the Indian Territory," *Am. Ph. Soc. Pr.*, vol. 36, pp. 326-419, 1897. Also in *Leland Stanford Univ. Contr. Biol.*, vol. 14, pp. 226-419, 1898.

2. Taff, J. A., and Adams, G. I., "Geology of the Eastern Choctaw Coal Field, Indian Territory": *U. S. Geol. Survey 21st Ann. Rept.*, Pt. 2e, pp. 257-311, 1900.

Taff, J. A., "The Southwestern Coal Field": *U. S. Geol. Survey 22nd Ann. Rept.*, Pt. 3, pp. 367-413, 1902.

Taff, J. A., "Maps of Segregated Coal Lands in the McCurtain-Massey District, Choctaw Nation, Indian Territory": *U. S. Department of the Interior Circular* No. 4, 1904. Also in "Coal Lands in Oklahoma": *61st Congress, 2nd Session, S. Doc.* 390, pp. 275-324, 1910.

3. Stone, J. A., and Cooper, C. L., "Oil and Gas in Oklahoma (Haskell, Latimer, Le Flore and Sequoyah Counties)": *Okla. Geol. Survey Bull.* 40, Vol. III, pp. 411-430, 1929.

of the coal of the district by Cooper and others,[4] and a map of the coal beds by Thom.[5] Thom made a geologic study of most of the area in 1927 and 1928 and prepared a geologic map and brief text for the administrative files of the Federal Geological Survey. Knechtel prepared a preliminary map and brief report covering the area described in this report.[6]

Adjacent areas whose geology is described in published reports include the neighboring part of Arkansas,[7] and the Quinton-Scipio,[8] Muskogee-Porum[9] and Howe-Wilburton[10] districts of Oklahoma. The adjacent part of Haskell County, Oklahoma, was studied by the writer in the autumn of 1943 and the summer of 1944 and is described in Bulletin 67,[11] of the Oklahoma Geological Survey.

## GEOGRAPHY

Northern Le Flore County is a part of the Arkansas Valley lying between the Ozark Plateaus on the north and the Ouachita Mountains on the south. The surface has moderate relief, ranging from about 400 feet above sea level along the Arkansas River, to more than 1,000 feet on the slopes of Cavanal Mountain (Elevation 2,369) and Sugarloaf Mountain (Elevation 2,564).

## LAND FORMS

Much of the county is hilly, owing largely to the action of streams upon bedrock strata differing greatly in their capacities for resistance to erosion. Much of the landscape is characterized by

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4. Fieldner, A. C., and others, "Analyses of Oklahoma Coals": *U. S. Bureau of Mines Technical Paper* 411, 1928.
5. Thom, W. T., Jr., "Coal Map of the Stigler-Poteau District, Pittsburg, Haskell, and Le Flore Counties, Oklahoma": *U. S. Geol. Survey Preliminary Edition*, 1935.
6. Knechtel, M. M., "Map of Northern Le Flore County, Oklahoma, Showing Geologic Structure, Coal Beds, and Natural Gas Fields": *U. S. Geol. Survey*, 1944.
7. Collier, A. J., "The Arkansas Coal Field": *U. S. Geol. Survey Bull.* 326, 1907.
Hendricks, T. A., and Parks, Bryan, "Geology and Mineral Resources of the Western Part of the Arkansas Coal Field": *U. S. Geol. Survey Bull.* 847-E, 1937.
8. Dane, C. H., Rothrock, H. E., and Williams, J. S., "Geology and Fuel Resources of the Southern Part of the Oklahoma Coal Field; Part 3, The Quinton-Scipio District, Pittsburg, Haskell, and Latimer Counties": *U. S. Geol. Survey Bull.* 874-C, 1938.
9. Wilson, C. W., Jr., and Newell, N. D., "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma": *Okla. Geol. Survey Bull.* 57, 1937.
10. Hendricks, T. A., "Geology and Fuel Resources of the Southern Part of the Oklahoma Coal Field; Part 4, The Howe-Wilburton District, Latimer and Le Flore Counties": *U. S. Geol. Survey Bull.* 874-D, 1939.
11. Oakes, Malcolm C. and Knechtel, M. M., "Geology and Mineral Resources of Haskell County, Oklahoma": *Okla. Geol. Survey Bull.* 67, 1948.

long, curving, nearly parallel hogbacks that coincide generally with the outcrops (Pl. I) of the hard, sandstone members of the rock sequence. Between them are wide valleys carved by erosion in less resistant, thick rock members composed mostly of shale. Where the strata dip steeply the hogbacks are closely spaced, narrow, and more or less sharp-crested; they are broader and more widely spaced where the dip is gentle. Prominent mesas occur in some places where the dip is horizontal or nearly so, as along the axes of some synclines. Recent alluvial plains along the Arkansas River, Poteau River, and Brazil Creek form considerable areas of bottomland. Remnants of an older alluvial plain of the Arkansas River form terraces near Spiro and at Pocola, and other alluvial terraces occur farther south in tracts adjacent to the slopes of Cavanal Mountain and Sugarloaf Mountain.

### "PIMPLE" MOUNDS

Hummocky plains of a type called "pimpled plains" by Fenneman[12] occur in many parts of this county. Such plains are characterized by vast numbers of rather evenly distributed small hummocks, or natural mounds, which are nearly circular in plan and symmetrical in profile. These mounds are generally 2 to 3 feet high and about 50 feet, though rarely as much as 100 feet, in diameter. The mounds commonly occur with a density of about 4,000 to the square mile and show on aerial photographs as small spots dotted, stipple-fashion, against a darker or lighter background. As seen in profile in many road cuts they are formed of silty soil. Some of them contain many small pellets composed of limonite and of silt cemented by limonite, distributed at random in the soil that forms the mound. The soil at the base of many of the mounds in Le Flore and Haskell Counties rests with a sharp, straight line of demarcation on a flat, nearly level surface commonly underlain by soil that is more firm and lighter in color than that composing the mound; good examples of this phenomenon were observed in road cuts along the east-west center line of sec. 7, T. 8 N., R. 27 E. Many of the mounds occur within areas of bedrock exposure but their areal distribution bears no direct relation to that of any of the different bedrock units. Some of them occur also on

12. Fenneman, N. M., "Physiography of Eastern United States": *McGraw-Hill Book Co.*, New York, p. 115, 1938.

ancient gravel terraces and others on the higher parts of the Recent alluvial plains along the larger streams.

Such natural mounds are of widespread occurrence in parts of Texas, Louisiana, Arkansas, and eastern Oklahoma. Those in LeFlore County occur at altitudes ranging through several hundred feet though they are present only on nearly level surfaces and gentle slopes. For example, on the gently sloping upper surface of a prominent hogback a mile south of Bokoshe mounds occur approximately 400 feet above the Arkansas River level; within half a mile of these and 300 feet lower are others on the higher parts of the alluvial plain along Buck Creek.

Clearly, the mounds on all such plains were formed since the region attained essentially its present stage of geomorphic development and can therefore scarcely be older than late Pleistocene. Their origin is not understood though explanations for these and for similar features in other parts of the United States have been proposed by various writers. A number of references to the literature concerning them are given by Veatch[13] and by Waters and Flagler.[14] Agencies that have been suggested hypothetically include wind action; stream erosion; pluvial erosion; weathering; chemical segregation by ground water; differential compaction of sediments; deposition around water, gas, oil or mud springs; uprooting of trees; burrowing by animals; and work of aborigines.

The present writer is inclined to favor the hypothesis advanced by Melton,[15] following Le Conte's[16] view, that the mounds have been carved by action of a network of small streams and rivulets upon a thin but widespread layer of soft, surficial material.

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13. Veatch, A. C., "Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas": *U. S. Geol. Survey Prof. Paper* 46, pp. 16, 55-59, 1906.
14. Waters, A. C., and Flagler, C. W., "Origin of the Small Mounds on the Columbia River Plateau": *Am. Jour. Sci.*, 5th Ser., vol. 18, pp. 209-224, 1929.
15. Melton, F. A., "Natural Mounds" of Northeastern Texas, Southern Arkansas and Northern Louisiana: *Oklahoma Acad. Sci. Proc.* vol. 9 (Univ. Bull. n. s. 456), pp. 119-130, 1929; abstract *Geol. Soc. America Bull.*, vol. 40, no. 1, pp. 184-185, 1929; Erosional Soil Hillocks (abstract): *Geol. Soc. America Proc.* 1933, p. 98, 1934.
16. Le Conte, Joseph, "On the Great Lava Flood of the Northwest, and on the Structure and Age of the Cascade Mountains": *California Acad. Sci. Proceedings*, vol. 5, pp. 219-220, 1873; *Am. Jour. Sci.* vol. 7, pp. 365-367, 1874; "Hog Wallows or Prairie Mounds of California and Oregon," *Nature*, vol. 15, pp. 530-531, 1877.

## EXPOSED ROCKS

The bedrock exposed in northern Le Flore County consists of sedimentary strata of the Pennsylvanian system which are of Pottsville and possibly, in part, of Allegheny age. There are also scattered surficial deposits of Pleistocene (?) and Recent age. The Atoka formation is overlain by the Hartshorne sandstone and the McAlester, Savanna, and Boggy formations, in the order named.

The exposed rocks are made up predominantly of shale, but include relatively thin and more or less widely spaced units of sandstone and siltstone with some shale. Coal beds ranging in thickness from less than an inch to several feet occur in all the formations above the Atoka formation, but are not known to be present in that formation within northern Le Flore County. Thin beds and lenses of clay ironstone and of limestone, commonly containing marine fossils, are present in all the exposed bedrock formations. The rock strata are largely concealed by surficial material, such as soil or alluvial deposits.

The oldest strata exposed belong to the Atoka formation, which crops out as large inliers on the Milton and Backbone anticlines; the youngest strata are preserved in outliers of the Boggy formation, the uppermost beds of which have been removed by erosion from the area here described. The greatest thickness of strata lies below Cavanal Mountain, where stratigraphic correlatives of all the rocks exposed in northern Le Flore County are believed to be present with a total thickness of at least 12,000 feet. In that locality the estimated average stratigraphic interval between the top of the Atoka formation and the base of the Bluejacket sandstone member of the Boggy formation is approximately 5,000 feet, whereas this interval at Short Mountain, 15 miles to the north, is believed to be not more than 1,500 feet. The northward thinning involves the stratigraphic intervals between many key horizons within the McAlester and Savanna formations and seems to be related (1) to increasing distance from a southerly source of the sediments that make up the Pennsylvanian rocks of this county, and (2) to differential crustal subsidence in which the rate of sinking was most rapid in the southern part of the county and was progressively less so toward the north. Most of the thinning probably represents a northward decrease in the amount of sediment that was deposited but is no doubt partly due to minor erosional unconformities, such as are believed to occur at the contacts between some sandstone units and the subjacent shales.

The following table shows the sequence and character of the exposed bedrock formations and the stratigraphic positions of the principal coal beds.

TABLE I.
GENERALIZED SECTION OF ROCKS EXPOSED IN NORTHERN LE FLORE COUNTY

| | | Thickness in feet |
|---|---|---|
| Quaternary | *Alluvium*: Sand and silt on flood plains of Arkansas River and tributaries; also higher remnants of older deposits of gravel and sand. | |
| Pennsylvanian system* Des Moines series | *Boggy formation*: Mostly gray shale and siltstone; includes widely spaced members consisting largely of hard, fine-grained sandstone. Lower Witteville coal about 1,200 feet above base of formation; Secor coal 170-210 feet higher. | 2,500+ |
| | *Savanna formation*: Mostly gray shale and siltstone; includes sandy members and a few persistent thin limestone beds immediately above coal beds. Cavanal coal about 100 feet below top; several unnamed coals locally present lower in formation. | 140-960 |
| | *McAlester formation.* Mostly gray shale and siltstone; includes sandy members at intervals of several hundred feet. Stigler coal and two locally minable unnamed coal beds in upper part of formation. | 1000-2.500 |
| | *Hartshorne sandstone*: Mostly sandstone and hard siltstone with small amount of shale. Upper Hartshorne coal at top of formation; Lower Hartshorne coal 0 to 60 feet lower. | 100-400 |
| | *Atoka formation*: Mostly gray shale and siltstone; includes sandy members and, locally, a thin limestone bed near top of formation. | 6,500± |

* The United States Geological Survey classifies the Pennsylvanian as a series of the Carboniferous System.

# PENNSYLVANIAN SYSTEM

## Des Moines Series

### ATOKA FORMATION

*First reference.* J. A. Taff and G. I. Adams, 1900.

*Nomenclators.* J. A. Taff and G. I. Adams, 1900.

*Type locality.* Atoka, Atoka County, Oklahoma, which is situated on an outcrop of the formation.

*Original description.* Taff's and Adams' original description reads in part:

> Aggregates a thickness of between 6,000 and 7,000 feet. At intervals of from 1,000 to 1,200 feet in these shales there are four groups of sandstone strata, each of which is nearly 100 feet thick. . . . . . . . The sandstone beds are brown or light gray and are often thin and slabby, being separated by shaly layers. The shales are very rarely exposed. Where exposed they are seen to be usually bluish clay shales with occasional ferruginous ironstone concretions.[17]

*General discussion.* The Atoka formation is exposed on the Milton and Backbone anticlines and has been reached in drilling for natural gas in the Poteau-Gilmore, Cameron, Rock Island, Spiro, and Cedars gas fields. The formation consists mostly of gray shale, commonly containing beds and lenses of clay ironstone and much siltstone, with ridge-forming sandstone units intercalated at widely spaced intervals. The shale units are in general more silty and less clayey in character than those of the Pennsylvanian formations younger than the Atoka and they contain no coal, except possibly a thin bed of no value that is tentatively included in the top of the formation at the Arkansas boundary south of Jenson. Some fossils are present in the Atoka formation and are most commonly found in clay ironstone nodules within the various shale units; rather abundant marine fossils occur in a lens of blue-gray limestone overlying a sandstone unit near the top of the formation in an exposure on the north side of Highway No. 9 in NW¼ SE¼ sec. 24, T. 9 N., R. 24 E.

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17. Taff, J. A. and Adams, G. I., "Geology of the Eastern Choctaw Coal Field, Indian Territory"; *U. S. Geol. Survey 21st Ann. Rept.*, Pt. 2e, p. 273, 1900.

Approximately 7,000 feet of Atoka beds are exposed underlying the Hartshorne sandstone along the Arkansas boundary north of the Midland Valley Railroad but the base of the Atoka does not come to the surface and its full thickness in the Backbone anticline has therefore not been determined. On the Milton anticline a maximum of about 1,500 feet of the uppermost beds is exposed which, together with approximately 5,000 feet of beds logged in Red Bank Oil Company's Fee No. 1 well, SW¼ NW¼ sec. 23, brings the total thickness there to approximately 6,500 feet. Farther northwest, however, the Atoka thins and is only about 1,850 feet thick 21 miles away, in Haskell County, near the confluence of the Arkansas and Canadian Rivers.

For measured outcrop sections of the Atoka formation see sections numbered 20, 21, 22, 23, and 24 in the appendix.

## HARTSHORNE SANDSTONE

*First reference.* J. A. Taff, 1899.

*Nomenclator.* J. A. Taff, 1899.

*Type locality.* Exposures near Hartshorne, Pittsburg County, Oklahoma.

*Original description.* Taff's original description reads in part:

> This is a brown to light gray sand rock which has an extreme thickness of about 200 feet. Near the top the beds are very thick and some are massive. Upon the surface they occur as roughly rounded masses and thick ledges. Below, and especially in the lower part, many of the beds are thin and slabby and are associated with sandy shales.[18]

*Other descriptions.* Taff's description, revised as of 1900, reads in part as follows:

> An aggregation of brown, gray and usually thin-bedded sandstones which locally become shaly constitutes this formation. The upper beds are in places thick, and even massive, while the lower ones are generally thin and grade into shale toward the base. In places the sandstone beds are thin and shaly throughout; at others—for instance, in the railroad cut south of Petros switch, on the Kansas City, Pittsburg and Gulf

18. Taff, J. A., "Geology of the McAlester-Lehigh Coal Field, Indian Territory": *U. S. Geol. Survey 19th Ann. Rept.*, Pt. 3, p. 436, 1899.

> Railroad—the sandstone is separated into three beds, with shale intervals, each containing a thin coal seam. . . .
>
> There are two coal beds associated with the Hartshorne sandstone, known as the upper and lower Hartshorne coals. The upper bed is . . . . in and at the base of the McAlester shale.[19]

Regarding the Hartshorne sandstone as it is mapped in the Arkansas coal field, Hendricks and Parks state:

> The Hartshorne sandstone in Arkansas is defined as the first continuous sandstone underlying the Lower Hartshorne coal. Taff and Adams defined the Hartshorne sandstone in Oklahoma as extending from the top of the first sandstone below the Upper Hartshorne coal to the base of the first continuous sandstone below the Lower Hartshorne coal. Thus it is apparent that the sandstone lying between the Upper and Lower Hartshorne coals in Oklahoma is not a part of the Hartshorne sandstone as mapped in Arkansas.[20]

*General discussion.* The Hartshorne sandstone is exposed on the limbs of the Backbone and Milton anticlines and has been logged in wells drilled for natural gas in other parts of northern Le Flore County. It includes the Lower and Upper Hartshorne coal beds, which are the most valuable coal beds in the county, and is the unit producing gas in the Poteau-Gilmore gas field. The formation consists mostly of sandstone and hard siltstone, with a smaller amount of shale. It ranges in thickness from about 100 feet to about 400 feet and in general thins in a northwesterly direction across northern Le Flore County.

In the present report the contact between the Hartshorne sandstone and the McAlester formation is thus placed at the top of the Upper Hartshorne coal bed. The customary Oklahoma practice of placing the contact at the top of a sandstone unit that commonly occurs between the Lower and Upper Hartshorne coal beds could not be followed consistently in northern Le Flore County because the sandstone referred to is absent in places, as for example on the Milton anticline, where the Lower and Upper Hartshorne coal beds are nearly everywhere so close together that they are mapped as a single bed. (See Pl. I.)

19. Taff, J. A., and Adams, G. I., *op. cit.*, p. 274, 1900.
20. Hendricks, T. A., and Parks, Bryan, *op. cit.*, p. 198, 1937.

For a measured outcrop section of the Hartshorne sandstone see section number 11 in the appendix.

MCALESTER FORMATION

*First reference.* J. A. Taff, 1899.

*Nomenclator.* J. A. Taff, 1899.

*Type locality.* Exposures around McAlester, Pittsburg County, Oklahoma.

*Original description.* Taff's original description reads in part:

> This formation, for convenience of discussion, may be divided into a series of three parts. The lowest one is composed almost entirely of shale, with thin sandstone and coal, in all 800 feet thick. Locally sandstone occurs with thin coal beds near the center of this shale. The Hartshorne or Grady coal occurs at the base of this shale. The middle division of the McAlester shale is composed of three to four beds of sandstone separated by shale 100 feet to 200 feet thick. Together these beds of sandstone and shale are about 500 feet thick. The lowest of these sandstone beds caps the mesa of Belle Starr Mountain and the ridge northwest of Hartshorne. Here it is nearly 200 feet thick. Over most of its surface area, however, the sandstone is not well exposed. The upper division is almost entirely of shale nearly 700 feet thick and the McAlester coal is about 50 feet above its base. Several thin seams of coal occur in this shale also, but none have been found thick enough to be workable. The shale is blue, gray, or black, with the gray color predominating.
>
> A thin band of buff fossil iron ore occurs near, below the McAlester coal. This iron ore, which may not be widespread in its occurrence, associated with the thin bedded sandstone nearly 50 feet thick, may prove a valuable aid to the prospector in locating the McAlester coal. A striking characteristic of the McAlester shale is its surface feature. Being almost throughout a soft shale it is worn down nearly to a level plain.[21]

*General discussion.* In the Cavanal syncline, in the southern part of the area mapped, the McAlester formation is approximately 2,500 feet thick, but thins northward and is only about 1,000 feet thick on the northwest side of the Milton anticline, near the Arkansas River. The formation consists mostly of shale, but includes sandstone units, coal beds, and beds and lenses of limestone

21. Taff, J. A., *op. cit.*, p. 437, 1899.

and clay ironstone. The subdivisions of the formation that are recognized in northern Le Flore County, listed in order with the oldest at the bottom, are as follows:

Shale member, unnamed
Keota sandstone member
Shale member, unnamed
Tamaha sandstone member
Shale member, unnamed (Stigler coal bed in basal part)
Cameron sandstone member
Shale member, unnamed
Lequire sandstone member
Shale member, unnamed
Warner sandstone member
McCurtain shale member

North of the Milton anticline, however, only three sandstone units—the Warner, Cameron, and Keota members—have been mapped. The Lequire member is either absent in that part of the area or, more probably, rests directly on the Warner member, and the Tamaha member is either absent or is too shaly to be recognized. At Sugarloaf Mountain, at the southeast corner of the area mapped, the Keota sandstone member has not been found. The Keota, if present in that locality, is probably shaly. The sandstone unit there mapped as the Tamaha sandstone member and the overlying shale unit that is mapped as the uppermost unit of the McAlester formation are mapped[22] as Savanna formation in the adjacent part of the Howe-Wilburton district. The writer believes also that the highest beds present in secs. 15 and 16 T. 9 N., R. 27 E. in the trough of the Central syncline are part of the McAlester formation because of the thinness of the section intervening between these beds and the beds mapped as the Lequire sandstone. These highest beds in the Central syncline in Oklahoma are shown on the map (Pl. I) as Cameron sandstone(?), although in the adjoining area in Arkansas they were mapped as the basal sandstone of the Savanna formation.[23]

22. Hendricks, T. A., *op. cit.*, pl. 27, 1939.
23. Hendricks, T. A., and Parks, Bryan, "Geology of the Fort Smith District, Arkansas": *U. S. Geol. Survey Prof. Paper* 221-E (in preparation).

The Tamaha and Keota members and the intervening unnamed shale member were tentatively assigned by Wilson[24] to the Savanna formation. They are here classified as members of the McAlester formation because they are continuous with layers in the uppermost part of that formation as traced by Hendricks[25] from its type locality in Pittsburg County.

The shale members of the McAlester formation are in general poorly exposed and are not easily distinguishable from one another lithologically. The identification of each is therefore largely dependent on tracing of outcrops in the field and comparisons of stratigraphic sequences in different localities. All of these members consist of dark to light gray shale containing (1) beds, lenses, and nodules of clay ironstone; (2) a few coal beds most of which are too thin to be of value; and (3) occasional beds and lenses of sandstone. Each of the members thins in general in a northerly direction across the county.

The sandstone units of the McAlester formation are irregular in thickness and are not readily distinguishable from one another by lithologic means; their identificaton, like that of the shale members, is largely dependent on tracing of their outcrops in the field and comparison of stratigraphic sequences in which they occur in various localities within this and adjacent areas. In comparing the sandstone members of the McAlester formation of northern Le Flore County with their counterparts in the Muskogee-Porum district, described by Wilson,[26] it is necessary to bear in mind that, excepting the McCurtain shale member, each subdivision of the McAlester formation shown on Wilson's map comprises a sandstone member and the shale overlying it, whereas the sandstone and shale members are mapped separately on Plate I of the present report.

24. Wilson, C. W., Jr., "Age and Correlation of Pennsylvanian Surface Formations, and of Oil and Gas Sands of Muskogee County, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 4, p. 504, 1935.
25. Hendricks, T. A., "Geology and Fuel Resources of the Southern Part of the Oklahoma Coal Field; Part 4, The Howe-Wilburton District, Latimer and LeFlore Counties": *U. S. Geol. Survey Bull.* 874-D, pl. 1, 1939.
26. Wilson, C. W., Jr., and Newell, N. D., *op. cit.*, pl. 1, 1937.

## McCurtain Shale Member

The term McCurtain shale member was first used in print by Wilson.[27] The unit takes its name from McCurtain, Haskell County, and crops out extensively in that locality. Newell published the earliest detailed description of the McCurtain shale:

> This unit consists almost entirely of shale, unbroken by resistant beds. The lower half is commonly dark to black, slabby and silty, and contains abundant unfossiliferous clay-ironstone concretions. The upper half is argillaceous, and buff to greenish, and concretions are not generally abundant.[28]

According to both Wilson and Newell the McCurtain shale of Muskogee County includes the upper Hartshorne coal, but according to the classification used in this report the coal is excluded and the McCurtain shale includes the strata above the Hartshorne coal and below the base of the Warner sandstone.

In northern Le Flore County the McCurtain shale member ranges in thickness from about 350 feet to about 800 feet. The thickness in general increases in a southeasterly direction. The member consists predominantly of shale, but includes a rather persistent sandy unit which, in most of the northern part of T. 8 N., R. 23 E., contains sandstone beds aggregating 175 feet in thickness, many of which are massive in character with swarms of shale pellets in some layers. This sandstone zone here forms prominent cliffs but at the Haskell County line and in other parts of northern Le Flore County it crops out in relatively inconspicuous, low ridges, is commonly about 10 feet thick and is made up mostly of thin flaggy sandstone beds, in some places showing abundant ripple marks. A calcareous marine fossiliferous layer is exposed in the lower part of this sandy zone in a road cut in sec. 22, T. 8 N., R. 24 E., 2½ miles southeast of Bokoshe. Just above the sandy zone at that locality is a 3-inch coal bed with an underclay, which is reported to occur persistently in the upper part of the McCurtain in the vicinity of Bokoshe. The coal bed is about 230 feet below the top of the McCurtain member. In T. 7 N., R. 26 E., another

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27. Wilson, Charles W., Jr., "Age and Correlation of Pennsylvanian Surface Formations, and of Oil and Gas Sands of Muskogee County, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.* Vol. 19, No. 4, p. 508, 1935.

28. Wilson, Charles W., Jr., and Newell, Norman D., "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma": *Okla. Geol. Survey Bull.* 57, p. 37, 1937.

sandstone bed 20 to 35 feet thick is logged in wells at about 150 feet below the top of the McCurtain member. Sandstone beds occurring locally in the basal part of the member produce natural gas in the Cameron gas field.

## Warner Sandstone Member and Overlying Shale Member

The name Warner sandstone was first used in print by Wilson.[29] The name is derived from the town of Warner, Muskogee County, and the type locality is about one-fourth mile east of the northwest corner of sec. 21, T. 12 N., R. 19 E., 1 mile north of Warner. Newell published the earliest detailed description:

> The Warner sandstone member produces one of the most prominent escarpments in the Muskogee-Porum district, being comparable in this respect to the Bluejacket and Taft sandstones of the lower Boggy formation. The sandstone generally consists of massive, buff, calcareous, and hard sandstone ranging in total thickness at measured outcrops from about 5 to 30 feet. The sandstone is commonly ferruginous, containing large, irregular limonite-cemented concretionary masses up to 2 feet across. These concretions are typically hollow, weathering into curious twisted and contorted forms. Fossil plants occur in the sandstone locally.[30]

The term was used by both Wilson and Newell in the same sense as it is used here.

The Warner sandstone member crops out in several belts in northern Le Flore County, where it characteristically forms prominent ridges, and is logged in most of the wells in the Poteau-Gilmore and Cameron gas fields. Its thickness, which is irregular, ranges from about 15 to about 150 feet. It consists largely of fine-grained sandstone including both massive, irregular beds and some slabby to platy layers intercalated with smaller amounts of siltstone and shale. In a roadside exposure in NW¼ NW¼ sec. 24, T. 8 N., R. 26 E., a thin, valueless coal bed occurs at the top of the member.

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29. Wilson, Charles W., Jr., "Age and Correlation of Pennsylvanian Surface Formations, and of Oil and Gas Sands of Muskogee County, Oklahoma"; *Bull. Amer. Assoc. Petrol. Geol.* Vol. 19, No. 4. p. 508, 1935.

30. Wilson, Charles W., Jr., and Newell, Norman D., "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma": *Okla. Geol. Survey Bull.* 57, pp. 37 and 38, 1937.

In most of northern Le Flore County the unnamed shale member between the Warner and Lequire sandstone members ranges in thickness from about 120 feet to about 300 feet. Farther north, in Tps. 9 and 10 N., R. 24 E., it is either absent through possible coalescence of the Warner and Lequire members, or is mapped together with the next higher shale member, owing to possible absence of the Lequire in that neighborhood. In the NW¼ NW¼ sec. 24, T. 8 N., R. 26 E., along the road northeast of Cameron, a weathered, impure coal bed 5 inches thick occurs about 170 feet below the top of this member.

### Lequire Sandstone Member and Overlying Shale Member

The name Lequire sandstone was first mentioned in the literature by Wilson[31] and is derived from the town of Lequire, Haskell County.

Newell published the earliest detailed description of this member:

> The Lequire sandstone member is a single buff sandstone unit ranging from 8 or 10 feet in the latitude of T. 10 N. to 3 feet and less at its northern terminus in T. 13 N. Apparently the Lequire thins out and is replaced by shale to the northward. Where the unit is relatively thin it is generally blocky and hard, but locally it consists of thin-bedded buff sandstone. In the southern part of the area it generally is slabby to thin-bedded. Fossils were not observed in the Lequire sandstone.[32]

The term Lequire sandstone member was used by both Wilson and Newell in the same sense as it is used here.

The Lequire sandstone member crops out in several localities southeast of the Milton anticline, and in sec. 6, T. 8 N., R. 23 E., forming in most places low, relatively inconspicuous ridges. Farther north, in Tps. 9 and 10 N., R. 24 E., it is either absent or is so close to either the Warner sandstone member or the Cameron sandstone member that it has not been recognized as a separate unit. It is

31. Wilson, Charles W., Jr., "Age and Correlation of Pennsylvanian Surface Formations, and of Oil and Gas Sands of Muskogee County, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 4, p. 508, 1935.
32. Wilson, Charles W., Jr., and Newell, Norman D., "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma": *Okla. Geol. Survey Bull.* 57, p. 41, 1937.

logged in numerous wells in the Cameron and Poteau-Gilmore gas fields. The member is largely made up of thin, slabby beds of fine-grained sandstone, commonly showing prominent ripple-marks, with smaller amounts of siltstone and shale.

The unnamed shale member between the Lequire and Cameron sandstone members is poorly exposed in northern Le Flore County. It ranges in thickness from about 180 feet to about 750 feet and is mostly composed of dark and light shale, with some zones containing beds, lenses and nodules of clay ironstone.

### Cameron Sandstone Member and Overlying Shale Member

Wilson was the first to use the term Cameron sandstone in publication.[33] The name is from the town of Cameron, northern Le Flore County. Newell published the earliest detailed description:

> The Cameron sandstone member is a relatively uniform buff, unfossiliferous sandstone ranging ordinarily from 3 to 5 feet, relatively platy and calcareous and sufficiently resistant to make a distinct low escarpment. Generally the Cameron sandstone is a well developed unit, but locally in T. 13 N., R. 18 E., it consists apparently of two thin blocky sandstone beds separated by 10 feet of sandy shale.[34]

Both Wilson and Newell used the term in the same sense as it is used here.

In northern Le Flore County the thickness of the Cameron sandstone member is irregular, ranging from about 10 to about 20 feet. It is made up chiefly of thin beds, commonly ripple-marked, of fine-grained sandstone with some interbedded shale. The member forms a broad area of outcrop east of Cameron and is fairly persistent in other parts of the county, but generally forms low inconspicuous ridges and in some localities is either absent or so poorly exposed that it could not be mapped.

33. Wilson, Charles W., Jr., "Age and Correlation of Pennsylvanian Surface Formations and of Oil and Gas Sands of Muskogee County, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.* Vol. 19, No. 4, pp. 507-508, 1935.
34. Wilson, Charles W., Jr., and Newell, Norman D., "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma": *Okla. Geol. Survey Bull.* 57, p. 41, 1937.

The unnamed shale member between the Cameron and Tamaha sandstone members ranges in thickness in northern Le Flore County from about 100 feet to about 250 feet, with a general thickening in a southeasterly direction. Within this member, ordinarily near its base, is the Stigler coal bed, which has been mined locally. Another fairly persistent coal bed occurring higher in the member is locally also of minable thickness.

### Tamaha Sandstone Member and Overlying Shale Member

Wilson[35] made the earliest published reference to the Tamaha sandstone member. The name is from the town of Tamaha, northeastern Haskell County. Newell gave the earliest detailed description of the member:

> The basal sandstone of the Savanna formation, (now known to be the Tamaha sandstone member of the McAlester formation) is a relatively thin but uniform bed of buff, rippled, flaggy, and calcareous sandstone. Local irregularities exist, probably due to conditions of weathering, so that in places along the Tamaha outcrop the sandstone is shaly or very thin-bedded. The unit is unfossiliferous, and is surprisingly uniform in thickness, varying generally between 3 or 4 feet, but locally attaining a thickness as great as 8 feet in T. 14 N.[36]

Wilson[37] and later Wilson and Newell[38] placed the Tamaha sandstone and overlying shale in the Savanna formation in an attempt to correlate them with Savanna rocks exposed in the vicinity of Savanna, Pittsburg County. At that time detailed geologic mapping of the intervening territory, including the area described in this report, was incomplete, and these units are now known to lie below the top of the McAlester formation.

The description of the Tamaha sandstone member in Muskogee County, as quoted above, applies equally well to the member as exposed in northern Le Flore County. The member is irregular

35. Wilson, Charles W., Jr., "Age and Correlation of Pennsylvanian Surface Formations and of Oil and Gas Sands of Muskogee County, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.* Vol. 19, No. 4, p. 509, 1935.
36. Wilson, Charles W., Jr., and Newell, Norman D., "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma": *Okla. Geol. Survey Bull.* 57, p. 43, 1937.
37. Wilson, Charles W., Jr., *op. cit.*
38. Wilson, Charles W., Jr., and Newell, Norman D., *op. cit.*

in thickness, but is ordinarily about 15 feet thick. The massive facies referred to by Wilson is represented in the outlier east of Cameron and in the outcrop west of Sugarloaf Mountain in T. 7 N., R. 27 E. In much of the area farther west and northwest within the county the Tamaha is thin-bedded and inconspicuous and in some localities seems to pinch out.

The unnamed shale member between the Tamaha and Keota sandstone members ranges in thickness from about 150 feet to about 500 feet, with a general thickening in a southerly direction across the county. Locally present within it, very near its base, is a coal bed that is of minable thickness in secs. 9 and 10, T. 7 N., R. 26 E.

### Keota Sandstone Member and Overlying Shale Member

Wilson[39] made the earliest published reference to the Keota sandstone member. The name is from exposures in the vicinity of Keota, eastern Haskell County. Newell published the earliest detailed description:

> A persistent coal and overlying limestone occur in the midst of the Keota division . . . . in the southern part of the area. Traced northward the lower sandstone of the section becomes sporadic, and at many localities is absent. . . .
>
> At most outcrops in the latitude of T. 10 N., the Keota division consists of three relatively calcareous, blocky, buff, sandstone beds separated by relatively thicker arenaceous gray shales, the whole including some 25 feet or more of beds. However in the northeast part of sec. 22, T. 10 N., R. 19 E., the lower half of the division is shaly sandstone, separated from a thin upper sandstone by 15 feet of shale containing an obscure coal near the middle. Fossiliferous concretions occur in the upper part of this shale.
>
> Good outcrops of the Keota are lacking across T. 11 N., but in sec. 10, T. 12 N., R. 18 E., it consists of six separate units. . . .[40]

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39. Wilson, Charles W., Jr., "Age and Correlation of Pennsylvanian Surface Formations, and of Oil and Gas Sands of Muskogee County, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.* Vol. 19, No. 4, pp. 507-508, 1935.

40. Wilson, Charles W., Jr. and Newell, Norman D., "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma": *Okla. Geol. Survey Bull.* 57, p. 44, 1937.

Wilson and later Wilson and Newell placed the Keota sandstone and overlying shale in the Savanna formation in an attempt to correlate them with Savanna rocks in the vicinity of Savanna, Pittsburg County. At that time detailed geologic mapping of the intervening territory, including the area described in this report, was incomplete, and these units are now known to lie below the top of the McAlester formation. The terms are used here in the same sense as they were used by Wilson and by Newell.

On the west and north sides of the Cavanal syncline the Keota sandstone member comprises 2 sandstone units and an intervening shale unit, aggregating about 100 feet in thickness. Farther north, in the vicinity of Cache Creek, T. 9 N., R. 24 E., the member consists of only one sandstone unit 10 to 20 feet thick and in this and other respects is like the Keota member in Muskogee County, as described in the above quotation.

For measured outcrop sections of the McAlester formation see sections numbered 1, 12, 13, 14, 15, 16, 17, and 18 in the appendix.

### SAVANNA FORMATION

*First reference.* J. A. Taff, 1899.
*Nomenclator.* J. A. Taff, 1899.
*Type locality.* Savanna, Pittsburg County, Oklahoma.
*Original description.* Taff's original description reads in part:

> Next above the McAlester shale there is a series of sandstones and shales about 1,150 feet thick. The shaly beds combined are probably thicker than the sandstones, but since the sandstones are better exposed and their presence is so strongly impressed upon the observer in the prominent ridges which they make, sandstone seems the more appropriate term. There are five principal sandstone beds, which have different thicknesses, from nearly 50 feet to 200 feet, the one at the top and the one at the base being generally thicker than the intermediate ones. These sandstones may be distinguished only by their position in the section or their thickness of bedding. They are brown or grayish brown, fine-grained, and compact. Except in the uppermost beds, upon which the town of South McAlester is built, the beds are generally thin and in part shaly. The uppermost sandstone occurs in two members, 75 to 100 feet thick, separated by variable blue clay shales. The uppermost beds of this sandstone are found in many places to be massive, and those in contact with the shale are often beautifully ripple

marked. No coal of any value has been found associated with these beds of sandstone in the McAlester district, though a thin bed has been reported to occur in the upper part of the series. Where the rocks dip at low angles they make ridges.[41]

*General discussion.* Hendricks[42] traced the Savanna formation from the type locality in the vicinity of Savanna, Pittsburg County, to the vicinity of Poteau, Le Flore County. The mapping here reported is a continuation of that work, and the upper and lower boundaries of the Savanna formation in northern Le Flore County are believed to be the same as the upper and lower boundaries in the type locality.

Further, the upper boundary of the Savanna formation in northern Le Flore County is substantially the same as the upper boundary in Muskogee County, as mapped by Wilson and Newell.[43] The lower sandstone unit of the Savanna formation cannot be traced farther north than sec. 18, T. 9 N., R. 19 E., northwestern Haskell County, but seems to occupy about the same stratigraphic position as the Spaniard limestone.[44]

Wilson[45] and later Wilson and Newell[46] included strata between the base of the Tamaha sandstone and the base of the Spaniard limestone in the Savanna formation in an attempt to correlate them with Savanna rocks in the vicinity of Savanna, Pittsburg County. At that time, mapping of intervening territory, including the area covered by this report, was incomplete and, as has been stated, it is now believed that the beds below the base of the Spaniard limestone are in the McAlester formation. Differences in mapping of the Savanna-McAlester contact in northern Le Flore County as compared with the mapping of this contact in adjacent areas to the

41. Taff, J. A., "Geology of the McAlester-Lehigh Coal Field, Indian Territory": *U. S. Geol. Survey 19th Ann. Rept.*, Pt. 3, 437-438, 1899.
42. Hendricks, Thomas A., "Geology and Fuel Resources of the Southern Part of the Oklahoma Coal Field": *U. S. Geol. Survey Bull.* 874-A, 1937.
43. Wilson, Charles W., Jr., and Newell, Norman D., "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma": *Okla. Geol. Survey Bull.* 57, p. 43 and Map, 1937.
44. Oakes, Malcolm C., and Knechtel, M. M., "Geology and Mineral Resources of Haskell County, Oklahoma": *Okla. Geol. Survey Bull.* 67, pp. 46, 47 and Map, 1948.
45. Wilson, Charles W., Jr., "Age and Correlation of Pennsylvanian Surface Formations, and of Oil and Gas Sands of Muskogee County, Oklahoma": *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 4, p. 504, 1935.
46. Wilson, Charles W., Jr., and Newell, Norman D., *op. cit.*, p. 43, 1937.

east and southeast are described in the discussion of the McAlester formation.

The thickness of the Savanna formation in northern Le Flore County ranges from about 140 to about 960 feet, increasing in a general southeasterly direction. It conforms in general to the description quoted from Taff, though the number of ridge-forming sandstone units is generally less than five and is variable from place to place. Four such sandstone units are present on Sugarloaf Mountain. On the north and east sides of the Cavanal syncline, the Savanna formation comprises in general the following five lithologic units, listed in order with the oldest at the bottom:

5. Sandstone unit, unnamed
4. Shale unit, unnamed
3. Sandstone unit, unnamed
2. Shale unit, unnamed
1. Sandstone unit, unnamed

The individual sandstone units below No. 5 are variable in thickness, ranging from about 10 feet to about 180 feet. They consist of both massive and thin beds of sandstone, with smaller amounts of siltstone and shale. In the vicinity of Poteau, the shale units Nos. 2 and 4 include several coal beds, each of which occurs at the base of a fossiliferous zone, of marine or brackish water origin, that includes thin beds of impure limestone and calcareous shale. One of these is the Cavanal coal bed in unit No. 4. Elsewhere in northern Le Flore County such coal beds and associated calcareous zones are fewer in number and in the neighborhoods of Cowlington and Spiro only one is known and it is tentatively correlated with the Cavanal bed.

Such calcareous zones are exposed at the portal of the Wells-Royal Coal Company's mine in the Cavanal coal bed at Poteau, at prospects in a bed below the Cavanal bed in secs. 35 and 36, T. 8 N., R. 24 E., secs. 5 and 6, T. 7 N., R. 24 E., and in an exposure of the Cavanal bed in a gully on the west side of Round Mountain, sec. 4, T. 9 N., R. 26 E.

The uppermost sandstone unit of the Savanna formation, No. 5, is mainly composed of sandstone, fine grained, generally light gray, in massive beds, and it ranges in thickness from 10 to about 100 feet. A coal bed 13 inches thick occurs in the lower part of sandstone unit No. 5, in secs. 11, 14, 15, and 22, T. 7 N., R. 23 E.

In the segment of the Savanna outcrop south of Shady Point, extending from sec. 11, T. 7 N., R. 25 E. to sec. 31, T. 8 N., R. 25 E., the uppermost shale unit, No. 4, seems to be absent and sandstone units Nos. 3 and 5 appear to coalesce. As mapped there and in the vicinity of Cowlington and northeast of Spiro, the Savanna is made up of upper and lower sandstone units and an intervening shale unit. Likewise, the Savanna formation in the Sansbois syncline, in southern Haskell County,[47] is made up of upper and lower sandstone units and an intervening shale unit; and this upper sandstone unit is represented in western and northwestern Haskell County by two groups of sandstone beds, the lower of which appears to be the same as the "Spiro" sandstone of Wilson and Newell[48] which they mapped as the uppermost member of the Savanna formation in Muskogee County. Because it has not been found feasible to identify exactly the equivalents of the "Spiro" in Haskell County or in northern Le Flore County, the term is not used in this report.

For measured outcrop sections of the Savanna formation see sections numbered 2, 3, 4, 5, 6, 9, 10, and 19 in the appendix.

## BOGGY FORMATION

*First reference.* J. A. Taff, 1899.

*Nomenclator.* J. A. Taff, 1899.

*Type locality.* Exposures along North Boggy Creek, Pittsburg and Atoka Counties, Oklahoma.

*Original description.* Taff's original description reads in part:

> . . . . In the Boggy shale there are probably not less than sixteen beds of sandstone ranging in thickness from 20 to 150 feet, separated by shale from 100 feet to 600 feet thick. One coal bed, about 2 feet 6 inches thick, has been located and

47. Oakes, Malcolm C., and Knechtel, M. M., "Geology and Mineral Resources of Haskell County, Oklahoma": *Okla. Geol. Survey Bull.* 67, pp. 50-51 and pl. I, 1948.
48. Wilson, Charles W., Jr., and Newell, Norman D., "Geology of the Muskogee-Porum District, Muskogee and McIntosh Counties, Oklahoma": *Okla. Geol. Survey Bull.* 57, p. 43, 1937.

worked to a small extent, though now abandoned. This coal bed is about 400 feet above the base of the Boggy shale and has been prospected and worked, to a small extent, on the Missouri, Kansas and Texas Railway, at points 1 and 3 miles south of South McAlester. In other parts of the field, upon further investigation, it may prove to be workable.

The shales of this series are exposed to a very slight extent. In the few hill slopes and stream cuttings where observed the shales are bluish fissile clay containing ironstone concretions, thin wavy sandstone plates, and shaly sandstone strata. The sandstones fall in one general class and vary but little in minor detail of texture. They are generally brownish or gray and some beds are quite ferruginous. In some of these the iron ore cuts the face of the ledge or particular bed into a network of angular blocks as if filling a plexus of mud cracks. All the sandstones are fine-grained and were without doubt deposited under very similar conditions.[49]

*General discussion.* The lower part of the Boggy formation is present and is mapped on the north and east sides of Cavanal Mountain and at Short Mountain, T. 10 N., R. 24 E. The part mapped at Cavanal Mountain includes the basal shale member, the overlying Bluejacket sandstone member, containing the Lower Witteville coal bed, and some hundreds of feet of Boggy beds above the Bluejacket. The Secor coal bed occurs in the shale between the Bluejacket and the next higher sandstone unit and is about 2,100 feet above the base of the Boggy at the west end of Cavanal Mountain. The highest beds mapped at Short Mountain belong to the Bluejacket, and the part of the Boggy represented there is about 625 feet thick.

## Lower Shale Member

The shale member mapped at the base of the Boggy formation is about 800 feet thick in the vicinity of Cavanal Mountain and about 570 feet thick at Short Mountain. However, about 230 feet of beds in the uppermost part of the member as mapped at Short Mountain include some sandstone beds and may be approximately equivalent to the large thickness of sandstone beds below the Lower Witteville coal bed and mapped with the Bluejacket east of Cavanal Mountain, in a zone about 340 feet thick which includes also much shale (see measured section No. 7, in the appendix).

49. Taff, J. A., *op. cit.*, pp. 438-439, 1899.

## Bluejacket Sandstone Member

Taff[50] published the earliest reference to the Bluejacket sandstone, without naming it, in a discussion of the Boggy formation in the Muskogee quadrangle.

The Bluejacket was named by D. W. Ohern from exposures in the hills west of the town of Bluejacket, Craig County, Oklahoma, in an unpublished manuscript cited by Gould. Gould's description is as follows:

> The Bluejacket sandstone member, 50 to 60 feet thick, occurs near the middle of the (Cherokee shale) formation. It consists sometimes of a solid mass of sandstone but is usually separated into several beds by intervening shales, and was named by D. W. Ohern (unpublished ms.) for exposures near the town of Bluejacket, Craig County. The Bluejacket is the basal sand of the Bartlesville group of oil sands. Its base is shown on Miser's map of Oklahoma.[51]

The Bluejacket sandstone member crops out on the slopes of Cavanal Mountain and also forms an outlier at Short Mountain, T. 10 N., R. 24 E., near the Arkansas River. The Bluejacket in Le Flore County is a prominent cliff-forming unit made up largely of massive beds of sandstone with interbedded thin sandy beds and shale. On the east side of Cavanal Mountain the Lower Witteville coal bed occurs in a shale interval about 80 feet from the top of the member. Some evidence for an unconformity above this coal bed is given under "Coal beds in Boggy formation" in the section on coal.

Approximately 500 feet of strata are mapped as Bluejacket in the vicinity of Witteville, on the east side of Cavanal Mountain, whereas only 50 feet of beds definitely recognizable as belonging to the Bluejacket are present at Short Mountain and these are lithologically similar to the uppermost 80 feet of the Bluejacket beds at Witteville. These uppermost beds, which are immediately above the Lower Witteville coal bed are distinctive in character, consisting of massive layers of sandstone, which form talus containing large exfoliated blocks, the weathered surfaces of which

50. Taff, Joseph A., "Geologic Atlas of the United States": *U. S. Geol. Survey*, Muscogee Folio (No. 132), p. 4, 1906.
51. Gould, C. N., "Index to the Stratigraphy of Oklahoma": *Okla. Geol. Survey Bull.* 35, p. 64, 1925.

show polygonal check-mark patterns formed in the exfoliation process. Stratigraphic equivalents of the sandstone beds of the Bluejacket below this member may be present at Short Mountain but, if so, have there been mapped in the upper part of the basal shale member, as explained above.

### Beds Above the Bluejacket Sandstone Member

The strata cropping out above the Bluejacket sandstone member on Cavanal Mountain, not all of which are shown on Plate I, aggregate about 2,000 feet in thickness. They include both shale and sandstone units, the base of the lowermost sandstone unit being about 200 feet above the Bluejacket and about 30 feet above the Secor coal bed. This coal bed is thus about 170 feet above the Bluejacket.

For measured outcrop sections of the Boggy formation see sections numbered 7, 8, and 25 in the appendix.

# QUATERNARY SYSTEM

## GERTY (?) SAND (PLEISTOCENE?)

*First reference.* J. A. Taff, 1899.

*Nomenclator.* J. A. Taff, 1899, who spelled the name "Guertie".

*Type locality.* Town of Gerty, (formerly spelled "Guertie") in southern Hughes County, Oklahoma.

*Original description.* Taff's original description reads in part:

> . . . . . an extensive deposit of gravel, sand and silt . . . . . These gravels and sands are not cemented into hard rocks; instead, they are incoherent deposits, and resemble recent river or lake sand plains. . . . .
>
> The material of the gravel is all foreign to this region. It is composed of brown quartzitic sand, conglomerate, and various shades of red, white, and black quartz, jasper, and chert. The gravel occurs at the base of the deposit, but is not everywhere present there.[52]

Deposits of gravel and sand occur on dissected terraces averaging approximately 50 feet above the level of the Arkansas River northeast of Spiro, at Pocola, and west of Cedars. They are tentatively correlated with the Gerty sand (Pleistocene?)[53] of the valley of the Canadian River. The areal distribution of these deposits in Le Flore County suggests that in Gerty time the Arkansas River flowed eastward across the neighborhood of Oak Lodge and Scullyville to the vicinity of Pocola, where the river made a sharp bend northward and continued through the area between Braden and Cedars. The gravel on the terraces is chiefly made up of well-worn erratics, including some boulders more than a foot in diameter, that were transported from outcrops outside Le Flore County. The gravel, however, contains some boulders of sandstone similar to that of sandy units of the local Pennsylvanian bedrock sequence. Some of the erratics are chert fragments containing marine invertebrate fossils of Mississippian age; others are of quartz, quartzite, and sandstone. As some of the chert fragments were derived

52. Taff, J. A., *op. cit.*, pp. 439-440, 1899.
53. Hendricks, T. A., "Geology and Fuel Resources of the Southern Part of the Oklahoma Coal Field: Part 1, McAlester District, Pittsburg, Atoka and Latimer Counties": *U. S. Geol. Survey Bull.* 874-A, pp. 26-33, 1937.

from the Boone formation (Mississippian) the materials that make up the gravels evidently came largely from the Ozark region, where that formation crops out extensively.

Deposits of coarse gravel of different composition that are nevertheless also tentatively correlated with the Gerty sand, occur farther south in Le Flore County on dissected plains sloping gently away from Sugarloaf Mountain north of Gilmore and away from Cavanal Mountain in the vicinity of Shady Point and Poteau. These deposits are made up almost entirely of worn fragments of sandstone derived from the Pennsylvanian formations exposed in Le Flore County and adjacent areas.

### RECENT ALLUVIUM

The beds of streams in all parts of northern Le Flore County are underlain by deposits of Recent alluvium. Such deposits, mainly composed of silt and sand, underlie considerable tracts of bottom-land, which are occasionally flooded, adjacent to the Arkansas and Poteau Rivers and along James Fork and Brazil Creeks.

### ROCKS NOT EXPOSED

More than 1,000 feet of strata of Pennsylvanian and pre-Pennsylvanian age that are not exposed in northern Le Flore County were penetrated beneath the Atoka formation in Red Bank Oil Company's Fee No. 1 well, a gas well 6,300 feet deep in SW¼ NW¼ sec. 23, T. 9 N., R. 24 E. These strata include much limestone and are in large part equivalent to rocks exposed in the Arbuckle Mountains. The well was started in the Atoka about 1,500 feet below the top of the formation, and finished in the Simpson. According to the Company geologist's log the Wapanucka limestone (Pennsylvanian) was entered at 5,085 feet; the Springer formation (Pennsylvanian) at 5,250 feet; the "Mayes" formation (Mississippian) at 5,495 feet; the Chattanooga shale (Devonian?) at 5,757 feet; the Misener sand at 5,830 feet; the Hunton limestone (Silurian and Devonian) at 5,837 feet; the Sylvan shale (Upper Ordovician) at 6,228 feet; the Fernvale limestone (Upper Ordovician) at 6,500 feet; the Viola limestone (Middle and Upper Ordovician) at 6,086 feet; and the Simpson group (Lower and Middle Ordovician) at 6,119 feet.

## STRUCTURE

Northern Le Flore County lies within a belt of moderately deformed Paleozoic rocks lying north of the strongly deformed rocks of the Ouachita Mountains. The structural features shown by the Paleozoic rocks of northern Le Flore County comprise many synclines and anticlines whose axes trend chiefly in easterly and northeasterly directions. There are also many faults, including both thrust and normal faults. Some of these are related to a system of subparallel fractures that trend in general east-northeastward in several counties on the southern and western flanks of the Ozark dome. Both the folding and the faulting are believed to have occurred in Pennsylvanian time and to have resulted from compressive forces that were exerted from a southerly direction. As the folding and faulting involved all the Pennsylvanian rocks exposed in northern Le Flore County, the latest deformation took place in late- or post-Boggy time.

The greater part of northern Le Flore County is occupied by five large structural features. Named in order from south to north these are the Cavanal syncline, the Backbone anticline, the Bokoshe syncline, the Milton anticline, and the Cowlington syncline. Small parts of two other structural features, the Sansbois syncline and the Brazil anticline, lie within the southwest margin of the area mapped.

### CAVANAL SYNCLINE

The Cavanal syncline is a large structural trough, extending eastward across T. 7 N., Rs. 24, 25 and 26 E., and dying out in R. 27 E., whose deepest part lies within the large outlier of the Boggy formation centering in Cavanal Mountain. The Savanna and McAlester formations are also involved.

### JAMES FORK SYNCLINE

The James Fork syncline is a shallow structural trough that crosses the State boundary 2 miles south of the Midland Valley Railroad and plunges gently in a west-southwesterly direction. It dies out near Cameron, just west of a prominent mesa which lies along its axis and is capped by an outlier of the Tamaha sandstone member of the McAlester formation. Between this mesa and the

State boundary the axis lies along a broad outcrop of the Cameron sandstone member.

### MIDLAND ANTICLINE

The Midland anticline is a gentle upwarped structure plunging from the State boundary westward and forming a broad anticlinal nose. The anticline dies out southwest of Cameron in a structural terrace on which the Cameron gas field is situated.

### GILMORE ANTICLINE

The Gilmore anticline, east of Poteau, is in the southeastern part of the area shown in Plate I. This anticline is poorly expressed at the surface. As determined from subsurface data by Klamt[54] it comprises two domes, both elongated northeastward, with their apices half a mile apart. The larger dome, which has its apex at the line between T. 7 N., Rs. 26 and 27 E., extends about 4 miles northeastward from a point half a mile south of Gilmore to the head of Gap Creek, where it dies out. The axis of the smaller one, which extends southwestward from SE¼ NE¼ sec. 26, has its apex in the southern half of that section and dies out south of the area mapped. The rocks exposed in the anticline belong to the McAlester formation, of which the oldest beds exposed are less than a hundred feet below the Cameron sandstone member. The youngest exposed unit involved is the Tamaha sandstone member. The Poteau-Gilmore gas field lies largely within the Gilmore anticline.

### BACKBONE ANTICLINE AND FAULT

The Backbone anticline is about 30 miles long and extends from the town of Greenwood, in Sebastian County, Arkansas, to the west side of Le Flore County. It crosses the State boundary at Jenson, Oklahoma, about 10 miles from its eastern end and terminates in a westward-plunging nose in T. 8 N., R. 23 E., southeast of Milton, Oklahoma. The anticline is broken along its crest by the Backbone fault, a thrust fault on the south side of which the rock strata have moved upward with a maximum displacement of

54. Croneis, Carey, "Natural Gas in Interior Highlands of Arkansas" in "Geology of Natural Gas": Edited by Ley, Henry A., *Amer. Assoc. Petrol. Geol.* fig. 16, p. 570, 1935.

more than 5,000 feet. At Panama, Oklahoma, there is a local sag in the anticlinal crest, west of which the structure is that of an elongated dome having its apex in sec. 7, T. 8 N., 25 E.

The oldest rocks exposed in the Backbone anticline belong to the Atoka formation, which forms a long inlier extending from Greenwood, Arkansas, to the neighborhood of Bokoshe. The greatest thickness, more than 5,000 feet, of the Atoka is exposed on the south limb along the Frisco Railroad between Rock Island, Oklahoma, and Bonanza, Arkansas, and the base of the Atoka may lie not far below the surface where that railroad crosses the State boundary south of Bonanza. On the south limb of the Backbone anticline and along most of the north limb, the Atoka is bordered by narrow belts of the coal-bearing Hartshorne sandstone; farther out on both sides and around the westward-plunging nose are broad exposures of the McAlester formation.

The Backbone fault crosses the State line a mile south of Bonanza, Arkansas, and follows the anticlinal crest to a point southeast of Coal Creek, west of which it continues north of the crest and dies out south of Bokoshe. The poor exposures along the Oklahoma portion of this fault do not permit a detailed study of its attitude, but such data as have been obtained, together with observations made in Arkansas by Croneis[55] and by Hendricks and Parks,[56] indicate that it is a thrust fault and that it comes to the surface with a steep southward dip; it may, however, flatten out gradually southward.

Near the State line the beds in the lower part of the Atoka formation dip steeply southward adjacent to the Backbone fault, on the south side of which they have moved upward more than 5,000 feet into contact with strata in the upper part of the Atoka formation dipping steeply northward. The displacement here reaches its maximum for the part of the fault lying within Oklahoma. In general the displacement decreases toward the west, though it increases locally adjacent to the south limb of the Pocola anticline and also west of the sag at Panama.

55. Croneis, Carey, "Natural Gas in Interior Highlands of Arkansas": Geology of Natural Gas, *Am. Assoc. Petrol. Geol.*, fig. 10, p. 551, 1935.
56. Hendricks, T. A., and Parks, Bryan, "Geology and Mineral Resources of the Westen Part of the Arkansas Coal Field": *U. S. Geol. Survey Bull.* 847-E, p. 202, 1937.

There is a small branch of the Backbone fault, with its upthrow on the south side, in secs. 4 and 5, T. 8 N., R. 26 E.

### POCOLA ANTICLINE

The Pocola anticline is a minor flexure on the north side of the Backbone fault southwest of Pocola. The anticline is a sharp-crested fold with steep limbs and is expressed in outcrops of the Atoka formation. Its axis passes eastward beneath the Backbone fault.

### BOKOSHE SYNCLINE

The Bokoshe syncline is a large basin-like structural feature expressed in outcrops of the Savanna and McAlester formations. The lowest point along its axis lies within an outlier of a sandstone member of the Savanna formation on the north side of the town of Spiro toward which the axis plunges in opposite directions from points of maximum structural altitude southeast of Bokoshe and north of Pocola.

### ROUND MOUNTAIN SYNCLINE

The Round Mountain syncline is a shallow downwarped basin, northeast of Spiro. Its structure cannot be studied in detail owing to scarcity of exposures. The rocks exposed belong to the McAlester and Savanna formations. At the axis of the syncline a small outlier of a thin-bedded sandstone in the upper part of the Savanna formation forms the top of Round Mountain, in sec. 4, T. 9 N., R. 26 E., and sec. 33, T. 10 N., R. 26 E. The synclinal axis probably continues northeastward beneath the Arkansas River flood plain.

### SPIRO ANTICLINE

The Spiro anticline is a minor flexure extending in an east-west direction about midway between Spiro and Coal Creek. It is interpreted from poor exposures of the McAlester formation to be a low westward-plunging anticlinal nose branching off the north side of the Pocola anticline.

### COAL CREEK SYNCLINE

The Coal Creek syncline, another minor flexure on the south side of the Bokoshe syncline, is a shallow structural depression, the western end of which lies north of the railroad junction at Coal Creek, whence it extends eastward for about 5 miles between the Spiro anticline and the Backbone fault.

### MASSARD PRAIRIE ANTICLINE

The Massard Prairie anticline, which crosses the Oklahoma-Arkansas boundary a mile and a quarter southeast of Cedars, extends westward across Poteau River and dies out beyond the Kansas City Southern Railroad between Scullyville and Braden. The rocks exposed in the Oklahoma part of this anticline belong to the McAlester formation, of which the oldest unit, the McCurtain shale member, is exposed at the crest of the anticline south of Cedars. The top of the Hartshorne coal, which marks the base of the McAlester formation, was logged at 145 feet in a gas well, Forbes No. 2, near the axis of the anticline in the center of NW¼ NE¼ sec. 9, T. 9 N., R. 27 E.

### CENTRAL SYNCLINE

The Central syncline crosses the State boundary 3 miles south of Cedars and extends westward to a low anticlinal cross-fold, about a mile north of Pocola, which separates it from the Bokoshe syncline. Within Oklahoma the Central syncline is expressed in outcrops of the McAlester formation.

### MILTON ANTICLINE

The Milton anticline is approximately 30 miles long. Its western end lies in Haskell County, about 12 miles west of the Le Flore County line, whence it extends northeastward to the Arkansas River. Its structure is essentially that of a great elongate asymmetrical dome with the steeper limb on its southeast side and its apex in the northeastern part, near State Highway No. 9. It includes, however, a number of minor flexures and faults.

The oldest formation cropping out is the Atoka formation which occupies a large elongate area lying between belts of the coal-bearing Hartshorne sandstone; farther out on the limbs are broad exposures of the McAlester formation and within the area of Atoka outcrop northwest of Milton, in T. 8 N., R. 23 E., there is a small area of Hartshorne sandstone, overlain by a small sandstone-capped outlier of the McCurtain shale member of the McAlester formation.

One of the minor flexures is a downwarped and downfaulted area within which lies this outlier; another is a small dome expressed in outcrops of the Atoka formation centering in secs. 17 and 18, west of Milton. There are 3 principal faults, all of which are strike faults. One is a thrust fault that extends eastward from the County line and splits into 2 branches in the eastern part of T. 8 N., R. 23 E. The rocks are displaced upward on its south side, probably not more than 150 feet at any place. The other two principal faults are normal faults on each of which the displacement is downward on the south side. One of these crosses the Haskell-Le Flore County line with a downward displacement of approximately 500 feet on its south side, and extends eastward with decreasing displacement at least as far as sec. 10, T. 8 N., R. 23 E.; the other cuts the apical part of the anticline, in the E½ T. 9 N., R. 24 E., with a maximum displacement, in sec. 13, of about 400 feet.

### COWLINGTON SYNCLINE

The Cowlington syncline, which is a long structural trough trending in a northeasterly direction, lies mainly in Haskell and Sequoyah Counties; a short segment of it is expressed in outcrops of the Savanna and Boggy formations occupying a small area in the extreme northwestern part of Le Flore County, between Cowlington and the Arkansas River. On the southeast limb of the trough, west of Cowlington, there is a gentle undulation consisting of a low anticline with a shallow syncline on its southeast side. Near the river the axis of the syncline extends in an east-northeasterly direction along the top of Short Mountain, a prominent mesa elongated in an east-northeasterly direction, which is capped by an outlier of the Bluejacket sandstone member of the Boggy formation. As the sandstone strata around the margins of this outlier dip inward not only on both its sides but also at its ends, the local structure appears to be that of a basinlike depression on the gently undulating axis of the Cowlington syncline.

### SANSBOIS SYNCLINE

The Sansbois syncline is a great structural trough lying mainly in Haskell and Latimer Counties with its eastern extremity extending a few miles into Le Flore County.

## BRAZIL ANTICLINE

The Brazil anticline lies mainly in Latimer County, with only its northeastern end in Le Flore County. It occupies a small area in T. 7 N., R. 23 E., between Sansbois and Cavanal Mountains.

## ECONOMIC GEOLOGY

### COAL

Northern Le Flore County lies within the Arkansas-Oklahoma coal field where valuable coal beds, as described in several Government publications,[57] occur in rock formations of Pennsylvanian age. Many coal beds are present, ranging in thickness from less than an inch to several feet. In Le Flore County the most valuable coal beds are the Lower and Upper Hartshorne beds, within and at the top of the Hartshorne sandstone respectively, which have been mined in many places. (see Plate II.) The Stigler bed in the McAlester formation, the Cavanal and other beds in the Savanna formation, and the Lower Witteville and Secor beds in the Boggy formation are also minable in many places. Several unnamed coal beds are of relatively small value as they are less than 14 inches thick at all of their exposures that have been examined. In most places the coal beds are concealed by soil or alluvium and they rarely crop out in natural exposures. Sections of the coal beds in numerous drill holes, mines, and prospects in northern Le Flore County are given in Table III (in envelope.)

The coal beds dip more than 5° at most places and are therefore mined chiefly by underground methods. The room-and-pillar method is generally employed, though a few mines at and near Poteau are worked by the longwall method, and there have been some small stripping operations. A few sites for possible future stripping operations are described in the following pages.

Much of the minable coal lies beneath land, formerly designated as segregated coal land of the Choctaw and Chickasaw Nations, mining rights on which were formerly leased or purchased through the Office of Indian Affairs, U. S. Department of the Interior. Sales of a number of tracts prior to 1949 account for differences in detail in the outlines of these lands as shown on

57. Taff, J. A., and Adams, G. I., "Geology of the Eastern Choctaw Coal Field, Indian Territory": *U. S. Geol. Survey 21st Ann. Rept.*, Pt. 2, 1900.
Wilson, C. W., Jr., and Newell, N. D., *op. cit.*, 1937.
Hendricks, T. A., Knechtel, M. M., Dane, C. H., Rothrock, H. E., and Williams, J. S., "Geology and Fuel Resources of the Southern Part of the Oklahoma Coal Field": *U. S. Geol. Survey Bull.* 874, published in 4 parts, 1937-1939.

Plate II of this report as compared with their outlines as shown on maps heretofore published. The lands were purchased by the Federal Government through Public Law 754, 80th Congress 1948, signed by the President on May 24, 1949, on which day they became part of the public domain. They are now subject to the Mineral Leasing Act of Feb. 25, 1920 and are administered by the Bureau of Land Management, under operational supervision by the United States Geological Survey.

The production of coal recorded in Le Flore County from 1908 to 1943, inclusive, was 11,353,628 tons, which represents the combined output of the northern and southern parts of the County, for which separate figures are not available. Most of this coal came from the northern part of the County, here described. Most of it was mined from the Hartshorne coal beds; smaller amounts from the Secor, Lower Witteville, Cavanal, and Stigler beds.

The coal is mostly bright coal and is largely composed of anthraxylon derived from the woody tissues of plants, with smaller amounts of translucent and opaque attrital material and small though considerable amounts of mineral charcoal (mother of coal). As shown by the analyses in Table II, the coal is low- to medium-volatile bituminous in rank, mostly with heating values between 13,000 and 15,000 B.t.u., on an air-dried basis. The coal of the Lower and Upper Hartshorne beds generally has low percentages of ash and sulphur, and this is probably true also of the Stigler bed and other coal beds locally of minable thickness in the McAlester shale. The coal of the Secor, Lower Witteville, and Cavanal beds generally contains more sulfur and ash.

## COAL BEDS IN THE HARTSHORNE SANDSTONE

### Hartshorne Coal

The most valuable coal beds in northern Le Flore County are the Lower Hartshorne bed in the Hartshorne sandstone and the Upper Hartshorne bed, 0 to 60 feet higher, at the top of the Hartshorne sandstone. These beds, as shown on Plate I, are present in nearly all of northern Le Flore County except two belts of exposure of the Atoka formation along the Milton and Backbone anticlines, from which the coal beds have been removed by erosion.

The thickness of coal worked in most mines in the Hartshorne beds is between 3 and 5 feet, and in many mines and prospects includes a thin shale parting. The roof is generally slaty shale and is fairly good at most places.

The coal of the Hartshorne beds is low- and medium-volatile bituminous coal, generally low in sulfur and ash, and with heating values between 14,000 and 15,000 B.t.u. Microscopic examination of the coal of these beds from Mine No. 17, sec. 27, T. 9 N., R. 24 E., show it to be anthraxylous coal similar in petrographic composition to coal of three beds higher in the Pennsylvanian rock sequence,—among them the McAlester bed,—that were sampled elsewhere in Oklahoma. The results of this examination are summarized by Davis and others[58] as follows:

> Although the Hartshorne coal from Mine No. 17 is of low-volatile rank and difficult to section, 91 thin sections were prepared from the columnar sample and examined microscopically. The bed contained one thin layer of semisplint, which constituted 2 percent of the thickness of the column. The percentages of the petrographic components were as follows: Anthraxylon, 72; translucent attritus, 17; opaque attritus, 6; and fusain, 5. The content of fusain was moderately high, and Hartshorne is similar in this, as well as other petrographic characteristics, to Henryetta and McAlester coals. The bed was very uniform in respect to distribution of impurities.

The friability of coal from Mine No. 17 was determined by the standard method of the American Society for Testing Materials to be 59.5 and its agglutinating value 7.0.

The large reserve of low- and medium-volatile bituminous coal in Hartshorne beds of northern Le Flore County is suitable for use in manufacturing metallurgical coke. When coked in beehive ovens this coal yields coke of great structural strength but it cannot be coked alone in byproduct ovens because its strong expansion in the coking process destroys the walls of the ovens. On the other hand, much of the high-volatile bituminous coal of areas farther west in Oklahoma contracts in coking and yields coke of low crushing strength which is therefore unsuitable for blast-furnace use.

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58. Davis, J. D., Reynolds, D. A., Elder, J. L., Ode, W. H., Holmes, C. R., and McCartney, J. T., "Carbonizing Properties of Western Region Interior Province Coals and Certain Blends of These Coals": *U. S. Bur. Mines Tech. Paper* 667, p. 23, 1944.

Carbonization studies by the Bureau of Mines, made in co-operation with the Oklahoma Geological Survey[59] demonstrate that proper blends of low- or medium-volatile bituminous coal from the Hartshorne beds of northern Le Flore County and adjacent areas with high-volatile bituminous coal from the McAlester or Henryetta beds of areas farther west, can be coked in byproduct ovens, and that such blends yield satisfactory blast-furnace coke. Medium-volatile bituminous coal of the Hartshorne bed mined near McCurtain, in Haskell County, by the McAlester Fuel Company and high-volatile bituminous coal of the McAlester bed mined by the same company at Carbon, Pittsburg County, Oklahoma, were blended and coked during World War II at a plant near Daingerfield, in eastern Texas, which includes a blast furnace constructed for the purpose of smelting brown iron ores mined in that locality. These coals have also been shipped for this purpose to Houston, Texas, and low-volatile Hartshorne coal was shipped to Los Angeles, California, and Provo, Utah, for blending with high-volatile Utah coal to make metallurgical coke.

Much of the coal of the Hartshorne beds is shipped to distant points and sold as "smokeless" domestic fuel, and much of it is used as railroad steam coal.

On the south limb of the Backbone anticline from Bokoshe eastward into Arkansas, and on the north limb as far east as Coal Creek, the two Hartshorne coal beds are separated by 35 to 60 feet of strata. The intervening strata locally consist entirely of shale, but include at most places a ridge-forming sandstone. On the Milton anticline the coal beds are well separated in a short segment of their outcrop near Bokoshe, but everywhere else are so close together that they are shown on the map as a single line of outcrop. At Bokoshe the intervening beds thin abruptly northward and locally pinch out, but persist between the two coal beds at most places as a shale parting a few inches thick. At the portal of the Gillie mine, on the south side of that town, the two Hartshorne beds are about

59. Davis, J. D., and Reynolds, D. A., "Carbonizing Properties of McAlester Bed Coal from Dow No. 10 Mine, Dow, Pittsburg County, Okla." (Preliminary report); *Okla. Geol. Survey Mineral Report* No. 15, 1942.
Davis, J. D., Reynolds, D. A., Elder, J. L., Ode, W. H., Holmes, C. R., and McCartney, J. T., "Carbonizing Properties of Western Interior Province Coals and Certain Blends of these Coals"; *U. S. Bur. Mines Tech. Paper* 667, 1944.

10 feet apart, with shale and sandstone intervening, whereas a drill hole put down by the operating company about a thousand feet farther south showed about 40 feet of rock between them. On the north limb of the Backbone anticline near Pocola, the Hartshorne coal exposed at the portal of a small abandoned mine (No. 4, NE¼ NW¼ sec. 25, T. 9 N., R. 26 E.) and logged in a number of drill holes shows two benches, 3 feet or more in total thickness and separated by a shale parting a few inches thick. These benches are tentatively regarded as the Lower and Upper Hartshorne beds. They may, however, belong only to the Upper bed, the Lower bed possibly being represented by a few inches of bony coal logged in diamond-drill holes Nos. 2 and 4A, T. 9 N., R. 26 E., stratigraphically 28 and 33 feet lower respectively, than the two benches.

In the Gillie mine at Bokoshe well-rounded erratic cobbles have occasionally been found by the miners in the upper part of the Lower Hartshorne coal bed. One of these is reported by Prof. Ray L. Six[60] of Oklahoma A. & M. College to be composed of igneous rock tentatively identified as quartz monzonite. Another, which was given to the writer by Mr. Paul Rees of Bokoshe, is of dark-gray quartzite. The cobbles were supposedly transported here from distant sources, as no bedrock that could have furnished the materials composing them is known to occur nearby. Such well-worn rock fragments must have travelled considerable distances as constituents of gravel. At first they must have been impelled along stream beds by fairly strong currents of water, but their presence in a coal bed suggests that there were no strong currents where they were finally deposited. They may therefore have been finally rafted into the coal-forming environment during floods, either attached to the roots of floating trees or embedded in ice floes.

Most mines in the Hartshorne beds lie on the south flanks of the Milton and Backbone anticlines, along belts passing northeastward through Milton and Bokoshe, and eastward through Buck Creek, Tahona, Williams, and Rock Island. A few small abandoned mines lie on the north side of the Backbone anticline between Bokoshe and Coal Creek and near Pocola. Owing to local varia-

60. Six, R. L., personal communication, 1944.

tions in thickness, pitch, dislocation by faults, and content of impurities, each of these beds can be mined more profitably in some localities than in others. On the south side of the Backbone anticline, where the beds are 35 to 60 feet apart, mining is restricted almost entirely to the Lower Hartshorne bed from Poteau River eastward through Rock Island, and to the Upper Hartshorne bed from Poteau River westward through Buck Creek. From Bokoshe westward through Milton, both beds are worked at some places where a thin parting separates them, but mining is mostly in the Lower bed. Northeast of Bokoshe, where the beds are close together, both are generally worked. Little of the Hartshorne coal has been mined on the north flank of the Backbone anticline and none on the north flank of the Milton anticline in Le Flore County. From Coal Creek station eastward for about 6 miles toward Pocola, the coal of the Hartshorne beds is believed to have little or no value. It cannot be traced here continuously, as the coal beds and the rocks containing them are almost wholly concealed beneath the alluvium along Poteau River. Their pitch, moreover, is generally steep and they are cut by faults associated with the Backbone fault zone. Farther east, on segregated land between Poteau River and the Arkansas boundary, the coal appears everywhere to have workable thickness and moderate pitch and seems to offer opportunities for profitable mining.

The Hartshorne coal was recorded within minable depths in three wells drilled for gas by the Le Flore County Gas & Electric Company near the crest of the Massard Prairie anticline in T. 9 N., R. 27 E. Coal was logged at 235-239 feet from the surface in Forbes No. 3 well, which is a dry hole in SE¼ SE¼ SE¼ sec. 4; at 145-148 feet in Forbes No. 2, a gas well in the center of NW¼ NE¼ sec 9; and at 184-187 feet in Gray No. 4, a gas well in NW¼ NW¼ SE¼ sec. 9. No data on the quality of this coal are available. The thickness of 3 to 4 feet of coal indicated by the logs, though subject to verification by further drilling, is not by any means improbable, as it agrees well with the thicknesses of the Hartshorne coal measured only 3 miles away in sec. 29, T. 9 N., R. 27 E., in secs. 24 and 25, T. 9 N., R. 26 E., and at Bonanza, Arkansas. The coal, if found to be of suitable thickness and quality, could easily be reached through a shaft sunk somewhere near the center of the Massard

Prairie anticline but, owing to its situation on that structure, might be expected to give off troublesome quantities of gas.

Favorable mining conditions seem to exist also on the northwest side of the Milton anticline, southwest of the Midland Valley Railroad; northeast of that railroad the coal is thinner but appears to offer opportunities for longwall mining operations similar to those carried on in the Cavanal coal bed in the vicinity of Poteau. At Bokoshe faulting of the Hartshorne beds has given considerable trouble in most of the mines. In sec. 16, a mile south of that town, on segregated land close to the Midland Valley Railroad, an attractive strip mining site extends for approximately a mile along outcrops of the two Hartshorne coal beds on the westerly-plunging nose of the Backbone anticline. The coal beds are here separated by about 60 feet of rock, mainly shale. The upper bed averages about 42 inches in thickness and the lower about 36 inches. Unfortunately both the dip of the beds and the rise of the ground are in the same westerly direction, but both are gentle and the average width of coal available for stripping to a depth of 40 feet is approximately 300 feet for the upper bed and 200 feet for the lower bed. It is estimated that at least 225,000 tons of coal could be uncovered and mined at this site. No comparable sites for strip mining are known to occur along outcrops of the Hartshorne beds elsewhere in northern Le Flore County, though the lower bed has been mined by that method at abandoned workings in sec. 8, T. 8 N., R. 25 E., and sec. 7, T. 8 N., R. 27 E.

## COAL BEDS IN MCALESTER FORMATION

### Stigler and Other Coals

The Stigler coal bed, in the McAlester formation just above the Cameron sandstone member, is tentatively correlated with the McAlester coal bed of areas farther west and south. It crops out from Tucker, SE¼ sec. 26, T. 10 N., R. 24 E., southwestward to the Haskell County line and a coal that is mapped as Stigler in southern Haskell County[61] occurs in a belt extending eastward from Haskell County, passing through Shady Point. East of Shady Point the Stigler coal continues at least as far as sec. 1, T. 7 N., R.

61. Oakes, Malcolm C. and Knechtel, M. M., "Geology and Mineral Resources of Haskell County, Oklahoma": *Okla. Geol. Survey Bull.* 67, Pl. II, 1948.

26 E. It also crops out on a prominent hill east of Cameron that is capped by the Tamaha sandstone member. Another coal bed, not far below the Tamaha member, crops out (1) on this hill 80 feet higher than the Stigler bed at this locality, (2) in a belt extending eastward from Shady Point, (3) possibly in the vicinity of Gap and Nail Creeks, in secs. 9, 10, 11 and 14, T. 7 N., R. 26 E., on the Gilmore anticline, and (4) possibly at Stony Point, in T. 9 N., R. 25 E. This bed above the Stigler may be the same as a bed tentatively designated "Stigler (?)" by Hendricks,[62] occurring above the McAlester coal bed in the Howe-Wilburton district and a thin but persistent coal known as the "rider vein" to the coal miners, that occurs above the Stigler coal bed in eastern Haskell County, Oklahoma. A still higher coal bed, not far above the Tamaha sandstone member, crops out in secs. 9, 10, 11 and 14, T. 7 N., R. 26 E., in the vicinity of Gap Creek.

Each of these coal beds shows less than 2 feet of coal at all exposures that were examined. In T. 7 N., R. 26 E., low dips and gentle surface gradients appear to favor strip mining along outcrops of the Stigler coal bed and the coal bed above the Tamaha sandstone member. Years ago small amounts of coal were mined from the Stigler (?) coal in four small slope mines near Stony Point and from the Stigler bed in strip pits near Tucker.

The coal of the Stigler bed from many localities makes excellent blacksmithing coal. It is believed to be low- to medium-volatile bituminous coal, though no analyses are available for coal of the McAlester formation from localities within northern Le Flore County.

## COAL BEDS IN THE SAVANNA FORMATION

### Cavanal and Other Coals

At least three and possibly four minable coal beds within the Savanna formation crop out in a wide arcuate belt passing through Poteau and centering in Cavanal Mountain. Coal occurs in the Savanna formation also in small prospects northwest of Tucker and at Round Mountain, sec. 4, T. 9 N., R. 26 E. None of these

62. **Hendricks, T. A.**, "Geology and Fuel Resources of the Southern Part of the **Oklahoma Coal Field**": *U. S. Geol. Survey Bull.* 874-D, 1937, pl. 28, 1939.

beds exceeds 2 feet, 2 inches in thickness and all are locally of less than minable thickness. None of them was found to be traceable throughout the belt of Savanna outcrop between Poteau and Brazil Creek. For example, one of these beds, cropping out on the west side of the town of Poteau and identified by Hendricks[63] south of that town as the Cavanal coal bed, was not found west of sec. 35, T. 8 N., R. 24 E., and another coal bed, higher in the Savanna, could not be found east of sec. 35, though it was traced there eastward from sec. 22, T. 7 N., R. 23 E. A still higher bed was found only in the vicinity of Wildhorse Creek, T. 7 N., R. 23 E., and a bed lower than the Cavanal bed was found only in the northeast suburbs of Poteau and from sec. 3 to sec. 12, T. 7 N., R. 25 E. Over each bed is a moderately strong roof formed by slaty shale, commonly containing thin beds of marine fossiliferous limestone. Most commonly the floor is an underclay. The Cavanal bed and the lower bed that is worked north of Poteau, are mined by the longwall method, which is favored by (1) the moderate thickness of each bed, which does not exceed 26 inches; (2) the character of the roof, which settles readily as the working face advances but is nevertheless easily supported by packwalls along haulageways and by props between gob and working face; and (3) the clay floor, which facilitates machine undercutting.

The Savanna coals, sampled at two localities (see table of analyses) show a rather high content of ash and sulfur and heating values lower than those of the Hartshorne coal beds.

## COAL BEDS IN BOGGY FORMATION

### Lower Witteville Coal

The Lower Witteville coal bed, in the lower part of the Boggy formation, just below a thick, massive sandstone unit in the uppermost part of the Bluejacket sandstone member, crops out on the east and north sides of Cavanal Mountain. It is absent from the Boggy strata near Calhoun and at Short Mountain, northeast of Cowlington, owing possibly to its removal by erosion in Pennsylvanian time prior to deposition of the overlying sandstone unit. That an unconformity exists at least locally at the base of that unit is suggested by the relation of the coal bed to it at two portals of

63. Hendricks, T. A., *op. cit.*, pl. 27, 1939.

an abandoned mine on opposite sides of a creek at Witteville in the SW¼ NE¼ sec. 15, T. 7 N., R. 25 E. In one of these openings the sandstone layer rests directly on the coal, but in the other, about 150 feet to the north, is separated from the coal by about 6 feet of shale. A little of this coal has been mined east of Calhoun and at Witteville. The bed is 4 feet thick but includes several shale partings and appears to contain much sulfur. No analyses of the Lower Witteville coal are available.

### Secor Coal

### (Formerly upper Witteville coal)

The Secor coal bed, in the Boggy formation, about 170 to 210 feet above the Lower Witteville coal bed, crops out in an arc extending around the east and north side of Cavanal Mountain, where it shows 3 feet or more of coal, free from partings, with a clay floor and a fairly good roof composed of slaty shale containing marine fossiliferous calcareous layers. This coal has a rather high content of ash and sulfur and, as mined from at least one locality, tends to ignite spontaneously in storage. Because of this and the high cost of truck haulage from mine to railroad, recent attempts to mine the Secor coal have proved unprofitable. Much of it was formerly mined at Calhoun and at Witteville and was hauled to Shady Point over railroad lines which have been dismantled.

## TABLE II
## CHEMICAL ANALYSES OF MINE SAMPLES OF COAL FROM LE FLORE COUNTY

| LOCALITY, BED, MINE, ETC. | Sample | | | Proximate | | | | | Ultimate | | | | | Calorific value | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Laboratory No.[1] | Kind[2] | Condition[3] | Moisture | Volatile matter | Fixed carbon | Ash | Sulfur | Hydrogen | Carbon | Nitrogen | Oxygen | Air-drying loss | Calories | B.t.u. | Softening temperature[4] | Bulletin No.[5] |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| ANALYZED BY THE U. S. BUREAU OF MINES | | | | | | | | | | | | | | | | | |
| Bokoshe, ¼ mile northeast of; Slope No. 3 mine, Hartshorne bed (face of 5 east entry, slope entry, 1,700 feet east of mine mouth, top bench). | 26801 | B | 1 | 3.2 | 17.3 | 76.3 | 3.2 | .5 | .... | .... | .... | .... | 2.6 | 8,100 | 14,580 | 2,230 | 193 |
| | | | 2 | .... | 17.8 | 78.9 | 3.3 | .6 | .... | .... | .... | .... | .... | 8,361 | 15,050 | ...... | ...... |
| Same (bottom bench). | 26802 | B | 1 | 3.0 | 19.2 | 71.1 | 6.7 | 1.0 | .... | .... | .... | .... | 2.6 | 7,767 | 13,980 | 2,300 | 193 |
| | | | 2 | .... | 19.8 | 73.3 | 6.9 | 1.0 | .... | .... | .... | .... | .... | 8,006 | 14,410 | ...... | ...... |
| 4 miles northeast of; sec. 26, T. 9 N., R. 24 E.; Premium Smokeless Coal Co. mine, Upper and Lower Hartshorne beds, no parting where sampled (No. 3 east breakthrough, 700 feet south and 450 feet east from mine mouth). | B66263 | | 1 | 1.4 | 17.2 | 73.6 | 7.8 | 1.5 | 4.2 | 81.0 | 1.7 | 3.8 | .8 | ...... | 13,890 | 2,310 | U |
| | | | 2 | .7 | 17.3 | 74.1 | 7.9 | 1.5 | 4.1 | 81.7 | 1.7 | 3.1 | .... | ...... | 14,000 | ...... | ...... |
| | | | 3 | .... | 19.0 | 81.0 | .... | 1.6 | 4.4 | 89.3 | 1.8 | 2.9 | .... | ...... | 15,310 | ...... | ...... |
| Same (main slope entry, 740 feet south and 435 feet east from mine mouth) | B66264 | | 1 | 1.8 | 16.6 | 74.1 | 7.5 | 1.3 | 4.2 | 81.5 | 1.7 | 3.8 | 1.1 | ...... | 14,020 | 2,140 | U |
| | | | 2 | .7 | 16.7 | 75.1 | 7.5 | 1.3 | 4.2 | 82.3 | 1.7 | 3.0 | .... | ...... | 14,170 | ...... | ...... |
| | | | 3 | .... | 18.2 | 81.8 | .... | 1.4 | 4.4 | 89.8 | 1.9 | 2.5 | .... | ...... | 15,440 | ...... | ...... |
| Calhoun, Central No. 8 mine, Lower Witteville bed (face of 7 east entry, main slope entry). | W69461 | A | 1 | 1.5 | 22.6 | 62.7 | 13.2 | 3.9 | .... | .... | .... | .... | .... | 7,395 | 13,310 | ...... | 193 |
| | | | 2 | .... | 22.9 | 63.7 | 13.4 | 4.0 | .... | .... | .... | .... | .... | 7,506 | 13,510 | ...... | ...... |
| Same (face of 13 west entry, main slope entry). | W69468 | A | 1 | 1.5 | 21.8 | 64.7 | 12.0 | 3.8 | .... | .... | .... | .... | .... | 7,456 | 13,420 | ...... | 193 |
| | | | 2 | .... | 22.1 | 65.7 | 12.2 | 3.9 | .... | .... | .... | .... | .... | 7,572 | 13,630 | ...... | ...... |
| Same (face of 12 west entry, main slope entry). | W69469 | A | 1 | 1.9 | 21.6 | 62.6 | 13.9 | 3.5 | .... | .... | .... | .... | .... | 7,256 | 13,060 | ...... | 193 |
| | | | 2 | .... | 22.0 | 63.8 | 14.2 | 3.6 | .... | .... | .... | .... | .... | 7,400 | 13,320 | ...... | ...... |
| Same (face of 11 west entry, main slope entry). | W69470 | A | 1 | 1.9 | 22.0 | 62.6 | 13.5 | 3.8 | .... | .... | .... | .... | .... | 7,267 | 13,080 | ...... | 193 |
| | | | 2 | .... | 22.4 | 63.8 | 13.8 | 3.9 | .... | .... | .... | .... | .... | 7,406 | 13,330 | ...... | ...... |
| Same (face of 8 east entry, main slope entry). | W69473 | A | 1 | 1.5 | 22.6 | 62.2 | 13.7 | 6.3 | .... | .... | .... | .... | .... | 7,239 | 13,030 | ...... | 193 |
| | | | 2 | .... | 22.9 | 63.2 | 13.9 | 6.4 | .... | .... | .... | .... | .... | 7,350 | 13,230 | ...... | ...... |
| Panama, 2 miles west of; Hanraty mine, Lower Hartshorne bed (face of 7 west room, main slope, 650 feet from mine mouth). | A21923 | B | 1 | 3.2 | 16.2 | 76.3 | 4.3 | .8 | .... | .... | .... | .... | 2.5 | 8,056 | 14,500 | 2,220 | 411 |
| Same (face of 8 room, main slope, 700 feet from mine mouth). | A21924 | B | 1 | 3.0 | 15.9 | 77.3 | 3.8 | .7 | .... | .... | .... | .... | 2.3 | 8,078 | 14,540 | 2,200 | 411 |
| Same (composite of samples A21923 and A21924). | A21925 | B | 1 | 3.1 | 16.0 | 76.8 | 4.1 | .8 | 4.8 | 84.0 | 1.7 | 4.6 | 2.4 | 8,072 | 14,530 | ...... | 411 |
| | | | 2 | .... | 16.5 | 79.3 | 4.2 | .8 | 4.6 | 86.6 | 1.8 | 2.0 | .... | 8,322 | 14,980 | ...... | ...... |
| | | | 3 | .... | 17.2 | 82.8 | .... | .9 | 4.8 | 90.4 | 1.8 | 2.1 | .... | 8,689 | 15,640 | ...... | ...... |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2½ miles west of; Buck Creek mine, Upper Hartshorne bed (face of 4 east entry, 1,100 feet from mine mouth). | A22020 | B | 1 | 2.1 | 17.2 | 73.9 | 6.8 | .8 | .... | .... | .... | .... | 1.2 | 7,850 | 14,130 | 2,340 | 411 |
| Same (face of 4 west entry, 1,100 feet from mine mouth). | A22021 | B | 1 | 2.1 | 18.8 | 72.1 | 7.0 | .8 | .... | .... | .... | .... | 1.4 | 7,844 | 14,120 | 2,350 | 411 |
| Same (composite of samples A22020 and A22021). | A22022 | B | 1 | 2.1 | 17.7 | 73.4 | 6.8 | .8 | 4.2 | 82.8 | 1.9 | 3.5 | 1.3 | 7,861 | 14,150 | ........ | 411 |
| | | | 2 | .... | 18.0 | 75.0 | 7.0 | .8 | 4.1 | 84.6 | 1.9 | 1.6 | .... | 8,028 | 14,450 | ........ | ..... |
| | | | 3 | .... | 19.4 | 80.6 | .... | .9 | 4.4 | 90.9 | 2.0 | 1.8 | .... | 8,628 | 15,530 | ........ | ..... |
| Poteau, 1½ miles north of; sec. 13, T. 7 N., R. 25 E.; Le Flore Coal Co. mine, Cavanal bed (west end of 200-foot longwall face). | A24780 | B | 1 | 2.0 | 20.9 | 66.2 | 10.9 | 4.7 | .... | .... | .... | .... | 1.4 | 7,544 | 13,580 | 2,340 | 411 |
| | | | 2 | .... | 21.3 | 67.5 | 11.2 | 4.8 | .... | .... | .... | .... | .... | 7,700 | 13,860 | ........ | ..... |
| 3 miles north of; sec. 11, T. 7 N., R. 25 E.; Poteau Machine Coal Co. mine, Cavanal bed (north end of 180-foot longwall face). | A24779 | B | 1 | 2.9 | 21.6 | 66.3 | 9.2 | 3.4 | .... | .... | .... | .... | 2.3 | 7,678 | 13,820 | 2,340 | 411 |
| | | | 2 | .... | 22.3 | 68.3 | 9.4 | 3.5 | .... | .... | .... | .... | .... | 7,911 | 14,240 | ........ | ..... |
| Tahona, 1 mile south of; Superior Smokeless No. 29 mine, Lower Hartshorne bed (on right rib 7½ west air course, 100 feet outby face). | A24785 | A | 1 | 1.4 | 17.4 | 72.9 | 8.3 | .6 | .... | .... | .... | .... | .6 | 7,772 | 13,990 | 2,140 | 411 |
| Same (on left rib, main slope entry, 75 feet outby face). | A24786 | A | 1 | 3.4 | 15.8 | 74.3 | 6.5 | .7 | .... | .... | .... | .... | 2.5 | 7,750 | 13,950 | 2,120 | 411 |
| Same (On right rib, 8 west entry, 10 feet outby face). | A24787 | A | 1 | 3.5 | 15.5 | 73.6 | 7.4 | .8 | .... | .... | .... | .... | 2.6 | 7,706 | 13,870 | 2,120 | 411 |
| Same (face of 8 east entry). | A24788 | A | 1 | 2.8 | 16.1 | 73.9 | 7.2 | 1.5 | .... | .... | .... | .... | 2.1 | 7,761 | 13,970 | 2,060 | 411 |
| Same (composite of samples A24785 to A24788, inclusive). | A24789 | A | 1 | 2.8 | 15.9 | 73.8 | 7.5 | .8 | 4.4 | 81.1 | 1.7 | 4.5 | 1.9 | 7,744 | 13,940 | ........ | 411 |
| | | | 2 | .... | 16.4 | 75.9 | 7.7 | .8 | 4.2 | 83.4 | 1.7 | 2.2 | .... | 7,967 | 14,340 | ........ | ..... |
| | | | 3 | .... | 17.7 | 82.3 | .... | .9 | 4.6 | 90.3 | 1.8 | 2.4 | .... | 8,628 | 15,530 | ........ | ..... |
| Williams, 1 mile west of; Williams No. 1 mine, Lower Hartshorne bed (face of 2 room, main slope entry, 1,500 feet southeast of mine mouth). | 19673 | A | 1 | 2.2 | 16.1 | 71.4 | 10.3 | 1.3 | .... | .... | .... | .... | 1.5 | 7,578 | 13,640 | 1,990 | 123 |
| Same (face of 25 room, 6 west entry, 1,500 feet south of mine mouth). | 19674 | A | 1 | 2.4 | 16.8 | 72.9 | 7.9 | .9 | .... | .... | .... | .... | 1.9 | 7,745 | 13,940 | 1,960 | 123 |
| Same (face of 2 room, 5 east entry, 1,100 feet southeast of mine mouth). | 19675 | A | 1 | 2.7 | 16.5 | 73.1 | 7.7 | .7 | .... | .... | .... | .... | 2.1 | 7,739 | 13,930 | 1,990 | 123 |
| Same (face of 35 room, 5 west entry, 1,500 feet southwest of mine mouth). | 19676 | A | 1 | 2.6 | 16.3 | 74.0 | 7.1 | .9 | .... | .... | .... | .... | 2.1 | 7,822 | 14,080 | 1,870 | 123 |
| Same (face of 7 room, 2 east entry, 250 feet from slope and 550 feet from mine mouth). | 19677 | A | 1 | 3.1 | 16.3 | 70.4 | 10.2 | 1.1 | .... | .... | .... | .... | 2.6 | 7,467 | 13,440 | 2,020 | 123 |
| Same (composite of samples 19673 to 19677, inclusive). | 19678 | A | 1 | 2.6 | 16.5 | 72.2 | 8.7 | 1.0 | 4.3 | 80.1 | 1.7 | 4.2 | 2.0 | 7,667 | 13,800 | ........ | 123 |
| | | | 2 | .... | 16.9 | 74.2 | 8.9 | 1.0 | 4.1 | 82.2 | 1.8 | 2.0 | .... | 7,872 | 14,170 | ........ | ..... |
| | | | 3 | .... | 18.6 | 81.4 | .... | 1.1 | 4.5 | 90.3 | 1.9 | 2.2 | .... | 8,644 | 15,560 | ........ | ..... |
| Same (face of 6 entry, main slope entry). | W69409 | A | 1 | 1.8 | 16.5 | 73.9 | 7.8 | .5 | .... | .... | .... | .... | .... | 7,800 | 14,040 | ........ | 193 |
| | | | 2 | .... | 16.8 | 75.3 | 7.9 | .6 | .... | .... | .... | .... | .... | 7,939 | 14,290 | ........ | ..... |
| Same (face of 7 west entry, main slope entry). | W69410 | A | 1 | 1.9 | 17.3 | 73.0 | 7.8 | .6 | .... | .... | .... | .... | .... | 7,783 | 14,010 | ........ | 193 |
| | | | 2 | .... | 17.6 | 74.5 | 7.9 | .6 | .... | .... | .... | .... | .... | 7,939 | 14,290 | ........ | ..... |
| Same (face of 8 west entry, main slope entry). | W69411 | A | 1 | 1.9 | 16.9 | 73.9 | 7.3 | .6 | .... | .... | .... | .... | .... | 7,833 | 14,100 | ........ | 193 |
| | | | 2 | .... | 17.2 | 75.4 | 7.4 | .4 | .... | .... | .... | .... | .... | 7,989 | 14,380 | ........ | ..... |

TABLE II—(Continued)

CHEMICAL ANALYSES OF MINE SAMPLES OF COAL FROM LE FLORE COUNTY

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FROM OKLAHOMA GEOLOGICAL SURVEY BULLETIN 51**[c] | | | | | | | | | | | | | | | | | |
| Bokoshe, 3 miles northeast of; W. S. Simpson No. 4 mine, Lower Hartshorne bed, composite of: Face of 3 east entry, 774 feet from mouth of slope. Face of 1 west entry, 405 feet from mouth of slope. | 239 | .... | 1 | 2.7 | 17.1 | 73.6 | 6.6 | 1.8 | .... | .... | .... | .... | 1.9 | 7,783 | 14,070 | | |
| | | | 2 | .... | 17.5 | 75.6 | 6.8 | 1.8 | .... | .... | .... | .... | .... | 8,009 | 14,410 | | |
| 3½ miles northeast of; I.X.L. No. 7 mine. Lower Hartshorne bed, composite of: Face of room 3 off 2 east entry, 505 feet from mouth of slope. Face of room 2 off 3 west entry, 700 feet from mouth of slope. | 238 | .... | 1 | 2.6 | 16.6 | 75.5 | 5.3 | 1.1 | .... | .... | .... | .... | 1.9 | 7,935 | 14,250 | | |
| | | | 2 | .... | 17.1 | 77.0 | 5.4 | 1.1 | .... | .... | .... | .... | | 8,115 | 14,660 | | |
| ¾ mile northeast of; Grayston Brothers mine, Lower Hartshorne bed, composite of: Face at bottom of main slope, 850 feet from mouth. Face of room 4 off 3 south entry, 1,240 feet from mouth. | 237 | .... | 1 | 2.5 | 17.7 | 72.9 | 6.9 | .8 | .... | .... | .... | .... | 1.8 | 7,778 | 14,000 | | |
| | | | 2 | .... | 18.2 | 74.8 | 7.1 | .8 | .... | .... | .... | .... | | 7,975 | 14,360 | | |
| ½ mile north of; Rees Smokeless No. 8 mine. Lower Hartshorne bed, composite of: Face of main slope, 2,050 feet from mouth of slope. Face of room 8 off 7 north entry, 1,610 feet from mouth of slope. | 236 | .... | 1 | 2.8 | 17.0 | 73.0 | 7.2 | 1.1 | .... | .... | .... | .... | 2.0 | 7,735 | 13,930 | | |
| | | | 2 | .... | 17.5 | 75.2 | 7.4 | 1.1 | .... | .... | .... | .... | .... | 7,980 | 14,370 | | |
| Milton, 1 mile west of; Hunter and Goodwin No. 2 mine, Lower Hartshorne bed, Composite of: Face of room 5 off east panel, 305 feet from mouth of slope. Face of 2 west entry, 450 feet from mouth of slope. | 240 | .... | 1 | 3.9 | 17.7 | 72.6 | 5.8 | 1.5 | .... | .... | .... | .... | 3.1 | 7,830 | 14,100 | | |
| | | | 2 | .... | 18.4 | 75.5 | 6.0 | 1.6 | .... | .... | .... | .... | .... | 8,156 | 14,630 | | |
| Panama, 2 miles west of; Panama Smokeless No. 1 mine, Lower Hartshorne bed, composite of: Face of room 1 off 1 east entry, 1,190 feet from mouth of slope. Face of room 3 off 1 west entry, 1,010 feet from mouth of slope. | 235 | .... | 1 | 3.2 | 16.7 | 75.0 | 5.1 | .9 | .... | .... | .... | .... | 2.4 | 7,960 | 14,330 | | |
| | | | 2 | .... | 17.2 | 77.5 | 5.3 | .9 | .... | .... | .... | .... | .... | 8,222 | 14,800 | | |
| 3 miles west of; White Oak No. 1 mine, Lower Hartshorne bed, composite of: Face of room 15 off 4 west entry, 1,705 feet from mouth of slope. Face of room 12 off 5 east entry, 1,900 feet from mouth of slope. | 234 | .... | 1 | 2.9 | 18.3 | 71.9 | 6.9 | .7 | .... | .... | .... | .... | 2.2 | 7,760 | 13,970 | | |
| | | | 2 | .... | 18.8 | 74.0 | 7.1 | .7 | .... | .... | .... | .... | .... | 7,995 | 14,390 | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Poteau, 2½ miles northeast of; Poteau Machine Co. No. 1 mine, Cavanal bed, composite of: Face of longwall off 1 south entry, 700 feet from mouth of slope. Face of longwall off 2 south entry, 750 feet from mouth of slope. | 223 | .... | 1 | 2.6 | 20.8 | 67.5 | 9.1 | 3.1 | .... | .... | .... | .... | 1.9 | 7,715 | 13,880 | ........ | |
| | | | 2 | .... | 21.3 | 69.3 | 9.3 | 3.2 | .... | .... | .... | .... | .... | 7,915 | 14,250 | ........ | |
| 1½ miles northwest of; Pure vein No. 1 mine, Cavanal bed, composite of: Face of 4 south entry, 800 feet from mouth of slope. Face of longwall off 4 north entry, 840 feet from mouth of slope. | 224 | .... | 1 | 2.1 | 21.2 | 66.5 | 10.2 | 3.7 | .... | .... | .... | .... | 1.3 | 7,615 | 13,700 | ........ | |
| | | | 2 | .... | 21.6 | 67.8 | 10.4 | 3.8 | .... | .... | .... | .... | .... | 7,768 | 13,900 | ........ | |
| 1¼ miles west of; Mongolian No. 1 mine, Cavanal bed, composite of: Face of 1 south entry, 400 feet from mouth of slope. Face of main slope, 310 feet from mouth of slope. | 225 | .... | 1 | 3.1 | 22.8 | 65.8 | 8.3 | 2.0 | .... | .... | .... | .... | 2.2 | 7,768 | 13,990 | ........ | |
| | | | 2 | .... | 23.5 | 67.9 | 8.6 | 2.1 | .... | .... | .... | .... | .... | 8,020 | 14,130 | ........ | |
| Tahona, ¾ mile south of; Superior Smokeless No. 29 mine, Lower Hartshorne bed, composite of: Face of room 14 off 9 west entry, 3,864 feet from mouth of slope. Face of room 24 off 8 east entry, 3,960 feet from mouth of slope. | 233 | .... | 1 | 2.6 | 17.1 | 72.0 | 8.3 | .7 | .... | .... | .... | .... | 1.7 | 7,700 | 13,860 | ........ | |
| | | | 2 | .... | 17.5 | 73.9 | 8.5 | .7 | .... | .... | .... | .... | .... | 7,898 | 14,220 | ........ | |
| Face of room 35 off 8 west entry, 5,100 feet from mouth of slope. 1 mile southwest of; Covington Slope No. 7 mine, Lower Hartshorne bed, composite of: Face of room 45, 910 feet from slope mouth. Face of room 47, 970 feet from slope mouth. | 231 | .... | 1 | 2.6 | 16.8 | 74.0 | 6.6 | .7 | .... | .... | .... | .... | 1.6 | 7,850 | 14,130 | ........ | |
| | | | 2 | .... | 17.3 | 76.0 | 6.8 | .7 | .... | .... | .... | .... | .... | 8,055 | 14,500 | ........ | |
| Williams, 2 miles west of; Acme Semianthracite mine, Lower Hartshorne bed, composite of: Face of room 4 off 2 east entry, 1,510 feet from mouth of slope. Face of 3 west entry, 1,365 feet from mouth of slope. | 232 | .... | 1 | 3.3 | 16.7 | 72.2 | 7.8 | .7 | .... | .... | .... | .... | 2.4 | 7,705 | 13,880 | ........ | |
| | | | 2 | .... | 17.3 | 74.7 | 8.1 | .7 | .... | .... | .... | .... | .... | 7,970 | 14,350 | ........ | |

[1] Laboratory numbers with a prefix "W" represent samples analyzed in the Washington laboratory of the bureau; all other Bureau of Mines samples were analyzed at the Pittsburg laboratory.
[2] A, mine sample collected by an engineer of the Bureau of Mines; B, mine sample collected by a geologist of the U. S. Geological Survey.
[3] 1, Sample as received; 2, dried at 105° C.; 3, moisture and ash free.
[4] Figures in this column represent the temperature at which the cone of coal ash fused to a spherical lump when heated in the furnace in a slightly reducing atmosphere.
[5] Figures in column 18 represent Bureau of Mines publications in which may be found the description of the section of the bed from which the sample was taken. Figure 411 refers to Technical Paper 411; other figures refer to Bulletins of the Bureau; U indicates an unpublished analysis by the Bureau.
[6] Samples were collected by J. E. Moose and W. R. Rutherford, July 3 to 11, 1928. The analytical work was done in the laboratory of the Department of Chemistry, University of Oklahoma.

# NATURAL GAS

The natural gas fields of northern Le Flore County include the Cartersville and Poteau-Gilmore fields, which are the largest, and the Spiro, Cameron, Rock Island, and Cedars fields. The gas in the Poteau-Gilmore field comes from the Hartshorne sandstone; that in the Cameron field from the Hartshorne sandstone or, possibly, from a sandy zone in the McCurtain shale member of the McAlester formation. All of it is dry gas, averaging about 97 percent of methane, with small percentages of carbon dioxide, oxygen, and nitrogen. Gas from the Cartersville field contains also a small percentage of ethane and a trace of helium. The gravity of the gas averages about 0.57 and the calorific value about 986 B.t.u. In relation to the depths of the gas sands the rock pressures are considerably lower than those of gas fields in most regions.

## CARTERSVILLE FIELD

The Cartersville gas field lies on the Milton anticline, in T. 9 N., R. 24 E., 2 miles north of Bokoshe. It extends for about 3 miles northeastward from sec. 29, mainly on the northwest side of the anticlinal axis. In May 1944, the productive area covered about 5 square miles, but the limits of the reservoir had not been fully determined. It is possible that the reservoir extends under a large part of the broad monoclinal area in the northwestern part of T. 9 N., R. 24 E., and the southern part of T. 10 N., R. 24 E., and that it also extends westward into Haskell County. A fault with a displacement of approximately 300 feet downward on its southeast side, enters the field from the northeast and extends as far as the NW¼ sec. 27. The Atoka formation crops out over most of the field, but a well at the center of sec. 20 was started at or a little above the base of the McAlester formation. Nearly all of the gas has come from sandy beds near the base of the Atoka formation. The first commercial well, Red Bank Oil Company's Fee No. 1 well, in the SE¼ SW¼ NW¼ sec. 23, which was drilled to the Simpson group, was completed in October 1930, at a depth of 6,300 feet with an initial pressure of 750 pounds per square inch and a daily open-flow capacity of 5,500,000 cubic feet; the gas was struck in the basal sands of the Atoka at 5,005 feet and in the Springer formation at 5,400 feet. The field was not further developed until 1941, when Western Oklahoma Gas Company's Bryan No. 1 well in the NW½ SE¼ sec. 22 was completed at a depth of 5,550 feet with a pressure of 1,000 pounds per square inch, and a daily open-flow capacity of more than 3,000,000 cubic feet. The gas was found in the basal sands of the Atoka. In the month of April 1944, eight wells with a total initial daily open-flow capacity of 133,197,000 cubic feet and an average pressure of 930 pounds per square inch produced a total of 386,803,000 cubic feet, computed on a 2-pound base. The field is owned and operated by the Arkansas-Oklahoma Gas Company and the gas is piped to Fort Smith.

#### POTEAU-GILMORE FIELD

The Poteau-Gilmore gas field lies in T. 7 N., Rs. 26 and 27 E., and extends eastward from Poteau through and beyond Gilmore. The productive area, the limits of which were determined years ago, covers about 15 square miles, including 3 square miles in Le Flore County south of the area shown on the accompanying map. Most of this area lies on the Gilmore anticline, where the surface rocks belong to the McAlester formation. Toward the northwest, however, the field extends almost to the axis of the Cavanal syncline.

According to records of the Le Flore County Gas & Electric Company, which owns and operates the field, the total production of gas, cumulative through 1943, computed on a 2-pound base, was 33,436,000,000 cubic feet. Nearly all of this came from the Hartshorne sandstone at depths ranging from 1,300 feet to 1,800 feet. A small amount was produced for a short time from a deeper sand, in the Atoka formation. The initial capacity of commercial wells drilled since discovery of the field has ranged from 250,000 to 8,000,000 cubic feet. The first commercial well, Le Flore County Gas & Electric Company's Hill No. 1 well in the SW¼ NW¼ sec. 25, T. 7 N., R. 26 E., was completed in 1910 at a depth of 1,687 feet with a pressure of 365 pounds per square inch and a daily open-flow capacity of 4,500,000 cubic feet. Since then the pressure has declined irregularly and is now declining at an extremely slow rate. The average pressue of 42 wells in 1944 was approximately 12 pounds per square inch, and a production of nearly 1,000,000 cubic feet per day was maintained by pumping. The gas from the Poteau-Gilmore field is mixed with that of the Red Oak field, in Latimer County, and the Cameron, Rock Island and Cedars fields, and is used as industrial and domestic fuel.

### CAMERON FIELD

The Cameron gas field, in Tps. 7 and 8 N., R. 26 E., lies south of Cameron. The field covers about 2 square miles, partly at the western end of the plunging nose of the Midland anticline and partly on the structural terrace west of that nose. The gas occurs in sandstone tentatively correlated with the Hartshorne sandstone, though the logs of several wells show a coal bed, which may be the Hartshorne coal, beneath the producing zone. The production may therefore be from sands in the McCurtain member of the McAlester formation. The discovery well, Le Flore County Gas & Electric Company's Tucker No. 9 well in the NE¼ NW¼ sec. 3, T. 7 N., R. 26 E., was completed in 1911 at a depth of 1,526 feet with a daily open-flow capacity of 500,000 cubic feet and a pressure of 285 pounds per square inch. The field was not further developed until 1923, when Le Flore County Gas & Electric Company's Holton No. 29 well, in the NE¼ SW¼ sec. 34, T. 9 N., R. 26 E., was completed at a depth of 1,505 feet, with a capacity of 2,570,000 cubic feet and a pressure of 355 pounds. The largest well, Le Flore County Gas & Electric Company's Merriman No. 34 well in the SE¼ NW¼ sec. 34, had an initial capacity of 4,186,080 cubic feet. The average shut-in pressure in 1943 of eight productive wells, including six wells in the Cameron field and one each in the Rock Island and Cedars fields for which separate figures are not available, was 172 pounds per square inch. The total production from these eight wells, cumulative through 1943 and computed on a 2-pound base, was 4,115,891,000 cubic feet; of this amount about 5 percent is estimated to have come from the Rock Island and Cedars fields. Salt water is encroaching upon the producing sands and will, according to present estimates, "take" the field when the pressure drops to approximately 100 pounds.

### ROCK ISLAND FIELD

The Rock Island field, on the south flank of the Backbone anticline, lies in the NW¼ sec. 18, T. 8 N., R. 27 E., 2 miles southwest of Rock Island. Only three wells, all of small capacity, have been drilled. The first well was completed in 1917 with an initial capacity of 68,000 cubic feet and a rock pressure of 250 pounds. The wells were started in the basal part of the McAlester formation and the gas was found in the Atoka formation in a sand about 1,700 feet below the Hartshorne sandstone.

### CEDARS FIELD

The Cedars gas field, on the crest of the Massard Prairie anticline, is in sec. 9, T. 9 N., R. 27 E., 1½ miles south of Cedars. The gas, which occurs in the Atoka formation, was found in three wells, all of which were started in the McAlester formation less than 245 feet above the top of the Hartshorne sandstone. The first of these wells, in the NW¼ NE¼ sec. 9, was completed in 1924 at a total depth of 3,340 feet; it yielded gas from shale at a depth of 2,210 feet and from a sand at 3,125 feet. The initial pressure was 225 pounds with an open-flow capacity of 1,108,000 cubic feet. The well in the NW¼ SE¼ sec. 9 had an initial capacity of 1,360,000 cubic feet and that in the SE¼ NE¼, 500,000 cubic feet.

### SPIRO FIELD

The Spiro gas field, 3 miles northwest of Stony Point, on the northeastward-plunging nose of the Milton anticline, is in the SW¼ sec. 6, T. 9 N., R. 25 E., and the NE¼ sec. 12, T. 9 N., R. 24 E. Years ago gas was piped from this pool to Spiro from five wells, all but one of which have been abandoned. The wells were started at or near the base of the McAlester formation and yielded gas from sandstone beds in the Atoka formation at about 1,470 feet. The first well was completed in 1906 with a pressure of 160 pounds per square inch. The initial capacities of the wells ranged from 400,000 to 750,000 cubic feet per day. The present pressure is about 50 pounds per square inch.

## SECONDARY MINERALS

Calcite and the clay mineral dickite occur as veinlets filling fractures along small faults in most of the coal mines on the Milton anticline and veinlets of dickite are visible in fracture zones along the Backbone fault and in a road-cut near a large reverse fault on the north side of Highway 31, in NE¼ NW¼ sec. 20, T. 8 N., R. 23 E. Specimens of these minerals from the dump of the Heather mine, sec. 23, T. 8 N., R. 24 E., have been examined mineralogically by W. E. Ham, of the Oklahoma Geological Survey, who furnished most of the following information.

The dickite examined, which occurs as veinlets in coal, is a soft white clay mineral that appears under the microscope as a microcrystalline mosaic of low birefringence, with *beta* 1.567 plus or minus 0.003. The mineral is not stained by malachite green nor by crystal violet and is thereby distinguished from kaolinite, which is strongly stained by these dyes. The mineral is not intumescent and in this respect differs from dickite as described by Schaller and Bailey[64] from Williams, farther east in Le Flore County.

The calcite is of two types: (1) veins as much as ¾ inch thick of rather pure, white, coarsely crystalline calcite, enclosed in dark gray shale; under the microscope shows rhombohedral cleavage, extreme birefringence and strong absorption; is optically uniaxial, negative; omega index is 1.662 plus or minus 0.002. (2) veins of calcite, mostly about ¼ inch thick, occurring enclosed in dark gray shale. The veins are made up of parallel needles perpendicular to the vein walls, though needle structure is scarcely visible under the microscope. In other respects the mineral is identical with that described above. The fibrous structure suggests that the calcite was formed by recrystallization of aragonite.

According to Ross,[65] who has examined specimens of dickite from Le Flore County and confirms their identification as such, this mineral is commonly of hydrothermal origin, and it is possible that solutions emanating from deep-seated magmas entered the

64. Schaller, W. T., and Bailey, R. K., "Intumescent Kaolinite": *Washington Acad. Sci. Jour.*, vol. 6, pp. 67-68, 1916.
65. Ross, C. S., personal communication, 1945.

Pennsylvanian rocks of Le Flore County during or following deformation of those rocks. Such solutions may also have deposited the calcite.

Sandstone beds in an outcrop adjacent to a large cross-fault at the south end of a ridge in NW¼ SE¼ SE¼ sec. 13, T. 9 N., R. 24 E., have been altered to quartzite for a distance of about 50 feet along the strike of the beds, probably by silica deposited in the form of quartz by solutions introduced from the fault.

# APPENDIX

# MEASURED STRATIGRAPHIC SECTIONS IN NORTHERN LE FLORE COUNTY

## TOWNSHIP 6 NORTH

1. W½ SW¼ SEC. 11, T. 6 N., R. 25 E., ALONG U. S. HIGHWAY 270 BETWEEN POTEAU AND HOWE (HOWE-WILBURTON DISTRICT.)

| | Feet |
|---|---|
| McAlester formation | |
| Keota sandstone member | |
| 1. Sandstone: gray, fine-grained, hard, massive | 20.0+ |
| 2. Shale: olive-drab, silty, micaceous; two thin sandstone beds near top | 8.5 |
| 3. Sandstone: gray, fine-grained, micaceous, in thin discontinuous ripple-marked plates; a few laminae of silty shale | 7.7 |
| Unnamed shale member | |
| 4. Shale: dark gray to olive-drab, silty, micaceous, brittle | 14.0 |
| 5. Shale: gray, containing many nodules and plates of clay ironstone | 14.0 |
| 6. Shale, calcareous: gray, containing marine invertebrate fossils; about | 0.1 |
| 7. Coal (Local): About | 0.1 |
| 8. Shale: in part silty; lower part olive drab, grading into gray in uper part; plant remains | 22.0 |
| 9. Shale: alternations of olive-drab lumpy layers with dark gray fissile layers | 5.0 |
| 10. Shale: dark gray, fissile, with a few limonite laminae | 2.0 |
| 11. Shale: olive-drab, lumpy, with seams of limonite | 8.0 |
| 12. Sandstone: olive-drab, fine-grained, micaceous, hard, massive, ripple-marked | 3.0 |
| 13. Shale: olive-drab, lumpy in lower part, fissile in upper part, with a few limonite concretions | 21.0 |
| 14. Sandstone: olive-drab, fine-grained, micaceous, thin-bedded | 3.0 |
| 15. Siltstone: greenish gray; thin, lenticular beds of fine-grained sandstone | 4.0 |
| 16. Shale: nearly black, carbonaceous | 8.0 |
| 17. Coal (Local): about | 0.1 |
| 18. Shale: dark gray; contains plant remains and pelecypods | 5.0 |
| 19. Sandstone: fine-grained, hard; massive | 13.0 |
| 20. Sandstone: calcareous: thin-bedded; marine invertebrates | 0.3 |
| 21. Shale: dark gray, fissile; fossiliferous | 10.0 |
| 22. Sandstone: olive-drab, fine-grained, with *Calamites* stem fragments | 1.0 |
| 23. Shale: dark gray, carbonaceous, with limonite nodules | 2.0 |
| 24. Coal (Local): about | 0.1 |
| 25. Shale: gray, micaceous; fossiliferous; subjacent rock not exposed | 1.0+ |

## TOWNSHIP 7 NORTH

2. NE¼ SE¼ SEC. 1, T. 7 N., R. 23 E., 4½ MILES WEST OF CALHOUN.

| | |
|---|---|
| Savanna formation, lower part | |
| 1. Sandstone: gray, fine-grained; massive | 3.0+ |
| 2. Shale: light gray, with a few thin layers of sandstone | 6.0 |

| | Feet |
|---|---|
| 3. Shale: dark gray, with thin beds of clay ironstone | 40.0+ |
| Subjacent rock not exposed. | |

**3.** SW CORNER OF SEC. 10, T. 7 N., R. 23 E.

| | Feet |
|---|---|
| **Savanna formation, middle** | |
| Unnamed sandstone unit | |
| 1. Sandstone: massive, hard, cross-bedded | 3.0 |
| 2. Sandstone: thin-bedded, with interbedded shale | 5.0 |
| 3. Sandstone: massive, hard, cross-bedded | 2.0 |
| 4. Sandstone: gray, micaceous, fine-grained; thin-bedded | 8.0 |
| 5. Shale: dark gray, with a few hollow limonite concretions in upper part | 9.0 |
| 6. Covered | 5.0 |
| 7. Sandstone: gray, fine-grained (base of unnamed sandstone unit) | 1.5 |
| 8. Shale: dark gray | 3.0+ |
| Subjacent rock not exposed. | |

**4.** E½ SW¼ SEC. 11, T. 7 N., R. 23 E., EXPOSURES ALONG ROAD.

| | Feet |
|---|---|
| **Savanna formation, upper** | |
| 1. Sandstone: light gray, fine-grained; massive | 55.0 |
| 2. Covered | 27.0 |
| 3. Shale: dark gray; with numerous thin layers of clay ironstone; coal bed 2 inches thick, 12 feet above base | 60.0 |
| 4. Sandstone: hard; beds 3 to 8 inches thick | 5.0 |
| 5. Shale: dark gray; with plant remains; coal bed 2 inches thick 5 feet above base; a few clay ironstone concretions | 13.0 |
| 6. Coal (Local bed above Cavanal coal) | 1.1 |
| 7. Covered | 1.0 |
| 8. Sandstone: gray, fine-grained; containing plant fragments | 2.0 |
| 9. Shale: dark greenish gray, silty (partly covered) | 10.0 |
| 10. Sandstone: micaceous; massive at base, grading upward to thin-bedded sandstone at top | 6.0 |
| 11. Shale: dark greenish gray, silty | 43.0 |
| 12. Coal (Cavanal) | 1.0 |
| 13. Covered | 10.0 |
| 14. Sandstone: light gray with greenish cast, hard, fine-grained; massive, ripple-marked, cross-bedded; *Sigillaria* and other plants | 8.0 |
| 15. Shale: dark greenish gray, silty, micaceous; thin beds of clay ironstone in upper part | 19.0 |
| 16. Covered: probably shale and continuous with unit 15 | 98.0 |
| 17. Sandstone: massive, partly covered | 50.0 |
| Subjacent beds not exposed. | |

**5.** SE¼ SW¼ SEC. 13, T. 7 N., R. 25 E., 1 MILE NORTH OF POTEAU.

| | Feet |
|---|---|
| **Savanna formation, middle** | |
| 1. Shale: silty, micaceous | 8.0+ |
| 2. Sandstone: fine-grained, micaceous; massive cross-bedded, ripple-marked | 10.0 |
| 3. Covered: probably mostly shale | 65.0 |
| 4. Coal (Cavanal), about | 1.0 |
| Subjacent rock not exposed. | |

**6.** NW¼ NW¼ SEC. 13 AND NE¼ NE¼ SEC. 14, T. 7 N., R. 25 E., ALONG SOUTH BANK OF POLK CREEK, NORTH OF POTEAU.

| | Feet |
|---|---|
| **Savanna formation, upper and middle** | |
| 1. Sandstone: olive-drab to gray, hard, fine-grained; imprints of *Calamites* (S. end of bridge at U. S. Highway 271) | 6.0+ |
| 2. Shale: highly carbonaceous, fissile; ferruginous [illegible] | [illegible] |

| | | Feet |
|---|---|---|
| 3. | Shale: dark bluish gray, carbonaceous, fissile, partly covered | 11.0 |
| 4. | Shale: "paper shale" variety, carbonaceous; pelecypods and ostracods | 1.0 |
| 5. | Shale: black, carbonaceous, fissile; traces of coal | 3.0 |
| 6. | Shale: black, carbonaceous; contains 3 thin beds of black limestone that weathers yellowish gray | 2.0 |
| 7. | Underclay: light gray | 1.0 |
| 8. | Sandstone: gray, fine-grained, hard | 1.2 |
| 9. | Coal (Cavanal) | 0.8 |
| 10. | Shale: olive-drab, with clay ironstone concretions in basal part; grades upward to micaceous siltstone containing a few thin sandstone beds | 65.0 |
| 11. | Shale: dark gray, carbonaceous, with thin streaks of coal | 2.0 |
| 12. | Siltstone with thin plates of sandstone: olive-drab; grades upward into shale | 10.0 |
| 13. | Sandstone: olive-drab, fine-grained, micaceous; massive, cross-bedded | 4.0 |
| 14. | Shale: dark gray, silty, micaceous, fissile; several thin layers of clay ironstone | 35.0 |
| 15. | Clay ironstone: contains abundant brachiopods | 0.2 |
| 16. | Siltstone with thin sandy layers | 1.5 |
| 17. | Sandstone with siderite concretions, grading down dip into clay ironstone, about | 0.4 |
| 18. | Siltstone: gray, micaceous | 0.1 |
| 19. | Sandstone: mottled olive-drab and gray, fine-grained with lenses and nodules of clay-ironstone | 0.2 |
| 20. | Siltstone: gray | 0.6 |
| 21. | Sandstone: mottled olive-drab and gray, fine-grained with lenses and nodules of clay-ironstone | 1.0 |
| 22. | Sandstone: mottled gray and olive drab, grading upward into siltstone | 0.8 |
| 23. | Siltstone: gray, micaceous | 1.0 |

Subjacent rock not exposed.

7. E½ SEC. 15, T. 7 N., R. 25 E., ALONG STREAM BED ON EAST SIDE OF CAVANAL MOUNTAIN, 2 MILES NORTHWEST OF POTEAU.

Boggy formation

Bluejacket sandstone member

| | | Feet |
|---|---|---|
| 1. | Sandstone: massive, blocky | 12.0+ |
| 2. | Shale: gray | 8.0 |
| 3. | Sandstone: thin-bedded | 3.0 |
| 4. | Shale: gray; contains plant remains and a few plates and nodules of clay ironstone | 3.0 |
| 5. | Coal (Lower Witteville), about | 4.0 |
| 6. | Shale: dark gray, replete with plant remains near top | 15.0 |
| 7. | Sandstone: thin-bedded, with thin layers of dark gray shale, grading downward to massive sandstone beds | 10.0 |
| 8. | Covered | 5.0 |
| 9. | Shale: with a few platy sandstone lenses | 3.0 |
| 10. | Sandstone: gray, hard, ripple-marked; in layers 2 to 10 inches thick, cross-bedded; a few clay pellet cavities | 10.0 |
| 11. | Covered | 23.0 |
| 12. | Sandstone: mostly thin-bedded with a few massive beds; small amount of dark gray shale, increasing in amount toward top | 30.0 |
| 13. | Sandstone: gray, fine-grained, micaceous; ripple-marked, platy to thin-bedded, platy variety contains interlaminated silty shale; heavy sandstone layer (8 to 20 inches thick) at below top of unit | 64.0 |

| | Feet |
|---|---|
| 14. Sandstone: massive, ripple-marked | 39.0 |
| 15. Covered | 8.0 |
| 16. Sandstone: mostly massive, with some zones of sandstone, thin-bedded, ripple-marked | 78.0 |
| 17. Sandstone: massive beds grading upward into thin-bedded to platy, micaceous sandstone | 30.0 |
| 18. Sandstone: massive beds grading upward into thin-bedded, ripple-marked, micaceous sandstone | 20.0 |
| 19. Sandstone: massive, hard (Base? of Bluejacket) | 22.0 |
| Unnamed shale member | |
| 20. Shale: gray, silty, micaceous; a few thin beds of sandstone; plant remains in some beds | 80.0 |
| Subjacent rock not exposed. | |

**8. E½ SEC. 15, T. 7 N., R. 25 E., ALONG STREAM BED ON EAST SIDE OF CAVANAL MOUNTAIN, 2 MILES NORTHWEST OF POTEAU.**

| | |
|---|---|
| **Boggy formation** | |
| Unnamed units | |
| 1. Sandstone: hard, massive, blocky | 15.0+ |
| 2. Shale: dark blue-gray, fissile; contains thin beds of clay ironstone in basal part | 35.0 |
| 3. Coal (Secor bed) | 4.2 |
| 4. Shale: silty, containing thin plates of clay ironstone; grades downward into sandstone, thin-bedded, with fairly thick beds in basal part | 133.0 |
| Bluejacket sandstone member | |
| 5. Sandstone: platy, with interlaminated shale | 24.0 |
| 6. Sandstone; hard, massive, cross-bedded, with a few thin sandstone beds and a little shale; clay-pellet cavities numerous in places | 48.0 |
| Unconformity (local?) | |
| 7. Shale: silty | 2.0 to 6.0 |
| 8. Coal with several shale partings, lower Witteville | 4.8 |
| 9. Shale: silty, grading downward into sandstone, thin-bedded | 29.0 |
| 10. Sandstone; massive, cross-bedded | 6.0 |
| 11. Shale: silty; with thin lenticular plates of sandstone | 5.0 |
| 12. Sandstone: French gray; hard, fine-grained; in massive beds, cross-bedded, a few clay pellets, ripple-marked on some beds | 18.0 |
| 13. Sandstone: micaceous; thin-bedded to platy, ripple-marked, platy variety contains interlaminated shale | 30.0 |

**9. SE¼ SW¼ SEC. 24, T. 7 N., R. 25 E,. SHALE PIT IN NORTHWESTERN PART OF POTEAU.**

| | |
|---|---|
| Savanna formation, middle, in shale interval below Cavanal coal | |
| 1. Shale: greenish gray, silty; with macerated plant remains | 50.0+ |
| 2. Sandstone: gray, hard, fine-grained; massive, blocky | 2.0 to 5.0 |
| 3. Shale: micaceous; thin plates of sandstone, increasing in number downward; macerated plant remains | 4.0 to 6.0 |
| 4. Shale: gray, silty, micaceous; weathers to dark gray; a few beds and nodules of clay ironstone; a few fossil invertebrates; contact with No. 3 unit is irregular | 50.0+ |
| Subjacent rock not exposed. | |

**10. NE¼ NE¼ SEC. 36, T. 7 N., R. 25 E., SOUTHEAST SIDE OF POTEAU.**

| | |
|---|---|
| Savanna formation, lowermost part | |
| 1. Sandstone: thin-bedded, fine-grained, ripple-marked, cross-bedded, micaceous; locally there are massive beds as much as 10 inches thick | 7.0 |

| | Feet |
|---|---|
| 2. Shale: greenish gray, silty, micaceous; platy beds of sandstone in upper part | 15.0+ |

Subjacent beds not exposed.

## TOWNSHIP 8 NORTH

**11.** EAST LINE OF SE¼ SE¼ SEC. 16, T. 8 N., R. 24 E., EXPOSURES ALONG ROAD.

Hartshorne sandstone, below Lower Hartshorne coal

Superjacent rock not exposed

| | |
|---|---|
| 1. Sandstone: fine-grained, micaceous; in thin, platy beds; interbedded with clay shale. Whole is rather poorly exposed, with tan to red color | 2.5 |
| 2. Covered: probably same as unit 1 | 3.0 |
| 3. Shale and sandstone like unit 1 | 1.0 |
| 4. Sandstone: light gray, slightly coarser than unit 1; in beds with 2½ inches maximum thickness, ripple-marked, slightly micaceous; interbedded with small amount of shale and sandy shale | 4.5 |
| 5. Sandstone: dark gray, hard, massive | 2.0 |
| 6. Shale: predominantly red in color; with some interbedded platy sandstone;poorly exposed | 6.0 |
| 7. Sandstone: gray; like unit 4 | 8.0 |
| 8. Sandstone: massive, containing abundant clay pellets | 3.0 |
| 9. Shale: red to brown, sandy; thin-bedded, containing a few platy sandstone layers | 8.0 |
| 10. Sandstone: light gray, fine-grained with many clay pellets; in beds about 1 foot thick at base of unit, grading upward to thinly bedded sandstone in upper half; interbedded with a little shale | 7.0 |
| 11. Shale: weathered brown; interbedded with sandstone and grading downward to sandstone at base with numerous clay pellets and few pebbles white calcite | 8.0 |

**12.** SW¼ NW¼ SEC. 22, T. 8 N., R. 24 E., TOP OF HILL AT SHARP BEND IN ROAD.

McAlester formation

Unnamed shale member

| | |
|---|---|
| 1. Shale: dark gray with bluish cast, sandy, micaceous; much of it showing lumpy concretionary structures and containing a few clay ironstone nodules | 3.0 |
| 2. Covered: probably shale | 10.0 |
| 3. "Paper" shale: light gray to buff, sandy, micaceous | 2.0 |
| 4. Covered: probably shale | 15.0 |
| 5. Sandstone: gray, fine-grained, micaceous; massive, prominently jointed | 1.0 |
| 6. Covered: probably largely shale | 55.0 |
| 7. Sandstone: fine-grained, micaceous; interbedded with small amount sandy shale | 75.0 |
| 8. Covered: probably same as unit 17 | 18.0 |

Warner sandstone member

| | |
|---|---|
| 9. Sandstone: gray, fine-grained, micaceous; massive, with abundant clay pellets and much ripple-marked; a few shale partings | 49.0 |

McCurtain shale member

| | |
|---|---|
| 10. Shale: dark gray, fissile, silty | 80.0 |
| 11. Shale: nearly black, fissile | 1.0 |
| 12. Shale: dark gray, fissile, silty | 128.0 |
| 13. Shale: dark gray, fissile, silty; with numerous clay ironstone layers, each 2 inches thick or less | 20.0 |

| | | Feet |
|---|---|---|
| 14. | Coal | 0.2 |
| 15. | Underclay | 0.5 |
| 16. | Sandstone: olive-drab, fine-grained, hard; massive, ripple-marked | 5.0 |
| 17. | Sandstone: gray, fine-grained; platy, interbedded with small amount silty shale | 7.0 |
| 18. | Sandstone: olive-drab to gray, fine-grained, micaceous; calcareous lens at base contains great profusion of brachiopods | 0.8 |
| 19. | Shale: light gray, silty | 1.5 |
| 20. | Sandstone: gray to brown, fine-grained; with casts of crinoid stems | 1.0 |
| 21. | Shale: drak gray to olive-drab, partly silty: a few clay ironstone concretions | 42.0 |
| 22. | Shale: dark greenish gray, fissile | 1.0+ |

Subjacent beds not exposed.

**13.** CENTER OF SW¼ SEC. 3, T. 8 N., R. 25 E., NORTH OF COAL CREEK JUNCTION, KANSAS CITY SOUTHERN RAILROAD CUT.

McAlester formation

Warner sandstone member

| | | |
|---|---|---|
| 1. | Sandstone: olive-drab, fine-grained, micaceous, hard; massive, cross-bedded | 10.0+ |
| 2. | Shale with plates of sandstone, interbedded with many evenly spaced thin sandstone beds; all beds dark gray | 11.0 |
| 3. | Shale: dark gray, micaceous, silty; with lenses and thin beds of sandstone | 6.5 |
| 4. | Sandstone: gray to olive-drab, fine-grained, hard, micaceous, thin-bedded, ripple-marked | 3.0 |
| 5. | Sandstone: dark gray, fine-grained; platy, with some interlaminated silty shale | 5.0 |

McCurtain shale member

| | | |
|---|---|---|
| 6. | Shale: dark bluish gray, silty, somewhat micaceous | 43.0 |

Subjacent beds not exposed.

**14.** NW¼ SW¼ SEC. 30, T. 8 N., R. 25 E., ROAD CUT 3 MILES WEST OF SHADY POINT.

McAlester formation

Keota sandstone member, lower part

| | | |
|---|---|---|
| 1. | Largely covered: probably shale and sandy shale grading upward into sandstone, thin-bedded, ripple-marked, micaceous | 26.0 |
| 2. | Sandstone: fine-grained, massive: alternating with sandstone, thin-bedded with some siltstone in basal part of unit | 15.0 |

Subjacent rock not exposed.

**15.** NW¼ NW¼ SEC.. 24 AND NE¼ NE¼ SEC. 23, T. 8 N., R. 26 E., ALONG ROAD NORTHEAST OF CAMERON.

McAlester formation

Lequire sandstone member

| | | |
|---|---|---|
| 1. | Sandstone: olive-drab, hard, fine-grained | 5.0+ |
| 2. | Sandstone: plates and thin beds, interbedded with thin layers of silty shale | 3.5 |
| 3. | Sandstone: olive-drab, hard, thin-bedded | 2.0 |
| 4. | Sandstone: olive-drab, fine-grained; ripple-marked, plates and thin beds; some interbedded silty shale increasing in amount toward top; most beds are micaceous (base of member) | 20.0 |

| | Feet |
|---|---|
| Unnamed shale member | |
| 5. Shale: dark gray, silty, fissile; macerated plant remains in some layers | 105.0 |
| 6. Sandstone: fine-grained, micaceous; platy to thin-bedded; grading upward into shale, gray, silty, carbonaceous; plant remains | 15.0 |
| 7. Shale: dark gray, fissile, in part silty; weathers bluish gray; macerated plant remains | 17.0 |
| 8. Shale: dark gray, highly carbonaceous with a few thin layers of coal | 2.5 |
| 9. Shale: light gray, silty, micaceous; partly covered | 9.0 |
| 10. Covered | 3.0 |
| 11. Sandstone: gray to olive-drab, thin-bedded, micaceous; ripple-marked | 16.0 |
| 12. Shale: olive-drab | 2.0 |
| 13. Shale: dark gray, carbonaceous | 2.0 |
| 14. Coal: impure, weathered (Local bed) | 0.5 |
| 15. Shale: gray, silty | 5.0 |
| 16. Sandstone: light gray, fine-grained, micaceous; massive, cross-bedded | 8.0 |
| Subjacent rock covered by alluvial deposits. | |

**16. SE¼ SEC. 26, T. 8 N., R. 26 E., ALONG ROAD THAT CLIMBS WEST SIDE OF CAMERON MOUNTAIN.**

| | |
|---|---|
| McAlester formation | |
| Tamaha sandstone member | |
| 1. Sandstone: gray to olive-drab, fine-grained, micaceous, hard; cross-bedded | 10.0+ |
| Unnamed shale member | |
| 2. Shale: dark gray to olive-drab, very sandy in uppermost 8 feet | 71.0 |
| 3. Coal: a few pelecypod fragments in roof (Stigler) | 1.2 |
| 4. Shale: dark gray to olive-drab, in part silty to sandy; contains nodules and beds of clay ironstone, especially in lower part | 28.0 |
| Subjacent rock not exposed. | |

## TOWNSHIP 9 NORTH

**17. NE¼ SEC. 17, T. 9 N., R. 25 E., 1 MILE NORTHWEST OF STONY POINT, AT CACHE CREEK BRIDGE; MEASURED FROM TOP OF RIDGE DOWN TO WATER LEVEL OF CREEK.**

| | |
|---|---|
| McAlester formation | |
| Warner sandstone member | |
| 1. Sandstone: fine-grained, micaceous; massive, cross-bedded, ripple-marked; a few angular intraformational pellets of shale and sandstone; a few plant remains | 29.0 |
| 2. Sandstone: fine-grained, micaceous; thin-bedded, intercalated with thin layers of shale and siltstone | 2.0 |
| 3. Sandstone: fine-grained, micaceous; massive | 4.0 |
| 4. Same as unit 2 | 25.0 |
| McCurtain shale member | |
| 5. Shale: sandy at base and top | 35.0 |
| 6. Sandstone: micaceous; thin-bedded, platy | 5.0 |
| 7. Shale: dark greenish gray; thin-bedded, contains nodules and thin beds of clay ironstone, and a few beds of micaceous siltstone; a few brachiopods | 46.0 |
| Subjacent beds covered by alluvial deposits. | |

Feet

18. SW¼ SEC. 33, T. 9 N., R. 25 E., ROAD CUT ON U. S. HIGHWAY 271, 3 MILES SOUTHWEST OF SPIRO, OKLAHOMA.

McAlester formation
Lequire sandstone member
1. Sandstone: fine-grained, micaceous; massive with some interbedded shale ........ 7.0
2. Sandstone: fine-grained, micaceous; massive beds interbedded with thin-bedded sandstone and siltstone........ 4.5
3. Sandstone: micaceous; thin-bedded, interbedded with thin layers of shale and siltstone ........ 10.0
4. Sandstone: blue-gray, fine-grained; massive, ripple-marked 4.0
5. Sandstone: blue-gray; thin-bedded, ripple-marked, interbedded with siltstone ........ 17.0
6. Sandstone: blue-gray, fine-grained; massive, interbedded with a little shale ........ 4.0

Unnamed shale member
7. Shale; dark gray, fissile; weathers blue-gray ........ 25.0+

19. NW¼ NE¼ SEC. 4, T. 9 N., R. 26 E., WEST SIDE OF ROUND MOUNTAIN.

Savanna formation, upper and middle
1. Sandstone: olive-drab, fine-grained, micaceous; thin-bedded 8.0+
2. Shale: olive-drab to gray, silty, micaceous; grading upward into siltstone with thin plates of sandstone ........115.0
3. Limestone: dark gray; thin beds separated by shale, dark gray, fissile, carbonaceous ........ 5.0
4. Coal (Cavanal), about ........ 2.0
5. Shale: dark gray, silty; a few thin layers of clay ironstone.. 20.0+

Subjacent rock not exposed.

20. SEC. 27, T. 9 N., R. 27 E., 1 MILE SOUTH OF BONANZA, ARK.; ALONG DAM OUTLET EAST OF FRISCO R. R., AT OKLAHOMA-ARKANSAS STATE LINE.

Atoka formation, in lower part
1. Sandstone: fine-grained; massive, interbedded with sandstone, thin-bedded, and siltstone ........150.0
2. Shale: silty ........ 8.0
3. Sandstone: fine-grained; massive, grading upward to relatively thin-bedded sandstone in top of unit ........ 60.0
4. Sandstone: thin-bedded, with a few massive beds ........ 43.0
5. Shale: silty ........ 8.0
6. Sandstone: fine-grained, quartzitic; massive ........ 8.0

Subjacent rock not exposed.

21. SE¼ SE¼ SEC. 28, T. 9 N., R. 27 E., FRISCO R. R. TUNNEL THROUGH BACKBONE RIDGE. (WALLED MASONRY COVERS ROCK THROUGH HORIZONTAL DISTANCE OF 310 FEET SOUTH FROM NORTH PORTAL OF TUNNEL AND 150 FEET NORTH FROM SOUTH PORTAL.) DIP AVERAGES ABOUT 40 DEGREES S.*

Atoka formation, top of section about 2,500 feet below top of formation
1. Covered: probably siltstone ........ 95.0

---

*(Editor's Note: Measured Sections numbers 21, 22, and 23, are continuous, except for the 95 feet at the top and about 200 feet at the base of Number 21, which are concealed by masonry at the entrances to the railroad tunnel through Backbone Mountain. Section 22, north of the tunnel, contains the oldest beds in the sequence; section No. 21, through the tunnel, is next; and Section No. 23, south of the tunnel, is at the top of the series.)

| | Feet |
|---|---|
| 2. Sandstone: fine-grained; massive beds grading upward to thin-bedded sandstone at top of unit | 49.0 |
| 3. Sandstone: thin-bedded, alternating with layers of siltstone | 12.5 |
| 4. Sandstone: quartzitic; massive beds | 32.0 |
| 5. Sandstone: platy, ripple-marked | 70.5 |
| 6. Sandstone: quartzitic; massive beds | 7.5 |
| 7. Sandstone: silty and siltstone in approximately equal amounts | 73.5 |
| 8. Sandstone: fine-grained; massive | 8.5 |
| 9. Sandstone: thin-bedded, interbedded with siltstone | 7.5 |
| 10. Sandstone: fine-grained; massive beds with some interbedded siltstone | 104.0 |
| 11. Sandstone: fine-grained; thin-bedded, with small amount of interbedded siltstone | 28.0 |
| 12. Siltstone: dark gray; contains thin plates of sandstone, light gray | 65.0 |
| Subjacent rock concealed by masonry, probably siltstone | 200.0 |

## 22. SE¼ SE¼ SEC. 28, T. 9 N., R. 27 E., NORTH PORTAL OF FRISCO R. R. TUNNEL SOUTH OF BONANZA, ARK.

Atoka formation, approximately 3,000 feet below top

| | |
|---|---|
| 1. Siltstone: blue-gray, fissile, micaceous; some beds contain macerated, carbonized plant fragments | 115.0 |
| Subjacent rock not exposed. | |

## 23. NW¼ NW¼ SEC. 34, T. 9 N., R. 27 E., MEASURED ALONG FRISCO R. R. NORTHWARD TO SOUTH PORTAL OF TUNNEL THROUGH BACKBONE RIDGE.

Atoka formation, top of section approximately 1,400 feet below top of formation

| | |
|---|---|
| 1. Covered to base of next higher sandstone unit, not measured | |
| 2. Shale: silty, micaceous | 13.0 |
| 3. Sandstone: fine-grained; massive bed | 3.0 |
| 4. Sandstone: micaceous; thin-bedded to platy | 15.0 |
| 5. Sandstone: fine-grained; massive, wavy beds | 12.0 |
| 6. Shale: dark gray, fissile, with minor amount of siltstone | 54.0 |
| 7. Sandstone: fine-grained; massive bed | 1.5 |
| 8. Shale: dark gray; fissile, a little siltstone and sandstone | 12.0 |
| 9. Siltstone: gray, a little shale; clay ironstone concretions near top, containing a few brachiopods | 41.0 |
| 10. Shale and siltstone: largely covered | 115.0 |
| 11. Sandstone: siltstone, with sandstone prominent near middle (makes low ridge); thin-bedded | 120.0 |
| 12. Siltstone with some layers of thin-bedded sandstone; largely covered | 330.0 |
| 13. Sandstone: mainly thin-bedded with several massive beds near top | 35.0 |
| 14. Sandstone: fine-grained, in beds 2 to 6 inches thick | 41.0 |
| 15. Sandstone: fine-grained; beds up to 4 inches thick with a few zones of thin-bedded sandstone | 28.0 |
| 16. Siltstone: blue-gray, fissile; interbedded with sandstone, light gray, thin-bedded and containing laminae of shale | 25.0 |
| 17. Siltstone: blue-gray, fissile | 88.0 |
| 18. Siltstone: blue-gray, fissile; interbedded with sandstone, light gray, thin-bedded and containing laminae of shale | 44.0 |
| 19. Siltstone: dark blue-gray, micaceous, fissile; a few lenticular beds of sandstone, fine-grained, containing a little pyrite | 200.0 |
| 20. Base of section covered by masonry at portal of tunnel. | |

| | Feet |
|---|---|
| **24. SW¼ SW¼ SEC. 34; T. 9 N., R. 27 E., FRISCO R. R. CUT NEAR JENSON.** | |
| **Atoka formation, top of section approximately 1,000 feet below top of formation** | |
| 1. Sandstone: (2nd sandstone unit below top of formation), fine-grained, micaceous; massive, interbedded with zones of thin-bedded sandstone, siltstone, all of which are gray in color; sandstones show ripple-marks and massive beds show in some places cavities from which shale pellets have been removed in weathering | 25.0 |
| 2. Sandstone: rather coarse-grained; massive, cross-bedded with many pellet cavities | 6.0 |
| 3. Sandstone: fine-grained, massive, interbedded with siltstone containing a few thin sandstone beds and a little shale | 15.0 |
| 4. Sandstone: rather coarse-grained; massive, hard, with thin siltstone bed in middle; light gray, ripple-marked | 2.5 |
| 5. Sandstone: thin-bedded, ripple-marked | 10.0 |
| Subjacent rock not exposed. | |

## TOWNSHIP 10 NORTH

| | |
|---|---|
| **25.** SW¼ SEC. 16, T. 10 N., R. 24 E., CANYON ON NORTH SIDE OF SHORT MOUNTAIN, 2 MILES NORTHEAST OF COWLINGTON. | |
| **Boggy formation** | |
| Bluejacket sandstone member | |
| 1. Sandstone: gray to tan, medium-grained, somewhat micaceous; cross-bedded, in massive layers showing tendency to exfoliate in weathering | 50.0 |
| 2. Siltstone and silty shale: olive-drab, micaceous | 9.0 |
| 3. Sandstone: massive layers at base grading upward into thin-sandstone and siltstone | 56.0 |
| 4. Sandstone: thin-bedded with interbedded platy sandstone layers | 60.0 |
| 5. Siltstone: dark gray; interbedded with thin layers of sandstone spaced 1½ to 4 feet apart | 57.0 |
| 6. Sandstone: olive-drab to light gray, fine-grained, micaceous; thin-bedded, ripple-marked, cross-bedded, with irregular laminae of silty shale, dark gray, carbonaceous; grades upward into siltstone, carbonaceous | 47.0 |
| Subjacent rock not exposed. | |

# INDEX

## A


| | Page |
|---|---|
| Aerial photographs, use of | 8 |
| Allegheny age of rocks | 12 |
| Alluvial plains, recent | 10, 34 |
| Alluvial terraces | 10, 33 |
| Analysis, chemical, of coal | 43, 52-55 |
| Ash in coal | 43, 44, 50, 51, 52-55 |
| Atoka formation | 12, 13, 14, 15, 34 |
| Fossils in | 14 |
| Gas in | 14, 56, 59 |
| Thickness | 13, 15 |


## B


| | |
|---|---|
| Backbone anticline and fault | 36 |
| Bluejacket sandstone member of Boggy formation | 12, 30, 31, 64 |
| Boggy formation | 12, 13, 29 |
| Beds above Bluejacket sandstone member | 32 |
| Bluejacket sandstone member | 12, 30, 31, 50, 64 |
| Coal in | 30, 32, 42, 43, 50, 51 |
| Lower shale member | 30 |
| Lower Witteville coal | 30, 43, 50 |
| Secor coal | 30, 32, 42, 43, 51 |
| Subdivisons | 30 |
| Thickness | 13 |
| Upper Witteville coal (see Secor) | |
| Bokoshe syncline | 38 |
| Brazil anticline | 41 |


## C


| | |
|---|---|
| Calcite | 60 |
| Cameron gas field | 58 |
| Cameron sandstone member of McAlester formation | 18, 23 |
| Stigler coal, in shale overlying | 24 |
| Carboniferous system | 13 |
| Carbonization | 45 |
| Cartersville gas field | 56 |
| Cavanal coal | 28, 42, 43, 49 |
| Cavanal Mountain | 9 |
| Bluejacket sandstone in | 31, 64 |
| Thickness of strata below | 12 |
| Cavanal syncline | 35 |
| Cedars gas field | 59 |
| Central syncline | 39 |
| Chattanooga shale | 34 |
| Chemical analysis of coal | 43, 52-55 |
| Clay ironstone | 12, 14, 18, 19, 23 |
| Coal | 42-51 |
| Ash in | 43, 44, 50, 51, 52-55 |
| Carbonization | 45 |
| Cavanal bed | 28, 42, 43, 49 |
| Chemical analysis | 43, 52-55 |
| Coking for metallurgical use | 7, 44, 45 |

Page
Composition ....43, 44, 52-55
Faulting in coal beds ....47
For metallurgical coke ....7, 44, 45
Grady bed (see also Hartshorne) ....17
Hartshorne beds ....16, 39, 42-48
In Boggy formation ....30, 32, 43, 50, 51
In McAlester formation ....21, 24, 25, 42, 43, 48, 49
In Savanna formation ....28, 43, 49
In shale overlying Tamaha sandstone ....25
Lower Witteville bed ....30, 42, 43, 50
Production ....43
Rank ....43, 44, 49
Secor bed ....32, 42, 43, 51
Sections ....envelope
Segregated lands ....42
Smithing ....49
"Smokeless" ....45
Stigler bed ....24, 42, 43, 48, 49
Sulfur in ....43, 44, 50-55
Upper Witteville bed (see Secor)
Coal Creek syncline ....38
Cobbles, igneous and metamorphic rocks in coal ....46
Coke, metallurgical ....7, 44, 45
Cowlington syncline ....40

D

Dickite ....60

E

Economic geology ....42

F

Faulting ....35, 36, 37, 40, 61
In coal beds ....47
Fernvale limestone ....34
Folding ....35

G

Gas, natural ....14, 16, 21, 56-59
Geography ....9
Gerty sand ....33, 34
Gilmore anticline ....36, 57
Gilmore-Poteau gas field ....57
Grady coal (see also Hartshorne) ....17
Gravel and sand, terrace ....33

H

Hartshorne coals ....16, 37, 39, 42-46
Hartshorne sandstone ....13, 15
Coal in ....16, 37, 39, 42-46
Definition, modified for this report ....16, 20
Original, by Taff ....15
Revised by Taff and Adams ....15
Used in Arkansas ....16
Gas in ....16, 56, 57, 58
Thickness of ....13, 15, 16
Hunton limestone ....34

## I

Page

Igneous rocks, cobble of in coal ........ 46
Inliers, of Atoka formation
  On Backbone anticline ........ 12, 37
  On Milton anticline ........ 12, 39
Ironstone, clay ........ 12, 14, 18, 19, 23

## J

James Fork syncline ........ 35

## K

Keota sandstone member of McAlester formation ........ 18, 25

## L

Leasing segregated coal lands ........ 43
Lequire sandstone member of McAlester formation ........ 18, 22
  Coalescence with Warner sandstone member ........ 22
Limestone ........ 12, 17, 28, 50
Longwall method of mining ........ 50
Lower Witteville Coal ........ 30, 42, 43, 50

## M

Massard Prairie anticline ........ 39
"Mayes" formation ........ 34
McAlester formation ........ 13, 17
  Cameron sandstone member ........ 18, 23, 36, 48
  Coal in ........ 21, 24, 25, 42, 43, 48, 49
  Definition, modified for this report ........ 16, 20
  Definition, original, by Taff ........ 17
  Gas in ........ 21, 56
  Keota sandstone member ........ 18, 19, 25
  Lequire sandstone member ........ 18, 22
  McCurtain shale member ........ 18, 20, 39, 58
  Stigler coal bed ........ 24, 42, 43, 48, 49
  Subdivisions of ........ 18
  Tamaha sandstone member ........ 18, 19, 24, 27, 35, 36, 49
  Thickness of ........ 13, 17
  Warner sandstone member ........ 18, 21
    coal in upper part of ........ 21
McAlester-Savanna boundary ........ 18, 19, 24, 26, 27
McCurtain shale member of McAlester formation ........ 18, 20
  Gas in sandstone beds of ........ 21, 56
Measured stratigraphic sections ........ 62
Metamorphic rocks, cobble of, in coal ........ 46
Midland anticline ........ 36, 58
Milton anticline ........ 39, 56
Minerals, secondary ........ 60
Misener sand ........ 34
Mounds, "pimple" ........ 10

## N

Natural gas ........ 14, 16, 21, 56-60
  Production ........ 57, 58

## P

Page
Pennsylvanian series ....13
Pennsylvanian system ....13, 14, 34
"Pimple" mounds ....10
Photographs, aerial, use of ....8
Pleistocene (?) age of rocks ....12, 33
Pocola anticline ....38
Poteau-Gilmore gas field ....57
Pottsville age of rocks ....12
Pre-Pennsylvanian rocks ....34, 56
Production of coal ....43
Production of gas ....57, 58

## R

Rank of coal ....43, 44, 49
Rock Island gas field ....59
Rocks not exposed ....34
Round Mountain syncline ....38

## S

Sand and gravel, terrace ....33
Sansbois syncline ....40
Savanna formation ....13, 26
  Cavanal coal ....28, 42, 43, 49
  Coal in ....28, 49
  "Spiro" sandstone member, name not used ....29
  Subdivisions ....28
  Thickness ....13, 26, 28
Savanna-McAlester boundary ....18, 19, 24, 26, 27
Secondary minerals ....60
Secor coal ....32, 42, 43, 51
Sections, stratigraphic ....62
Segregated coal lands ....42
Simpson group ....34, 56
"Smokeless" coal ....45
Spaniard limestone member of Savanna formation ....27
Spiro anticline ....38
Spiro gas field ....59
"Spiro" sandstone member of
  Savanna formation, name not used ....29
Springer formation ....34
Stratigraphic sections ....62
Stigler coal ....24, 42, 43, 48, 49
Structure ....35
Sugarloaf Mountain ....(Frontispiece) 9
Sulfur in coal ....43, 44, 50-55
Sylvan shale ....34

## T

Tamaha sandstone member of McAlester formation ....18, 24
  Coal in shale overlying ....25
Terraces, dissected ....33, 34
Terraces, high level ....33
Thickness:
  Atoka formation ....13, 15
  Boggy formation ....13

Hartshorne sandstone ........13, 15, 16
McAlester formation ........13, 17
Pennsylvanian system ........13
Savanna formation ........13, 26, 28
Strata below Cavanal Mountain ........12
Thinning, northward, of strata ........12, 15, 17, 19, 20, 24, 28
Thrust faulting ........36, 40

U

Unconformities, minor ........13, 50
Within Bluejacket sandstone ........50
Upper Witteville coal (see Secor coal)

V

Viola limestone ........34

W

Wapanucka limestone ........34
Warner sandstone member of McAlester formation ........18, 21
Coal in ........21
Coalescence with Lequire sandstone member ........22
Witteville coal, Lower ........30, 42, 43, 50
Witteville coal, Upper (see Secor coal)