OKLAHOMA GEOLOGICAL SURVEY

CARL C. BRANSON, *Director*

CIRCULAR 50

GEOLOGY OF NORTHERN LATIMER COUNTY, OKLAHOMA

UNIVERSITY OF OKLAHOMA
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FOREWORD

Russell's report supplies geologic information on a rugged area previously left unstudied. This region has few roads and is largely a wilderness.

A commercial gas well on the Brazil anticline (Midwest Oil et al., No. 1 Orr) has been drilled since the report went to press. The well is less than one mile out of the mapped area.

The name of the chain of hills and of the syncline has caused much trouble to map-makers, draftsmen and editors. Sans bois is French for tree-less, and the name was (probably in error) affixed to the heavily timbered hills of northern Latimer County. The name of the former town was spelled Sansbois, the hills are labeled Sansbois on the topographic map (Sansbois quadrangle), Sanbois on the State Highway map. On the accompanying map to this report (Plate I) the survey's draftsmen (and editors) erred in spelling the word Sanbois in three places, were right (Sansbois) in one.

A guide book to the Robbers Cave area was prepared by Russell and published by the survey as Guide Book VII. The boy scout camp, Camp Tom Hale, is scheduled to be removed to LeFlore County.

Carl C. Branson

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GEOLOGY OF NORTHERN LATIMER COUNTY, OKLAHOMA

Dearl T. Russell

ABSTRACT

Northern Latimer County is underlain by Pennsylvanian rocks of the Atoka, Hartshorne, McAlester, Savanna and Boggy formations. Structural features are the Adamson anticline, Sansbois syncline, Burning Springs anticline, and Brazil anticline. Coal beds of commercial thickness are the Hartshorne coals and the McAlester coal.

INTRODUCTION

LOCATION AND DESCRIPTION

The area embraces 195 square miles of a rugged, semi-wilderness region. Included are secs. 1 and 2, T. 5 N., R. 19 E., the eastern half of T. 6 N., R. 17 E. through all of Rs. 18, 19, 20, and the greater part of 21 E. Also contained within its boundaries are two square miles in the northwest corner of T. 6 N., R. 22 E., and two tiers of sections along the southern limit of T. 7 N., Rs. 19, 20, 21 and part of 22 E.

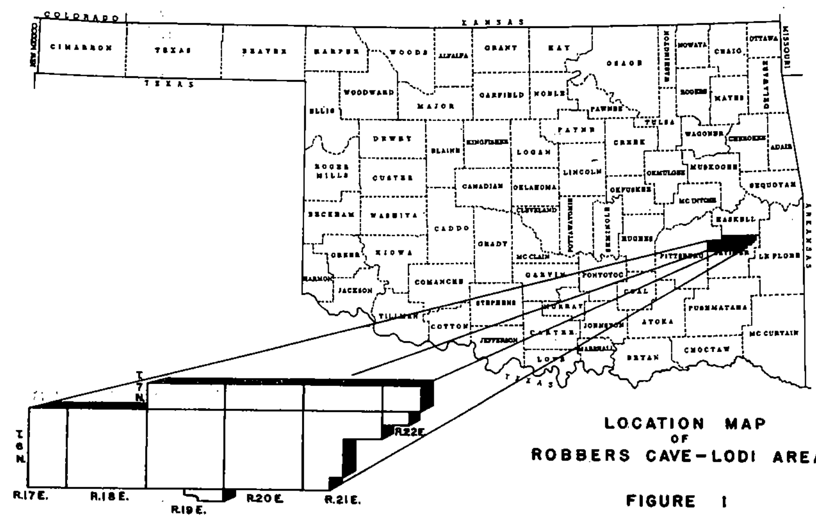

Figure 1. Index map showing location of area.

PURPOSE AND METHOD OF INVESTIGATION

The primary aim of this report was to submit a detailed geologic map of rock units cropping out in an area which had, heretofore, not been mapped for publication. Attention was also directed to character of lithology, thickness of strata, structural anomalies, and correlation of units with those cropping out to the north in Haskell County.

Chance (1890) and Drake (1897, p. 342) each included a portion of the area in early studies on the geology of the coal fields of Indian Territory. Taff (1899, p. 436-438) in a report on the McAlester-Lehigh coal field, named and described the Hartshorne, McAlester, Savanna, and Boggy formations. The following year Taff (1900, p. 273) and Adams named and described the Atoka formation from the type locality near Atoka, Oklahoma. Taff (1905) later reported on the progress of coal operations in Indian Territory. A report on coal lands in Oklahoma was published by the U. S. Senate in 1910. Notes on the geography and geology of Latimer County are included in an Oklahoma Geological Survey bulletin written by Snider (1917, p. 287-288). Shannon (1926 p. 32) included a description of a part of the area in his publication on coals in Oklahoma.

Beginning with the work of Stone and Cooper (1930, p. 417-420) on the geology of Haskell, Latimer, LeFlore, and Sequoyah Counties, and that of Hendricks (1937) in 1930 and 1931 on the McAlester district, there have been comprehensive investigations of the regions surrounding the area of this report. Colton (1935) discussed the structural features of the area and their economic aspects in an article contained within a symposium on stratigraphy, structure, and production. Small portions of the area were discussed by Hendricks (1939) in his report on the Howe-Wilburton district, and by Dane, Rothrock, and Williams (1938) in a report on the Quinton-Scipio district. The southern extent of the mapping in Haskell County by Oakes and Knechtel (1948) defines the northern boundary of this report.

ROBBERS CAVE STATE PARK

Thirteen square miles lie within the boundary of this park in T. 6 N., Rs. 18 and 19 E. In addition to being a game preserve, it is a popular tourist resort with camp grounds, picnic areas, and fishing, swimming, and boating facilities on Lake Carlton in sec 24, T. 6 N., R. 18 E. (see figure 2). Tourist cabins are picturesquely situated on a high, pine-covered ridge of Savanna sandstone overlooking Lake Carlton and vicinity.

Two miles farther north, in sec. 7, T. 6 N., R. 19 E., is Camp Tom Hale, a Boy Scout camp. Immediately north of the camp is a large recess formed by gravitational separations along joints and bedding planes in a thick upper Savanna sandstone. This recess is called Robbers Cave (see figure 3).

Personnel of the State Planning and Resources Board operate and maintain the park.

TOWNS AND VILLAGES

No major town or city is located within the area. Patterson and Degnan in the southwestern portion, Center Point in the south central portion, and Lodi in the eastern portion each consist of no more than a few dwellings in the vicinity of a church or school.

Wilburton (population: 1,939), one of the active centers of coal strip-mining in the state, is the largest town in the vicinity, one mile south of the area in secs. 8 and 9, T. 5 N., R. 19 E. Red Oak, a mining community with a population of 568, is adjacent to the southeast corner of the area.

ROADS AND RAILWAYS

State Highway 2, the only hard-surfaced road traversing the area, trends north-south through Ranges 18 and 19 East. U. S. Highway 270, a hard-surfaced road lies along an east-west route south of the area of this report. It traverses the extreme southeast corner for a distance of four miles.

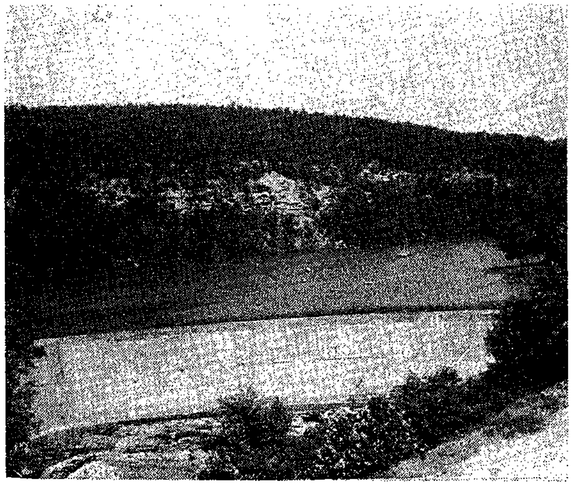

Figure 2. Lake Carlton, with Bluejacket sandstone escarpment, in the background. Located in C-W ½ sec. 24, T. 6 N., R. 18 E.

For the most part, improved gravel roads are maintained only in the shale valleys of the McAlester formation along the extreme southern and eastern edges of the area. The southern extent of the Savanna formation forms a high escarpment against which most of the north-south roads abruptly terminate. The rugged topography and the absence of roads over the greater part of the area render it inaccessible by automobile. Access to the more remote portions may be gained by utilization of numerous unimproved trails which lead through the mountains. Ash Creek road, with an improved gravel surface extending from its junction with State Highway 2 northwestward to sec. 9, T. 6 N., R. 18 E., affords convenient access to the northwestern portion. A slightly improved trail extending from Lodi northwestward into Haskell County allows some degree of accessibliity by automobile in the eastern portion. In earlier times this trail was known as the Sanbois-Tuskahoma Road. It lies in the valley of Rock Creek, and is passable only during the seasons when the waters of the creek are at a low level. Paucity of roads is a reflection of the sparse population of the area.

The Chicago, Rock Island, and Pacific Railroad, immediately south of and parallel to U. S. Highway 270, is the only railroad serving the Robbers Cave-Lodi area.

TOPOGRAPHY

The area is located within the McAlester Marginal Hills Belt (Okla. Geol. Survey, 1957, Educ. Series Map 4):

The topography of the area is typically an inverse reflection of the underlying structure. The isolated erosional remnants of the Boggy formation, which define the higher and more inaccessible mountains, are restricted to the synclinal areas, whereas the anticlines form low, undulating plains in the lower part of the Savanna and the upper part of the McAlester formations. Relief, caused by hogbacks, cuestas, and synclinal mountains, varies from 100 to 900 feet, and is related to the resistance, thickness, and degree of dip of the supporting strata. The thicker and more resistant sandstones and siltstones form sharply defined cuestas and hogbacks along the structural flanks. Those areas in which the structural axes plunge or rise are identified by relatively abrupt changes in direction of dip and strike, so as to define, in areal extent, crescentic outcrop patterns.

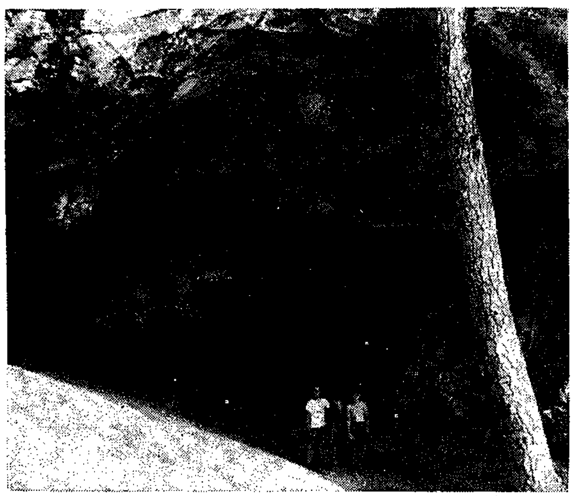

Figure 3. Robbers Cave as seen in upper Savanna sandstone in NW¼ NW¼ SE¼ sec. 7, T. 6 N., R. 19 E.

Several zones made up predominantly of sandstone beds are present in the Savanna and Boggy formations. These zones also contain thin shale intervals. Individual zones crop out as broad, high hogbacks. Outcrops of individual sandstone beds lie alternately along the crest of the hogback or in its dip slope. As a result, the crest of the hogback shifts from one sandstone bed to another.

A direct reflection of the topography, as well as of the underlying structure, is manifested in the drainage pattern and the genetic types of streams in the area. Most of the streams can be classified as subsequent, a minor number as resequent and obsequent, and some of the larger ones, in part, as superimposed. Together they delineate a trellis drainage pattern. The structural axis of the Sanbois syncline may be generally considered a divide of the drainage system. Streams on the north of the axis flow to the north and streams on the south flow to the south. The names and directional orientation of creeks may be ascertained by reference to the geologic map (Plate I).

ACKNOWLEDGMENTS

The Oklahoma Geological Survey gave financial assistance and provided airplane photographs. Dr. Carl C. Branson, director of the Survey and director of the School of Geology, served as supervisor and visited the area. Dr. George G. Huffman, School of Geology and Mr. Malcolm C. Oakes, of the Oklahoma Geological Survey read the paper and offered constructive criticism of its content. Mr. C. W. Allen, owner of the Kinta Stripping Company of Wilburton, Oklahoma, provided information concerning coal beds in the southern part of the thesis area.

This report is modified from a thesis submitted for the Master of Science degree at the University of Oklahoma.

STRATIGRAPHY AND LITHOLOGY

General Statement

The entire area displays generous exposures of resistant beds separated by predominantly covered shale intervals. The strata which crop out have an accumulative thickness of approximately 7, 500 feet, and compose an integral part of the McAlester Basin of sedimentary deposition. All are included in the Pennsylvanian system and are composed almost entirely of alternating sandstone or siltstone and thick intervening shales. General lithic characteristics and thicknesses of formations are graphically illustrated by Plate II (in pocket).

Widely spaced coal horizons in the post-Atoka formations maintain their position in the stratigraphic column with a relatively constant degree of lateral persistence. This adds substantially to their value as reliable stratigraphic markers, especially in the southern and eastern portions of the area.

The only limestone observed occurs in the Savana formation in a roadcut along State Highway 2 at which place it is in a cyclic unit.

Contacts between formations, where exposed, are gradational and conformable, with occasional interruptions by channeling.

Correlation of any individual unit by lithologic character alone is difficult. The relatively thin, fine- to medium-grained sandstones range in color from gray to brown. The shales are greenish-gray to black, fissile to blocky, and contain clay-ironstone concretions in random arrangement.

The area occupies a position north of the deeper part of the coal basin in which the sediments attain maximum thickness. Abrupt thinning to the north is illustrated by Plate III (in pocket).

The nature of the sediments and of the included fauna define their origin as both marine and non-marine. Most of the sandstones and shales appear to be of continental origin (Hendricks, 1939, p. 263).

PENNSYLVANIAN SYSTEM

Atokan Series

Atoka Formation

Definition and correlation. The Atoka formation includes all strata below the Hartshorne formation and above the Wapanucka formation. It is correlated with a portion of the upper part of the Pottsville series of the Pennsylvanian system in the eastern United States, and composes the Atokan series of the Mid-Continent region.

Taff and Adams (1900, p. 273) named this formation from the town of Atoka, Oklahoma.

Character and thickness. Comprehensive study and accurate determination of thickness of that part of the Atoka formation cropping out on the surface is precluded by a thick soil cover. An estimated 1,230 feet of the upper part of the Atoka lies within the area. Scarce exposures in borrow ditches along section-line roads reveal a predominantly silty, micaceous, gray to brown shale with a ridge forming, brown sandstone occurring approximately 266 feet below the top contact (see measured section 7).

The Magnolia Petroleum Company No. 1 Manschrech well, C SE¼ NE¼ sec. 28, T. 6 N., R. 17 E. reveals the Atoka of the subsurface as alternating shales and sandstones 6,810 feet thick.

Distrbiution. The Atoka formation crops out only in the southern part of T. 6 N., R. 18 E. It is concealed by soil cover and lies in a plain on the south flank of the Adamson anticline.

Stratigraphic relations. The Atoka contact with the overlying Hartshorne formation is gradational and apparently conformable in the area of this report. The same conformity is reported by Oakes and Knechtel (1948, p. 21) in Haskell County. Hendricks (1939, p. 263) reported the existence of an unconformity between the Atoka and Hartshorne formations in the Howe-Wilburton district.

The base of the Atoka formation is not exposed in this area as it is on the flanks of the Ozark Mountains in the region to the northeast. At that locality it rests unconformably upon rocks of the Morrowan series (Oakes and Knechtel, 1948, p. 21).

Desmoinesian Series

Krebs Group

Hartshorne Formation

Definition and correlation. The Hartshorne formation lies above the Atoka formation and below the McAlester formation. It is equivalent in age to a portion of the upper part of the Pottsville series of eastern United States and is the lowest formation in the Des Moines series of the Mid-Continent region. The base of the Krebs group is drawn coincident with the base of this formation.

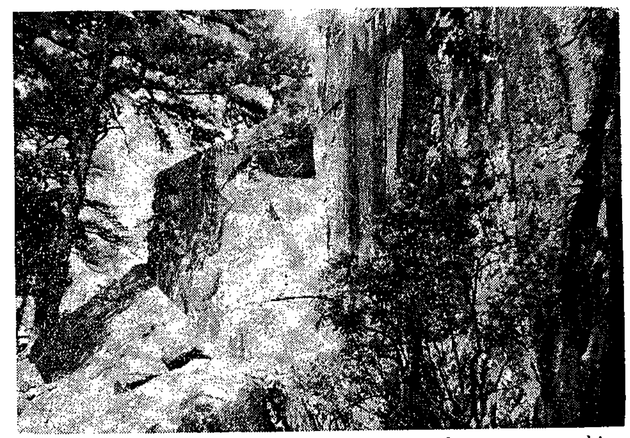

Figure 4. Slump blocks of upper Savanna sandstone approaching the size of three story buildings. Located in the immediate vicinity of Robbers Cave, sec. 7, T. 6 N., R. 19 E.

H. M. Chance (1890, p. 658-659) described, mapped, and named the Tobucksy sandstone, a unit later named by Taff (1899, p. 436) the Hartshorne sandstone at the type locality near the town of Hartshorne, Oklahoma. Taff and Adams (1900, p. 274) later enlarged the scope of the name Hartshorne sandstone to include both the sandstone mapped by Chance in 1890 and the Lower Hartshorne coal.

The Hartshorne sandstone in Arkansas was limited by Hendricks and Parks (1937, p. 198) to the equivalent of the Tobucksy sandstone member. This usage corresponds with Taff's definition of 1899.

Oakes and Knechtel (1948, p. 22-26) and Knechtel (1949, p. 16) redefined the Hartshorne formation in 1943 and 1944 to include both the Upper and Lower Hartshorne coals because they converge in eastern Haskell County and in northern LeFlore County. A similar coalescence of the Upper and Lower Hartshorne coals occurs in the area of this report. This phenomenon is clearly observed in fresh exposures of both coals in recently excavated strip pits. The coalescence occurs in a northwest direction between the southwest corner of sec. 36, T. 6 N., R. 18 E., where the separate strip pits of the two coals enter the area, and the C N½ sec. 35, T. 6 N., R. 18 E., where a single strip pit terminates. At the locality marking the entrance of the Hartshorne formation into the area, the Upper and Lower Hartshorne coals are four feet thick and six feet thick respectively and are separated by 64 feet of shaly sandstone (see measured section 7). In the C N½ sec. 35, T. 6 N., R. 18 E. they are separated by a 0.5-foot carbonaceous shale and measure 10 feet in the aggregate (see measured section 8 and figure 5).

Figure 5. Coalesced Upper and Lower Hartshorne coals in strip pit C. N½ sec. 35, T. 6 N., R. 18 E.

Branson (1956, p. 93-98) proposed that the beds from the top of the Atoka formation to the top of the Upper Hartshorne coal be included in the Hartshorne formation and the lowermost sandstone unit be referred to as the Tobucksy sandstone member.

Character and thickness. The Hartshorne formation attains a maximum thickness of 316 feet at the eastern extent of its outcrop in the area. The Tobucksy sandstone member at this locality consists of approximately 242 feet of thin-bedded, fine-grained, micaceous, ripple-marked gray to brown sandstones interbedded with thin, silty, gray shale. The upper portion of the formation includes in ascending order six feet of Lower Hartshorne coal, 64 feet of gray to brown, silty, micaceous sandstones interbedded with thin, silty, gray shale, and four feet of Upper Hartshorne coal.

At the western extent of its outcrop in the area the Tobucksy sandstone member is a dense, massive to thin-bedded sequence of fine- to medium-grained, ripple-marked, gray sandstones totaling 84 feet in thickness. The upper portion of the Hartshorne formation is not exposed at this locality. It is suggested that the Upper and Lower Hartshorne coals maintain their convergence here because the same structural environment prevails as is associated with their exposure in the strip pit in C N½ sec. 35, T. 6 N., R. 18 E.

Carbonized remains of tree rtunks, measuring several feet in length, were observed on the basal bedding plane of the steeply dipping Lower Hartshorne coal as it is exposed in the strip pit in C N½ sec. 35, T. 6 N., R. 18 E.

In sec. 26, T. 5 N., R. 25 E. of the Howe-Wilburton district the Hartshorne formation seems to have been deposited in a series of stream channels. At some localities hundreds of calamite and cordaite trunks are buried in the shale overlying the Lower Hartshorne coal (Hendricks, 1939, p. 265-266).

Invertebrate fossils were not discovered in the Hartshorne formation during the course of field work. Only one species, *Lingula carbonaria,* has been found in the McAlester district to the west (Hendricks, 1937, p. 13).

The Lower Hartshorne coal in this area marks the lower extent of the productive coal measures.

Distribution. A narrow outcrop extending for a distance of 4 miles along the southern tier of sections in T. 6 N., R. 18 E. is the only exposure of the Hartshorne formation in the area. The position of this outcrop defines the structural flank along the open fold of the Adamson anticline.

Extended from the area of this report, the Hartshorne formation has been traced eastward across LeFlore County into Arkansas and southwestward across Pittsburg and Coal Counties (Gould, 1925, p. 39). It is also found at several localities in Haskell County (Oakes and Knechtel, 1948, p. 25).

Wilson (1937), p. 36) identified outcrops of the Hartshorne formation in the Muskogee-Porum district.

Stratigraphic relations: The contacts of the Hartshorne formation with the underlying Atoka formation and the overlying McAlester formation are apparently conformable in the area of exposure in T. 6 N., R. 18 E.

Hendricks (1939, p. 264) states that a minor unconformity locally separates the Hartshorne formation and the underlying Atoka formation. The same relation exists between the two formations in Arkansas (Hendricks and Parks, 1937, p. 198).

The Hartshorne formation thins northward across Haskell County to the Muskogee-Porum district where its thickness ranges between 3 and 25 feet (Wilson and Newell, 1937, p. 35).

McAlester Formation

Definition and correlation. The McAlester formation includes the strata between the top of the underlying Hartshorne formation, as defined in this report, and the base of the Savanna formation, above. It is included in the Krebs group in the lower part of the Des Moines series. Taff (1899, p. 437) apparently named the formation from the city of McAlester. He did not designate a type locality.

Most of the included sandstones and the basal shale of the McAlester formation were named and assigned member status in 1927 by Thom (1935) during the course of a preliminary investigation in Haskell and northern LeFlore Counties. The name McCurtain was assigned to the basal shale member overlying the Hartshorne formation. The sandstone units named in ascending order above the McCurtain shale member are the Warner sandstone member, the Lequire sandstone member, the Cameron sandstone member, the Tamaha sandstone member, and the Keota sandstone member. Each of these sandstone members is overlain by an unnamed shale. These names were later extended northward by Wilson (1937, p. 11-12) to apply to equivalent surface outcrops in Muskogee County.

Subsequent investigations by Oakes and Knechtel (1948) in Haskell County and by Knechtel (1949) in northern LeFlore County effected continuity between the surface outcrops in the Muskogee-Porum district and those mapped, but not named, by Hendricks (1939) in southern LeFlore County.

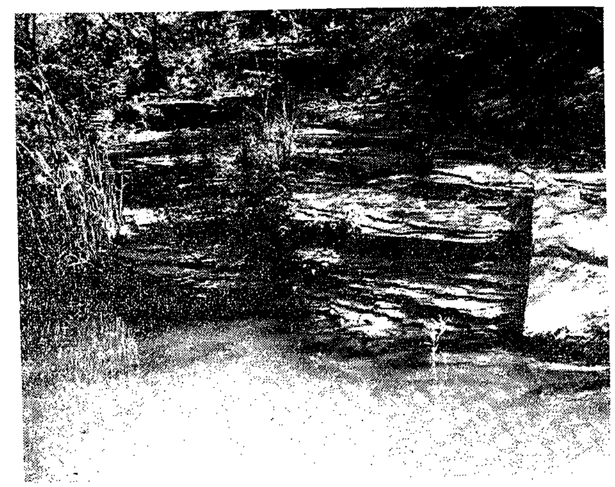

Figure 6. Exposure of the Cameron sandstone in Bear Creek on north flank of the Brazil anticline. SE¼ NE¼ NW¼ sec. 12, T. 6 N., R. 21 E.

The present investigation, in its southern portion, overlaps the work of Hendricks (1939) in the Howe-Wilburton district and permits the extension of the previously named members of the McAlester formation into the area. The Lequire sandstone member is the only one not recognized in the area. A study by aerial photography of the outcrops lying immediately south of the area reveals the presence of the Lequire sandstone member as a prominent escarpment. In sec. 2, T. 5 N., R 20 E. it loses its topographic expression and apparently grades westward into the shale overlying the Warner sandstone member. Another explanation may be that the shale separating the Warner sandstone member and the Lequire sandstone member thins sufficiently to allow their convergence into one escarpment. This situation occurs in Haskell County and the sandstone is mapped as the Lequire-Warner sandstone unit (Oakes and Knechtel, 1948, p. 34).

Character and thickness: The McAlester formation attains its greatest known thickness south of the thesis area near the village of Red Oak (Hendricks, 1939, p. 269-270). Here it is 2,830 feet thick. Throughout the greater part of the Howe-Wilburton district it is 2,000 to 2,400 feet thick, but is only 700 feet thick in northern Haskell County (Oakes, 1948, p. 30).

In T. 6 N., R. 18 E. where the entire McAlester formation is exposed the thickness is 2,011 feet (see measured section 8). In this vicinity the McCurtain shale member is 961 feet thick and consists predominantly of dark gray to black, blocky shales. Abundant clay ironstone concretions are concentrated at random intervals throughout the extent of its exposures. *Calamites* was found approximately 24 feet below the contact with the overlying Warner sandstone member. A locally persistent thin sandstone lies approximately in the middle of the McCurtain shale member. Its presence south of the area of this report is verified by aerial photograph reconnassiance. The base of the McCurtain shale member coincides with the base of the McAlester formation and lies conformably upon the top of the Upper Hartshorne coal.

In the McAlester district the McCurtain shale member exhibits the same general lithic characteristics and ranges from 500 to 640 feet in thickness (Hendricks, 1937, p. 13). In northern Haskell County it is about 200 feet thick (Oakes, 1948) p. 32).

The Warner sandstone member overlies the McCurtain shale member with a conformable contact, and is present only in the southern portion of T. 6 N., R. 18 E. At this locality it is 77 feet thick. It consists of a brown, fine-grained sequence of dense, thin-bedded to massive sandstone beds. In southern Haskell County the Warner sandstone member averages 50 feet in thickness, and the thickness decreases considerably to the north (Oakes, 1948, p. 34). In the Muskogee-Porum district it ranges from five to 30 feet in thickness (Wilson, 1935, p. 508).

The unnamed shale, designated on the geologic map by the symbol (IPm) is 210 feet thick in the southern portion of T. 6 N., R. 18 E. This is the only locality where the entire unit is exposed in the thesis area. It lies between the Warner sandstone member, below, and the Cameron sandstone member, above.

The Cameron sandstone member overlies the shale (IPm) with apparent conformity. Its thickness throughout the western extent of the area is constant and averages 46 feet. It is a persistent member consisting predominantly of thin-bedded, fine-grained sandstone beds. Ripple marks abound within this member (see figure 6). The Cameron sandstone member is erratic in thickness and is absent in some parts of Haskell County (Oakes, 1948, p. 39-41). The name Cameron was used by Caster in 1934 for a red shale in the "Greenbrier series" of Pennsylvania. The name is not replaced here because the Oklahoma unit is not clearly a useful one deserving a name.

An unnamed shale, which is designated on the geologic map as IPm lies conformably upon the Cameron sandstone member and extends to the base of the overlying Savanna formation. The map unit includes the shale overlying the Cameron sandstone member, the Tamaha sandstone member and its overlying shale, and the Keota sandstone member and its overlying shale. This scheme lends convenience to the mapping of these units because the Tamaha sandstone member and the Keota sandstone member are erratic and discontinuous. This shale (IPm) ranges in thickness from 694 feet in the western portion to 951 feet in the eastern portion of the area of this report. The best exposure of this shale along State Highway 2 exhibits a predominantly gray to black color, a blocky to fissile appearance, several thin coal seams, including the Upper and Lower McAlester coals, and abundant clay ironstone concretions. Numerous thin, micaceous sandstone and siltstone beds are also present.

The Upper and Lower McAlester coals maintain impressive continuity in an east-west direction across the area in the basal portion of this shale. The stratigraphic distance between the top of the underlying Cameron sandstone member and the base of the Lower McAlester coal averages 88 feet. The average thickness of the shale separating the Upper and Lower McAlester coal seams is 70 feet. The shales enclosing these two coal seams are dark gray to black, characterized by a blocky to hackly appearance, and by abundant clay ironstone concretions. These concretions are at many places aligned as stringers in the enclosing shale. The thicknesses of the Lower McAlester coal and the Upper McAlester coal remain strikingly constant at 1.6 and 1.5 feet respectively. There is one exception; in the area of their outcrop across State Highway 2, in sec. 31, T. 6 N., R. 19 E. they are 0.4 and 0.06 foot thick respectively. Their identity as the Lower and Upper McAlester coals is substantiated by stratigraphic interval and by core hole data obtained in that vicinity by the Kinta Stripping Company of Wilburton, Oklahoma (Mr. C. W. Allen, personal communication, 1957).

The Tamaha sandstone member crops out locally. Its maximum recorded thickness in this area is 13 feet. It is a brown, fine-grained, thin-bedded sandstone with silty shale partings. It lies approximately 450 feet below the base of the Savanna formation in the western part of the area. Oakes (1948, p. 42) reported similar characteristics of the Tamaha sandstone member in Haskell County.

The Keota sandstone member, like the Tamaha sandstone member, is erratic in occurrence. It consists of thin-bedded intercalations of fine-grained sandstone beds and silty shale partings. The maximum thickness of the Keota sandstone member occurs along State Highway 2 where it totals 30 feet. Thin coal seams were found approximately 10 feet below the base of the Keota sandstone member in two localities (see measured sections 10 and 15). This member lies between 133 and 237 feet below the base of the Savanna formation. It is concealed over most of the extent of its outcrop by slump debris from the high escarpment of the overlying Savanna formation.

Local lenses of impure limestone occur in the McAlester formation (Hendricks, 1939, p. 269), but these are limited in lateral extent.

Invertebrate fossils were not found in the McAlester formation in the thesis area, but well preserved specimens are abundant in the McAlester district to the west (Hendricks, 1939, p. 268). Internal molds of fossil pelecypods were found by D. A. Busch immediately south of the eastern extent of the area. They occur in the overlying zone of the Upper (?) McAlester coal in SW¼

sec. 9, T. 6 N., R. 22 E. (Branson, personal communication, 1957).

Distribution. In the area the McAlester formation is exposed in its entirety only in the southern part of T. 6 N., R. 18 E. along the north flank of the Adamson anticline. In this vicinity the width of its outcrop is approximately one half mile. In the eastern part of the area the upper portion of the formation is exposed as a wide plain in the valley developed in the axis of the Brazil anticline.

The McAlester formation is widespread over the coal basin in Oklahoma and Arkansas.

Stratigraphic relations. The contacts of the McAlester formation with the underlying Hartshorne formation and the overlying Savanna formation are both apparently gradational and conformable in the area of this report. Oakes (1948, p. 30) reported essentially the same relationship in Haskell County.

Hendricks, (1937, p. 13-15) reported an unconformity between the McAlester formation and the Savanna formation in the McAlester district.

The fact that most of the members of the McAlester formation maintain their identity from south to north leads to the conclusion that the northward thinning of the formation is apparently due to the variation in thickness of individual members rather than to post-McAlester erosion.

Savanna Formation

Definition and correlation. The Savanna formation includes all strata between the underlying McAlester formation and the overlying Boggy formation. It is included in the Krebs group of the Des Moines series.

The Savanna formation was named by Taff in 1899, presumably from a type locality in the vicinity of the town of Savanna in Pittsburg County, Oklahoma.

Wilson (1935, p. 509) mapped the Savanna formation in Muskogee County. Work by Knechtel (1949) in LeFlore County and by Oakes and Knechtel (1948) in Haskell County served as a basis for correlating the upper limit of the Savanna formation, as mapped by Hendricks (1939), with the top of the Spiro sandstone member of the Muskogee-Porum district. In the mapping of

Oakes and Knechtel and others the thick shale unit under the Bluejacket sandstone member was included in the Boggy formation. This same shale is now assigned to the upper part of the Savanna formation.

Character and thickness: In the area the Savanna formation ranges in thickness from 1, 470 feet in the western portion to 1,990 feet in the southern half of T. 6 N., R. 20 E. (see plate II). Individual units are extremely variable in thickness throughout the formation. The formation thins to between 100 and 200 feet in northern Haskell County. In the Howe-Wilburton district in T. 6 N., R. 25 E. it is 1,750 feet thick and in the McAlester district it is 1,120 to 1,325 feet thick (Hendricks, 1939, p. 272).

The Savanna formation consists predominantly of brown to grayish-green shales with 2 to 14 mappable sandstone units (see geologic map, explanation). Generally, the sandstone beds may be grouped into upper and lower groups. Each group contains several sandstone beds separated by shale. The shale unit separating these two groups, ranges in thickness from 200 to 540 feet. A shale is the uppermost unit of the Savanna formation and varies from approximately 100 feet to 400 feet in thickness.

In those areas characterized by steep dip the lower and upper sandstone groups are each mapped as one unit. Individual sandstone beds are shown on the map where they dip at low angles because the shale intervals are eroded down the dip slope so as to expose the sandstones.

The Spiro sandstone member of Muskogee County is identified as a sandstone IPsv-1a which lies approximately in the middle of the Savanna formation of the area (see Plate III). The correlation is based on the measured section of this report and the work of Oakes (1949, Plate III) in Haskell County. The units shown on the geologic map represent individual sandstone beds where they could be recognized and groups made up of sandstone beds separated by shale where the dip is steep. As a result of this scheme of mapping, shales wedging out at several localities. Such is not the case. The the individual sandstones appear to coalesce, with the intervening intervening shales are continuous, but cannot be differentiated.

The tops of the sandstone beds were difficult to locate in most instances and the contact was drawn from aerial photographs along slope breaks and subsequent streams.

The sandstone beds in the Savanna formation are generally brown, dense, fine-grained and micaceous. Some locally attain a thickness up to 200 feet and break off along the line of outcrop into slump blocks the size of a three-story building (see figure 4). Others display little continuity and lense into the stratigraphically adjacent shales. Many are ripple-marked. Some contain fucoidal markings.

Figure 7. Fossil tree stump in the upper part of the Savanna formation. Exposed in fresh roadcut of Highway 2 in sec. 24, T. 6 N., R. 18 E.

Large oblate masses and pronounced undulations commonly occur on the bedding planes of the sandstones. Cross-bedding of various magnitudes is also present in different sandstone beds. At some localities an intricate pattern of ferric stringers is deeply impregnated in massive sandstone beds.

Channel features were observed at the base of the sandstone IPsv-3 at its outcrop along State Highway 2 in C sec. 24, T. 6 N., R. 18 E. Clay pellets from the underlying shale are enclosed in the basal bed of this sandstone.

The only limestone observed directly in the Savanna formation occurs in a green shale approximately 920 feet above the base of the formation. It is an impure, fossiliferous, yellowish-brown limestone less than one foot thick. The invertebrate fossils preserved within it consist predominantly of brachiopods. At this locality on State Highway 2 in SW¼ SE¼ SW¼ SE¼ sec. 24, T. 6 N., R. 18 E. there is evidence of cyclic deposition in the stratigraphic sequence. The strata, in ascending order, consist of a brown sandstone 19 feet thick, a green shale 38 feet thick, a thin gray underclay, a one-inch impure coal seam, a 12-inch black shale, yellowish-brown limestone, and an overlying green shale.

Outcrops of thin limestone were reported by Dane (1938, p. 159-160) in the northwest portion of the area, but were not observed during the course of the present investigation. Oakes (1948, p. 50) found a limestone less than one foot thick in the Savanna formation of southern Haskell County.

Several thin coal seams are present in the Savanna formation, but none is of commercial value in the area.

Plant remains are relatively abundant in the Savanna formation. Numerous *Stigmaria* and *Calamites* were found eroded out of shales. A fossil scale-tree stump was found freshly exposed in a road cut on State Highway 2 (see figure 7). Delicate imprints of *Neuropteris* leaves are excellently preserved in a thin zone of green shale lying approximately 862 feet below the top of the Savanna formation. These leaves are contained within the shale at its outcrop on State Highway 2 in NW¼ SW¼ sec. 33, T. 7 N., R. 19 E. Plant remains were also found in the upper portion of the shale in the NW¼ SE¼ NW¼ SE¼ sec. 12, T. 6 N., R. 17 E. Hendricks (1937, p. 18) stated that marine invertebrates and continental plant fossils appear to be present at the same horizon of the Savanna formation in different parts of the McAlester district.

Distribution. The Savanna formation is widely distributed over portions of the entire area. The extent of its outcrop area is roughly equivalent to that of the overlying Boggy formation. In the southwestern part its outcrop band occupies an area one mile to one half mile wide on the south limb of the Sanbois syncline. The topographic expression of the Burning Springs anticline is formed in the Savanna formation in the northwest portion. Its outcrop area covers almost all of T. 6 N., R. 19 E. In the eastern part it crops out in the southern half of T. 6 N., R. 20 E. and also occurs as an outcrop band one to 1½ miles wide on the south limb of the Sanbois syncline. Extended from the area, the Savanna formation is present in many localities over the coal basin and on the shelf to the north.

Stratigraphic relations. The contact of the Savanna formation with the underlying McAlester formation is conformable in the Robbers Cave-Lodi area. The grayish-green shales of the Savanna formation, especially in the middle and upper portions, differ considerably in appearance from the dark gray to black shales of the McAlester formation. This change is subtle and gradational and offers no criteria for an unconformity.

Hendricks (1937, p. 16-17) presented evidence supporting the existence of an unconformity at this horizon in the McAlester district. In the Howe-Wilburton district he (Hendricks, 1939, p. 271) stated that the transition from one formation to the other appears gradational at places, but he drew an unconformity between the two formations on the basis of an observaton made on the south side of Sugarloaf Mountain. At this locality the Savanna formation truncates strata in the upper part of the McAlester formation.

The base of the Savanna formation, especially in the McAlester district, was considered by Cheney (1945, p. 147-156) to be the boundary between the Pottsville and Allegheny series. Morgan (1924, p. 75) was a proponent of an unconformity at the base of the Savanna formation along the northern flank of the Arbuckle Mountains. The concept of an unconformity at the Savanna-McAlester contact was opposed by Read (Hendricks and Read, 1934, p. 1055) on the basis of paleontological data. Oakes, 1948, p. 52) did not support the existence of an unconformity at the base nor at the top of the Savanna formation in Haskell County. In northern Latimer County the upper contact of the Savanna formation with the overlying Boggy formation is apparently conformable, with local channeling.

The correlation of the Spiro sandstone member in the Muskogee-Porum district with the sandstone IPvs-1a in northern Latimer County indicates that the Savanna formation of the Muskogee-Porum district is equivalent only to that part of the formation below the top of the sandstone IPsv-1a. Thus, it appears that the units overlying the sandstone IPsv-1a progressively lense out or grade into different lithologies to the north.

Boggy Formation

Definition and correlation: The Boggy formation occupies a stratigraphic position as the upper unit of the Krebs group in the Desmoinesian series. It is underlain by the Savanna formation. It is the youngest formation exposed in the area.

The Boggy formation was named by Taff (1899, p. 438-439). The type locality is not specifically located in his report, but it is apparently along Boggy Creek in Atoka and Coal Counties. Later writers agreed with Taff's original delimitation of the formation.

The state geologic map of Oklahoma (1954) set a precedent by redefining the base of the Boggy formation as coincident with the base of the Bluejacket sandstone member. This redefinition excluded the shale underlying the Bluejacket sandstone member from the Boggy formation and assigned it to the upper part of the Savanna formation.

Character and thickness. The top portion of the Boggy formation is removed by erosion in northern Latimer County. The greatest thickness of the formation occurs along the axis of the Sansbois syncline in T. 7 N., Rs. 20 and 21 E. Here the Boggy formation is approximately 2,140 feet thick. Farther west in T. 6 N., Rs. 19 and 20 E. the Boggy forms a topographic feature locally referred to as Yancey Mountain. The formation is approximately 850 feet thick in this mountain. In the western portion of the area in T. 6 N., R. 18 E. the formation is approximately 713 feet thick. Oakes (1948, p. 56) reported the thickness of the Boggy formation in Tucker Knob of southern Haskell County to be 1,100 feet. This thickness includes the shale interval that is now assigned to the Savanna formation. Excluding this shale, the thickness of the Boggy formation at that locality is estimated at 600 feet. According to Hendricks (1937, p. 272) 4,000 feet of the formation is present in Cavanal Mountain near Poteau, Oklahoma.

In the area of this report the Boggy formation consists primarily of thick shale units alternating with 8 to 10 mappable sandstone zones. The sandstone units shown on the geologic map

consist, in most instances, of thin-bedded to massive, fine-grained sandstone beds intercalated with silty shales. At some localities the sandstones lose identity and apparently grade into shale. At many localities their dip slopes are exposed over a considerable area.

Figure 8. Exposure of black shale in the Boggy formation in Beaver Creek as observed in sec. 21, T. 6 N., R. 18 E.

The shales in the Boggy formation are predominantly covered by residual debris. At widely scattered localities they are exposed in part as brown to dark gray to black shales with clay ironstone concretions included within them. They are also commonly firm and blocky. The shale that overlies sandstone IPb-1 is well exposed in its lower portion in sec. 21, T. 6 N., R. 18 E. (see measured section 4 and figure 8). Elliptical nodules, lying approximately 503 feet above the base of the Boggy formation, occur in a thin zone of this shale. They average five inches in diameter and are black. Their density is such that they offer strong resistance to fracture.

The basal unit of the Boggy formation is the Bluejacket sandstone member. It is a prominent escarpment-forming bed in the central and eastern portion of the area. In these localities its thickness varies between 154 and 266 feet. In the western portion it is prominently exposed in the escarpment overlooking Lake Carlton (see figure 2), but loses a part of its topographic prominence along its outcrop west of the Latimer-Pittsburg County line. At this locality it averages 100 feet in thickness. The thickness, as well as the upper contact, of the Bluejacket sandstone member is determined with difficulty because the upper portion is almost everywhere distributed down a long dip slope. The top contact of the Bluejacket, as well as the top of the sandstone beds above, were drawn from aerial photographs along slope breaks and subsequent streams.

The sandstone beds of the Bluejacket sandstone member are generally brown to buff, fine- to medium-grained, massive. The contact with the overlying shale is covered with ripple marks in many localities. Over most of the area the Bluejacket sandstone member consists of two massive sandstone beds, upper and lower, with an intervening shale. An exposure of this shale in sec. 5, T. 6 N., R. 21 E. reveals a grayish-green color, a fissile to blocky appearance, and the presence of clay ironstone concretions. At other localities it is covered. Toward the western extremity of the area the upper and lower sandstone beds in the Bluejacket sandstone member are differentiated with difficulty.

The Bluejacket sandstone was described originally by Ohern (1914, p. 28-29) from the hills near the town of Bluejacket, Craig County, Oklahoma. Howe (1951, p. 2090) redefined the type section more specifically in an area along the road from Bluejacket west to Pyramid Corners, in the east slope of Timbered Hill. This type section is located in the NE¼ NE¼ sec. 25, T. 27 N., R. 20 E. Mapping by Wilson (1935, p. 508-509, Dane and Hendricks 1936, p. 312-314), and Dane and others (1938) enabled the correlation of the Bluejacket sandstone member over a wide area in eastern Oklahoma.

The outcrop pattern of the Bluejacket sandstone delineates the extent of the Sanbois syncline except in T. 6 N., R. 19 E. where there is a high on the structural axis of the syncline.

Strata above the Bluejacket sandstone member in the eastern part of the area total approximately 1,900 feet in thickness. The stratigraphic sequence consists of seven sandstone units with intervening shales (see geologic map). In the western portion of the area the strata of the Boggy formation higher than the Bluejacket sandstone member total approximately 600 feet in thickness and consist of four main sandstone units and intervening shales.

In sec. 34, T. 7 N., R. 21 E. is an outcrop of what is tentatively mapped as the Secor coal. This seam lies 170 feet above the top of the Bluejacket sandstone member shown on the geologic map as IPbb. The coal is 10 inches in thickness. It generally coincides with the Secor horizon of adjacent regions. Dane and others (1938, p. 162) reported coal seams 200 feet, 240 feet, and 265 feet respectively, above the Secor coal in the Quinton-Scipio district. Equivalents of these coals were not found in the area.

Figure 9. Rectangular joint pattern exposed on bedding plane of the sandstone, Pb-2a, in the Boggy formation. Located in SW¼ SW¼ SE¼ sec. 25, T. 6 N., R. 17 E.

Calamites and *Stigmaria* were observed in relative abundance in the Boggy formation. Fucoidal markings are also abundant. Hendricks (1937, p. 23) reported the common occurrence of *Sigillaria, Lepidodendron,* and *Calamites* in the sandstones of the Boggy formation in the McAlester district.

Distribution. The Boggy formation is restricted to the synclinal areas. It occupies a large part of the area, occurring in three disconnected localities. In the northeastern portion it forms a series of rugged hills (Sansbois Mountains) which extend from the eastern boundary to the point where the axis of the Sansbois syncline rises in secs. 14 and 23, T. 6 N., R. 19 E. It is present for a short distance in the north-central portion in secs. 28, 29, and 31, T. 7 N., R. 19 E; from which place it dips into the Panther Mountain syncline in Haskell County. The formation is present in the western portion from a point where the axis of the Sansbois syncline plunges in secs. 13 and 24, T. 6 N., R. 18 E. to the Latimer-Pittsburg County line.

The Boggy formation is widespread throughout the coal basin on the shelf to the north.

Stratigraphic relations. The Boggy formation appears to be generally conformable with the underlying Savanna formation in the area of this report (see figure 14). A few local occurrences of channeling suggest the possible existence of a minor unconformity in some localities. Oakes (1948, p. 57) described this horizon in Haskell County as being conformable. An unconformity exists at the base of the Boggy formation in the Stonewall Quadrangle (Morgan, 1924, p. 78).

QUARTERNARY SYSTEM

Flood Plain Deposits

Alluvial deposits occur in a small part of the area. These deposits consist of unconsolidated sands, silts, and clays with included recent organic matter. Their color ranges from brown to gray to black. Over the greatest part of the area their distribution is restricted to the narrow V-shaped valleys of high-gradient streams. Under such conditions alluvium is absent or only a few inches thick.

A more significant deposit occurs in the flood plain of Fourche Maline Creek in sec. 31, T. 6 N., R. 19 E. The thickness at this locality is estimated to be 30 to 40 feet.

A relatively thick deposit of alluvium is also present two miles north of the village of Red Oak. This deposit lies in the Flood plain of Brazil Creek along the south limb of the Brazil anticline. At this locality numerous "pimple mounds" occur on the flat, soil-covered surface of the alluvium. These mounds average 2 to 3 feet in height and approximately 40 feet in diameter. Hypotheses for their origin were presented by Melton (1954, p. 109) and Knechtel (1952, p. 689).

STRUCTURAL GEOLOGY

Regional Environment

The area lies within a larger zone of folded Pennsylvanian strata characterized by broad shallow synclines and narrow anticlines. The axes of these structures are commonly en echelon and are generally parallel to the frontal margin of the adjacent Ouachita salient. The intensity of deformation in the zone of open folds in the Arkansas Basin decreases to the north, The name McAlester Basin is applicable to this thick sequence of folded sedimentary strata.

Many writers consider the Ouachita Mountains to be an allochthonous series of huge thrusts with a root somewhere to the south. The Choctaw fault is designated in such cases as the structural boundary between the open fold zone and the Ouachita thrust zone. A recent publication by Misch and Oles (1957, p. 1899-1905) supports an authochthonous origin of the Ouachita Mountains. The authors, in blunt contradiction to previous hypotheses, write " there are no indications of flat overthrusting in the Ouachita Mountains."

The age of the Ouachita orogeny is controversial. According to Huffman (personal communication, 1957), pulsations occurred in Middle Mississippian, post-Morrowan-pre-Atokan, post-Boggy-pre-Thurman, and possibly in Late Virgilian time. Eardley (1951, p. 209) suggested Late Mississippian as the time of the first pulsation on the basis of an unconformity between the Arkansas novaculite and the Caney shale. Miser (1929, p. 26) and Van der Gracht (1931, p. 1022) assigned the time of the orogeny to Middle or Late Pennsylvanian. Melton (1930, p. 71) considered the orogeny to be early Permian.

Local Structural Features

Structures in the area of this report reflect the powerful influence of the Ouachita salient. The Choctaw fault as defined by Miser (1954) lies approximately four miles south. The general asymmetric attitude of the folds in the southwestern part lends support the theory of thrust from the south (see structure section A-A', Plate I). Folds in the eastern part display more symmetrical profiles (see structure sections B-B' and C-C', Plate I). Taff (1900, p. 283) observed the same structural characteristics in his description of the Sansbois syncline. Thus, it appears that vertical pulsations may have contributed more impetus to the folding of the eastern structures than did horizontal thrusts. Misch and Oles (1957, p. 1902) add strength to this hypothesis. They state that they strongly folded marginal belt of the Ouachita Mountains grades northward without any structural break into the more gentle folds of the coal basin east of the village of Red Oak. The postulated extension of the Choctaw fault eastward into Arkansas is discounted. The presence of the Choctaw fault south of the western part of the area is not denied. A westward increase of thrust force along the Choctaw fault probably accounts for the convergence of the axes of the Brazil anticline and the Cavanal syncline with the south flank of the Sansbois syncline in the southern portion of T. 6 N., R. 20 E. On the basis of these observations, it seems evident that the structures in the area were found by both horizontal and vertical movements.

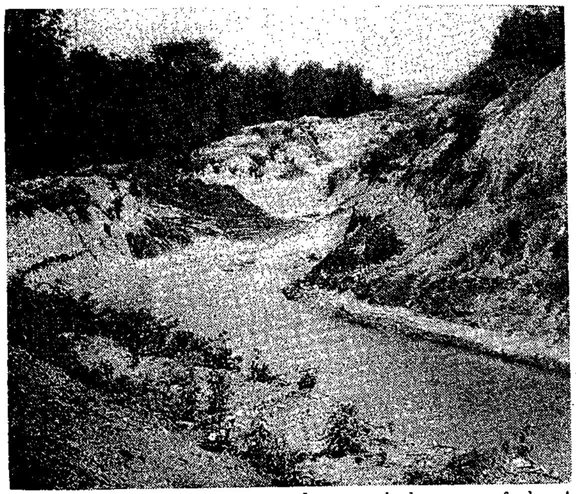

Figure 10. Strip pit of Hartshorne coals around the nose of the Adamson anticline. The dip in foreground in 85°, and that in background on opposite side of the Carbon fault is 15°. SW¼ NE¼ SW¼ NE¼ sec. 35, T. 6 N., R. 18 E.

Structural thinning of thick shale units occurs along the flanks of some structures. Measured sections in the vicinity of plunging structural axes reveal a thickening of the same shales. This phenomenon was also observed by Hendricks (1937, p. 45) in the McAlester district.

The structural configuration of the area is clearly delineated by topography and drainage patterns.

Joints exist in abundance. Their directional orientation is generally northwest-southeast (see figure 9).

Normal faults of small magnitude were identified at a few localities. Their trace is rendered indistinct by dissipation in incompetent shales and by cover. Two such faults were mapped in secs. 5 and 6, T. 6 N., R. 19 E. at the convergence of the structural axes of the North Wilburton fold and the Burning Springs anticline in a zone between the Sansbois and Panther Mountain synclines. The distribution of outcrops in this locality is abnormal and the rocks are probably ruptured by several small faults not evident on the surface.

Carbon Fault

A coal strip pit excavated during 1956 exposes the unquestionable presence of the Carbon fault in the vicinity of C N½ sec. 35, T. 6 N., R. 18 E. At this locality it severs the Hartshorne formation in the nose of the Adamson anticline so as to display opposing dips of 85° and 15° on the north and south fault blocks respectively. The Hartshorne coals are discontinuous across the fault zone (see figure 10). This fault dissipates in the overlying McCurtain shale. It is hypothetically extended through the subjacent Atoka formation to the southwest corner of sec. 32, T. 6 N., R. 18 E. The strike of the fault plane is drawn coincident with the axis of the Adamson anticline. The nature of movement along the southward-dipping fault plane appears to have been that of a scissors motion. The negligible amount of displacement of strata across this fault indicates the presence of a hinge point near the surface exposure of the fault plane. It is estimated that the opposing fault blocks rotated approximately 70° in relation to each other. Slickensides were found near the fault zone in the waste heaps from the strip pits.

Adamson Anticline

This asymmetrical structure lies in the southern tier of sections in T. 6 N., R. 18 E. Steeply dipping beds on the north flank contrast to the gently dipping strata on the south (see figure 11). The Carbon fault severs beds of the Atoka formation along the crest of the fold. The axis of the open-type fold plunges steeply into the subsurface in sec. 35, T. 6 N., R. 18 E.

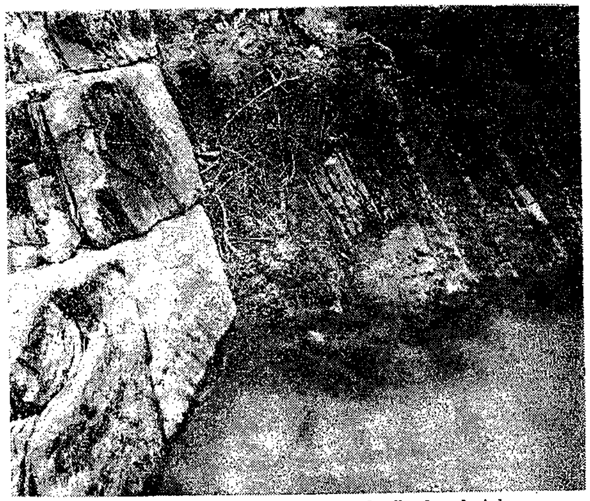

Figure 11. Lower Savanna sandstone on north flank of Adamson anticline dipping 65° N. as seen in bed of Beaver Creek in SW¼ SW¼ SE¼ sec. 28. 6 N., R. 18 E.

Sansbois Syncline

The dominant structural feature in the area is the Sansbois syncline. It extends in a WSW-ENE direction throughout the length of the area. The western portion is strongly asymmetrical with steeply dipping strata on the south flank. The eastern portion is essentially symmetrical, with equal dips on both the north and south flanks. The form of the syncline is altered by a structural high on the axis across the middle of T. 6 N., R. 19 E. At this locality the structure is undulating and irregular and is difficult to recognize as synclinal. The strata cropping out on the south flank of the Sansbois syncline in T. 6 N., R. 20 E. are contorted at its convergence with the axes of the Brazil anticline and the Cavanal syncline. Isolated mesa-like outliers supported by strata in the Boggy formation lie at random intervals along the greater length of the axis.

Burning Springs Anticline

Generally low dips characterize either flank of this wide flat anticline, which lies in the northwest corner of the area. At this locality only the eastern extent of the fold is present. The axis plunges ENE so as to define crescentic outcrop patterns in the

lower part of the Savanna sandstone zone.

A well drilled by the Empire Gas Company during 1930 lies west of the area in sec 9, T. 6 N., R. 17 E. Gas is still seeping from this well. Other tests have been drilled on both ends of this structure with small shows of gas (Colton, 1935, p. 529), but the structure is not commercially productive.

North Wilburton Fold

This anticlinal fold is 8 miles north of Wilburton, Oklahoma, in Townships 6 and 7 North, Range 19 East. The southeastern extent of the southwest-northeast trending axis is marked by the presence of a dome in secs. 3 and 4, T. 6 N., R. 19 E. In effect, this feature is a "knob" on the end of the southwestward plunging anticline. The cuestas circumscribing this dome are formed in the lower sandstone zone of the Savanna formation. The dips along the flanks range between 2 and 5 degrees. It appears that this structure is a continuation of the same structure mapped in Haskell County as the Milton anticline (Oakes, 1948, p. 65-66).

An early test well encountered gas in non-commercial quantities in a sandstone of the McAlester formation at a depth of 1,482 feet. There was practically no sand at the horizon of the Hartshorne formation. No production was found in the upper part of the Atoka formation. According to Colton (1935, p. 529) this fold has structural reversal with depth. He further states that the structure is of secondary origin and occupies the "lows" of a low area in Hartshorne time.

Brazil Anticline

A portion of this broad structure lies in the eastern part of of the area. It begins in sec. 13, T. 6 N., R. 20 E. at which place the axis rises at an angle of 15 degrees from the south flank of the Sansbois syncline. It extends to the east boundary of the area and beyond. Its surface development is in the upper part of the McAlester formation in the form of a wide valley. Inliers of the Cameron sandstone member and the subjacent shale IPm-1 are exposed near the axis in the middle part of the eastern half of T. 6 N., R. 21 E.

The Red Oak gas field is situated over this structure. Gas was produced from the Hartshorne formation at depths of 1,450 to 1,770 feet (Colton, 1935, p. 518). Porosity and permeability of the sandstones vary to such a degree that estimation of production, regardless of position on structure, is impossible. At the present time gas from the wells is shut in or used only by local inhabitants.

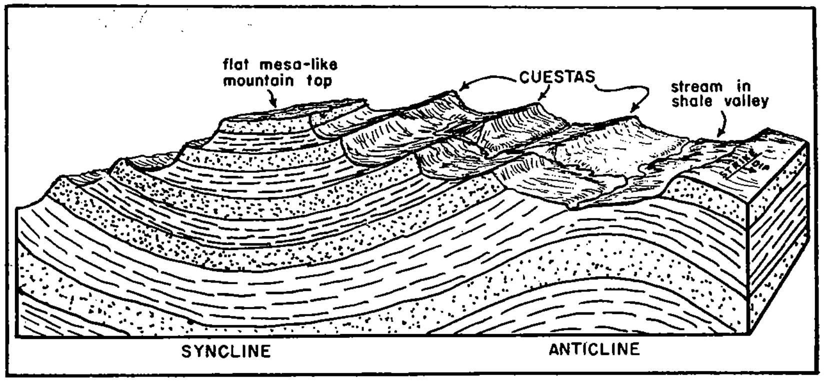

Figure 12. Diagram of synclinal mountain in Robbers Cave State Park area.

Cavanal Syncline

Only the extreme western extent of this structure lies in the area. Its topographic expression defines a mountain in the southwest part of T. 6 N., R. 21 E. which rises abruptly from the surrounding plain of the upper part of the McAlester formation. Sandstone beds of the lower part of the Savanna support the abrupt escarpment above the McAlester plain (see structure section C-C', Plate I) A structural high on the axis of this shallow, canoe-like syncline occurs approximately one mile north of the village of Red Oak. This accounts for the erosional interruption of its continuity along the south flank of the Brazil anticline.

GEOLOGIC HISTORY

Sedimentation in a subsiding geosyncline occurred throughout the geologic history of the coal basin. Branson (1953, p. 83) states that it was a true geosyncline from the beginning of Atoka time to the end of Desmoinesian time. The uplift of the Hunton Arch and the Ozark Arch terminated the first stage of Pennsylvanian history with the resultant regression of the sea into the trough of the incipient coal basin. Coarse clastic sediments of Atoka age were deposited by this retreating sea (Dott, 1927, p. 12). The post-Morrowan uplift of the Ouachita Mountains, as well as the

Hunton Arch, created source areas for these sediments (Dott, 1941, p. 1669-1670). Throughout that part of Early Pennsylvanian time subsequent to Atoka deposition, the shoreline of the geosynclinal sea transgressed intermittently northwestward, and the margin of the coal basin shifted accordingly (Weirich, 1953, p. 2027). Continued subsidence of this unstable basin resulted in a thick accumulation of clastic sediments of the Hartshorne, McAlester, Savanna, and Boggy formations.

Deposition of these sediments occurred in shallow seas which probably did not exceed a hundred feet in depth. The low degree of porosity and permeability and the high silt content of sandstones points to their classification as "dumped deposits." This classification was originated by Weeks (1952, p. 2107). The load of sediments apparently exceeded the carrying power of the transporting streams in extensive estuarine areas and nullified the sorting process of wave action. In part, the sediments may have encroached into the sea in deltaic fashion. The bedding planes of several Savanna sandstones are interrupted by oblate "rolled masses." These irregular features could have been formed by gradational movement along the foreset beds of deltas. Cross-bedding, present in many of the sandstones, could be explained as related to deltas.

Such an environment of deposition, coupled with intermittent regressions of the epeiric seas, caused the sea bottom to be emergent for rather long periods of time. The basinal sediments were probably non-marine for longer durations than were those of the shelf area on the north (Branson, 1954, p. 1). The resultant landscapes were of monotonously low relief and were barely above sea level. Abundant plant remains suggest landscapes covered by luxuriant flora. The climate was apparently warm and humid. Euxinic environments in the marshy shallaws of post-Atokan time preserved the organic remains which now appear as coal seams in the stratigraphic column. Sluggish streams traversed the emergent lowlands, leaving their record as channel deposits.

With continued deposition, subsidence recurred intermittently. Whether the subsidence was the cause of sedimentation, or the load of accumulated sediments the cause of subsidence is a point of conjecture. De Sitter (1956, p. 350) is of the opinion that compression causes the sinking of a basin. Thin and widely spaced horizons of marine invertebrate fossils indicate only brief durations of the resultant transgressions of the sea. The turbid waters of this paralic environment hindered abundant growth of invertebrate life.

Mild tectonic pulses at the end of Atoka, McAlester, and Savanna time account for regional unconformities at those horizons. Evidence of their existence is not everywhere present in the coal basin. The absence of profound unconformities and the general concordance of the folded stratigraphic layers in the area indicate that all the strata were deformed at the same time. Thus, the age of folding can locally be considered as post-Boggy.

ECONOMIC GEOLOGY

The most important mineral resource of northern Latimer County is coal. The Upper and Lower Hartshorne coals and the Upper and Lower McAlester coals attain a thickness sufficient to merit commercial exploitation in the southern part. Recent strip mining activity in the southeastern portion has uncovered seams of the Lower and Upper Hartshorne coals 6 feet and 4 feet thick respectively. Operations are presently suspended (see figure 10).

During the last phases of field work in August, 1957, new surface cuts were being stripped on the Upper and Lower McAlester coal horizons immediately south of the area in secs. 3 and 4, T. 5 N., R. 19 E. (see figure 12). The average thickness of each of the McAlester coal seams in this locality is 1.5 feet. These same horizons were stripped around the structural nose and flanks of the Brazil anticline during 1954 (Mr. C. W. Allen, personal communication, 1957).

The exploited coals are of high quality. Their characteristics are comprehensively discussed by Hendricks (1939, p. 279-284) in the overlapping Howe-Wilburton district.

Several thin seams, including the Secor coal of the Boggy formation, occur in the section in addition to the Hartshorne and McAlester coal horizons. These are not commercial.

Commercial quantities of natural gas have been produced in the Red Oak gas field. Production was from the Hartshorne sandstone in the Brazil anticline. Most of the gas has been shut in.

Shows of gas have been encountered in the Burning Springs anticline and the North Wilburton fold, but these structures are not commercially productive.

Geologic structures favor the accumulation of petroleum in parts of the area, but none is produced. The absence of liquid hydrocarbons may be ascribed to high fixed carbon ratios of the surrounding coal region and to the lack of source beds and permeable reservoir rocks.

SUMMARY

The rocks cropping out in northern Latimer County, Oklahoma, constitute about 7,500 feet of the upper part of the Atoka, Hartshorne, McAlester, Savanna, and Boggy formations. Terrestrial environments prevailed during the deposition of the clastic sediments of the coal basin. The Upper and Lower Hartshorne coals coalesce on the north flank of the Adamson anticline to an aggregate thickness of 10 feet.

The sandstone IPsv-9 of the Savanna formation is correlated in this report with the Spiro sandstone member of the Savanna formation in the Muskogee-Porum district.

Structures are present in the form of the Burning Springs, Adamson, and Brazil anticlines, the North Wilburton fold, and the Sansbois and Cavanal synclines. These anomalies lie in the open fold zone of the coal basin and are readily perceptible by surface mapping. The eastern extent of the Carbon fault is dissipated in a scissors type movement along the fault plane.

The most important resource of the area is coal.

Small quantities of natural gas have been produced from the Red Oak field, but there is no present production.

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APPENDIX

MEASURED STRATIGRAPHIC SECTIONS

1. HARTSHORNE FORMATION, MEASURED AT ABANDONED RAILROAD CUT, SW¼ SE¼ SE¼ SECTION 31, T. 6 N., R. 18 E.

Formational Description	Thickness in feet
Hartshorne Formation:	
Tobucksy sandstone member:	
Sandstone, gray to brown, fine to medium grained, silty, micaceous, ripple marks, dense, massive, thin-bedded white to gray sandstone in upper 10 feet	27.3
Sandstone, covered, exposed in upper 3 feet as gray, fine-grained, micaceous, thin-bedded with gray shale intercalations	38.2
Sandstone, gray to brown, fine-grained, micaceous, ripple marks, dense, massive	19.1

2. PORTION OF BOGGY FORMATION, TAKEN FROM TRAIL INTERSECTION SE¼ SE¼ NE¼ SECTION 24, T. 6 N., R. 17 E. IN A SOUTHEAST DIRECTION TO THE TOP OF THE MOUNTAIN IN THE VICINITY OF C. SECTION 19, T. 6 N., R. 18 E.

Formational Description	Thickness in feet
Boggy Formation:	
Sandstone (IPb-3) brown to buff, fine-grained, magnetite grains. micaceous, dense, massive	27.5
Shale covered	55.0
Sandstone (IPb-2) brown, fine-grained, silty, thin-bedded with shale intercalations	40.0
Shale:	
Shale, covered	94.8
Sandstone, brown, fine-grained, thin-bedded intercalations with silty shale	11.6
Shale, covered	31.4
Sandstone (IPb-1b) brown to buff, fine-grained, dense, massive, not measured.	

3. PORTION OF THE BOGGY FORMATION, TAKEN FROM SE¼ NE¼ SE¼ SECTION 29, T. 6 N., R. 18 E. IN A NORTHWEST DIRECTION ALONG TRAIL TO VICINITY OF NW CORNER SECTION 29, T. 6 N., R. 18 E.

Formational Description	Thickness in feet
Boggy Formation:	
Shale, not measured.	
Sandstone (IPb-2) brown, fine-grained, micaceous, dense, massive to thin-bedded	36.9
Shale:	
Shale, covered	33.0
Shale, dark gray to brown, blocky	38.2
Shale, covered	23.5
Shale, brown, silty, blocky, interbedded with silty, brown sandstone	21.9
Shale, covered	54.5
Sandstone (IP-1b) brown to buff, fine-grained to silty, dense thin-bedded, intercalated with thin silty shale partings	18.6

Shale:	
Shale, covered	27.9
Shale, dark gray to brown, silty to clayey, clay ironstone concretions	3.8
Sandstone (IPb-1a):	
Sandstone, buff, fine-grained to silty, dense, thin-bedded to massive	14.9
Shale, green to brown, blocky	7.8
Sandstone, brown to buff, fine-grained, dense, thin-bedded to massive	26.3
Shale, covered	214.1
Bluejacket sandstone:	
Sandstone, brown to buff, fine-grained, ripple marks, dense, massive	18.5
Sandstone, silty, covered	68.9
Sandstone, brown, fine-grained, micaceous, ripple marks, dense, massive	22.4
Savanna Formation:	
Shale, covered	178.5

4. PORTION OF BOGGY FORMATION, TAKEN FROM SW¼ NE¼ SE¼ SE¼ SECTION 21, T. 6 N., R. 18 E. IN VICINITY OF LARGE POND NORTHWARD ALONG BEAVER CREEK ¼ MILE TO JUNCTION WITH TRIBUTARY.

Formational Description	Thickness in feet
Boggy Formation:	
Shale:	
Shale, dark gray to brown, firm, silty, blocky	20.0
Siltstone, brown, dense, irregular bedding undulations	2.0
Shale, dark gray, firm, blocky, intercalated with sand stringers one inch thick	10.0
Shale, black, firm, hackly to blocky, intercalated with thin sandstone stringers	4.0
Sandstone, brown, silty, micaceous, stained by limonite	1.5
Siltstone, brown, dense ferruginous	0.5
Shale, black, firm, hackly to blocky, clay ironstone concretions	8.0
Shale, black, firm, hackly to blocky, elliptical chert-like nodules at top	3.0
Shale, covered	76.4
Sandstone (IPb-1b), not measured.	

5. SAVANNA, AND PORTIONS OF McALESTER AND BOGGY FORMATIONS, MEASURED FROM CAMERON SANDSTONE OUTCROP IN SW¼ SW¼ NE¼ NE¼ SECTION 33, T. 6 N., R. 18 E. NORTHWARD ALONG BEAVER CREEK TO VICINITY OF CENTER SECTION 28, T. 6 N., R. 18 E.

Formational Description	Thickness in feet
Boggy Formation:	
Bluejacket sandstone:	
Shale, not measured.	
Sandstone, buff, fine-grained, dense, massive, interbedded with silty shale	44.8

Savanna Formation:	
Shale:	
Shale, covered	40.0
Shale, brown to gray, silty, blocky, covered in lower portion	40.8
Sandstone (IPsv-3):	
Sandstone, brown, fine-grained to silty, dense, thin-bedded, interbedded with silty shale partings	7.1
Shale, black, carbonaceous, trace of coal	1.0
Sandstone, brown, fine-grained to silty, dense, thin-bedded with silty shale partings	14.3
Shale, dark gray, silty, blocky in lower portion grading up into brown with abundant clay ironstone concretions	7.5
Sandstone, white to tan, fine-grained, micaceous, dense, thin-bedded, with thin siltstone at top	14.0
Shale, black, carbonaceous, trace of coal	0.5
Shale, gray, blocky	13.7
Shale, black, carbonaceous, trace of coal	1.0
Sandstone, white to tan, fine-grained to silty, thin-bedded intercalations with thin silty shale partings	5.0
Shale, gray to green, fissile to blocky, interbedded with thin sandstone stringers	10.0
Sandstone, white to brown, fine-grained, dense, massive, pronounced bedding plane undulations	17.5
Shale, brown to gray, silty to blocky, clay ironstone concretions	67.4
Shale, covered	76.9
Sandstone, gray in lower 10 feet, grading up into brown, fine grained to silty, dense, massive, intercalated with undulating silty shale partings	62.9
Shale, covered	546.4
Sandstone (IPsv1), brown, fine-grained, micaceous, dense, massive	30.0
Shale, covered	16.5
Shale, dark gray, firm, blocky, clay ironstone concretions	10.0
Shale, black, carbonaceous, trace of coal	1.5
Clay, gray	1.0
Shale, dark gray, silty, firm, blocky	41.6
Sandstone, brown, fine-grained, dense, massive, thin silty shale partings	34.6
Shale, gray, silty, fissile, interbedded with thin silty, sandstone stringers	25.3
Sandstone, brown, silty, micaceous, thin-bedded with thin silty shale partings	18.4
Shale, covered	89.1
Sandstone, brown, fine-grained micaceous, dense, interbedded with silty shale partings, ripple marks on upper contact	24.6
Shale, gray to brown, silty, fissile, interbedded with siltstone stringers	29.7
Sandstone, brown, fine-grained, micaceous, dense, thin- bedded	12.3
Shale, gray, silty, blocky, clay ironstone concretions	49.5
Sandstone, brown, fine-grained, micaceous, dense	3.0
Shale, gray to green, silty, blocky	10.0
Sandstone, brown, fine-grained, micaceous, dense	3.1
Shale, gray to green, silty, fissile to blocky, interbedded with silty sandstone stringers	31.1
Sandstone, brown, fine-grained, micaceous, dense, thin-bedded intercalations with silty shale partings	13.5
Shale, covered	46.6
Sandstone, brown, fine-grained to silty, dense, massive, interbedded with thin silty shale partings	66.4

McAlester Formation:	
Shale:	
Shale, covered	110.1
Sandstone, brown, fine-grained, micaceous, (Keota sandstone member?)	1.0
Shale, covered	157.0
Sandstone, brown, fine-grained, silty, micaceous, thin-bedded, (Tamaha sandstone member ?)	4.2
Shale, covered	421.7
Cameron sandstone, brown, fine-grained, micaceous, dense, massive in lower 20 feet grading up into silty, thin-bedded	44.4

6. PORTION OF BOGGY AND SAVANNA FORMATIONS, TAKEN FROM NE¼ SE¼ NW¼ SE¼ SECTION 2, T. 6 N., R. 18 E. SOUTHWARD TO TOP OF CUESTA IN VICINITY OF NE CORNER SECTION 15, T. 6 N., R. 18 E.

Formational Description	Thickness in feet
Boggy Formation:	
Sandstone (IPb-1b), brown, fine-grained, dense, massive, lower contact indeterminate	
Shale, covered, thickness indeterminate	93.5
Sandstone (IPb-1a), brown, fine-grained, dense, massive to thin-bedded, upper contact indeterminate	
Shale:	
Shale, covered	187.0
Sandstone, covered, forms topographic bench	11.0
Shale, covered	152.0
Sandstone, covered, forms topographic bench	8.0
Shale, brown, silty, micaceous, fissile, clay ironstone concretions	27.0
Bluejacket sandstone:	
Sandstone, buff to brown, fine-grained to silty, micaceous, dense, thin-bedded to massive, ripple marks on upper contact, interbedded with thin shale partings	19.4
Sandstone, shaly, covered	30.2
Sandstone, brown, fine-grained, micaceous, ripple marks, interbedded with thin shale partings	10.9
Savanna Formation:	
Shale, covered	199.4
Sandstone (IPsv-3):	
Sandstone, tan to white to buff, fine-grained, dense, thin-bedded to massive	30.8
Shale, covered	107.8
Sandstone, brown, fine-grained to silty, dense, thin-bedded to massive	84.1
Shale, covered	63.2
Sandstone, brown, fine-grained to silty, thin bedded to massive	75.4
Shale, green to dark gray, silty, blocky, clay ironstone concretions	47.9
Siltstone, buff, dense, ferruginous, ripple marks, interbedded with thin silty shale partings	10.9

7. HARTSHORNE FORMATION AND PORTION OF ATOKA FORMATION, MEASURED FROM A POINT APPROXIMATELY 840 FEET WEST OF SW CORNER SECTION 35, T. 6 N., R. 18 E., IN AN EASTWARD DIRECTION ALONG SECTION-LINE ROAD TO STRIP PIT OF UPPER HARTSHORNE COAL SE¼ SW¼ SW¼ SECTION 36, T. 6 N., R. 18 E.

Formational Description	Thickness in feet
Hartshorne Formation:	
Upper Hartshorne:	
Coal, Upper Hartshorne	4.0
Sandstone, gray to brown, fine-grained, silty, micaceous, thin-bedded	64.4
Coal, Lower Hartshorne	6.0
Tobucksy sandstone:	
Sandstone, white to tan, silty, micaceous, thin-bedded with thin silty shales	38.7
Shale, green to brown, silty, clay ironstone concretions, interbedded with thin sandstone and siltstone stringers	64.9
Sandstone, buff to white, fine-grained, micaceous, ripple marks, fucoids, thin-bedded with silty shale partings	26.9
Sandstone, brown, fine-grained, ferruginous, dense, ripple marks, thin-bedded with silty shale partings	12.2
Sandstone, shaly, covered	28.4
Shale, covered	9.8
Sandstone, gray to white, fine-grained, micaceous, dense, ripple marks	2.4
Shale, gray, silty, micaceous, blocky to fissile, clay ironstone concretions	19.6
Sandstone, gray to white, fine-grained, silty micaceous, ripple marks, thin-bedded with silty shale partings	4.9
Shale, gray, silty, fissile	9.8
Siltstone, brown, dense, interbedded with thin shale partings	9.8
Sandstone, light tan to white, fine-grained, micaceous, dense, thin-bedded with thin silty shale partings	14.7
Atoka Formation:	
Shale, gray, mottled with brown, silty, covered in lower 20 feet	63.2
Shale, gray, mottled with brown, silty, interbedded with thin siltstone stringers	203.2
Sandstone, light tan to brown, fine-grained, silty, micaceous, dense, thin-bedded, with thin shale partings	33.8
Shale, gray, mottled with brown, silty, fissile to blocky, intercalated with thin siltstone stringers	148.1
Shale, brown to gray, silty, micaceous, interbedded with sandstone stringers	20.1
Sandstone, brown, fine-grained, micaceous, in beds 1 inch to 18 inches, interbedded with thin, silty shale partings	8.0
Shale, green to brown, silty, blocky to fissile	63.0
Sandstone, brown, fine-grained, micaceous, dense, thin-bedded with thin silty shale partings	4.5
Shale, brown, silty, fissile, interbedded with thin sandstone and siltstone stringers	18.0
Siltstone, brown, micaceous, dense, beds up to one foot thick interbedded with thin silty shale partings	15.5
Shale, dark gray to brown, silty, fissile to blocky	116.4
Shale, covered by soil	538.0

8. McALESTER AND PORTIONS OF SAVANNA AND HARTSHORNE FORMATIONS, TAKEN FROM CENTER NORTH ½ SECTION 35, T. 6 N., R. 18 E. TO CENTER WEST ½ SECTION 26, T. 6 N., R. 18 E.

Formational Description	Thickness in feet
Savanna Formation:	
Shale, covered	455.8
Sandstone (IPsv-1):	
Sandstone, brown, fine-grained, dense, massive to thin-bedded	9.8
Shale, covered, lower contact indeterminate } Sandstone, brown, fine-grained, dense, massive, top covered	181.3
Shale, covered, lower contact indeterminate } Sandstone, brown, fine-grained, dense, thin-bedded to massive, with thin, silty shale partings, top covered	429.1
McAlester Formation:	
Shale:	
Shale, covered	359.7
Shale, dark gray to brown, silty, blocky, clay ironstone concretions	50.6
Shale, brown, silty, fissile	43.3
Sandstone, (Tamaha member ?), brown fine-grained, silty, micaceous, dense, thin-bedded, with thin, silty shale partings	13.2
Shale, black to brown, fissile, clay ironstone concretions, interbedded with gray, silty sandstone stringers	86.5
Coal, Upper McAlester	1.5
Clay, gray	1.0
Shale, dark gray to brown, firm, blocky, clay ironstone concretions	28.3
Shale, brown, silty, fissile, interbedded with thin, gray siltstones	41.4
Coal, Lower McAlester	1.6
Shale, brown, silty, fissile, interbedded with thin, gray siltstone stringers	88.4
Cameron sandstone:	
Sandstone, brown, fine-grained, silty, thin-bedded, ripple marks, with thin, silty shale partings	4.0
Shale, brown, silty, fissile	10.0
Sandstone, brown, fine-grained, silty, thin-bedded with thin, silty shale partings	9.0
Sandstone, brown, fine-grained, silty, dense, thin-bedded to massive	24.0
Shale, covered	210.7
Warner sandstone, brown, fine-grained, silty, thin-bedded to massive	77.1
McCurtain shale:	
Shale, black to brown to gray, silty, fissile to blocky, thinly laminated with silty sandstone stringers, *Calamites*	24.5
Shale, covered, with brown sandstone of indeterminate thickness at base	319.8
Shale, covered	583.4
Shale, brown to black, silty, fissile to blocky, thin laminations of silty sandstone, abundant clay ironstone concretions	32.5
Shale, dark gray, blocky	1.0

Formational Description	Thickness in feet
Hartshorne Formation:	
Upper Hartshorne:	
Shale, black, carbonaceous, thinly laminated	1.8
Coal, Upper Hartshorne	4.0
Shale, black, carbonaceous	0.5
Coal, Lower Hartshorne	6.0
Shale, black, carbonaceous, plant remains	0.5
Tobucksy sandstone:	
Sandstone, white to brown, fine-grained, silty, thin-bedded with thin silty shale partings	2.3
Shale, gray, silty, fissile	4.6
Sandstone, white to tan, fine-grained, silty, micaceous, not measured.	

9. SAVANNA AND PORTION OF BOGGY FORMATION, TAKEN FROM NE¼ NE¼ NE¼ NE¼ SECTION 4, T. 6 N., R. 19 E. NORTHWESTWARD ALONG STATE HIGHWAY 2 TO HASKELL COUNTY LINE IN SECTION 29, T. 7 N., R. 19 E.

Formational Description	Thickness in feet
Boggy Formation:	
Bluejacket sandstone:	
Sandstone, shaly, gray to brown, micaceous, thin-bedded with thin silty shale partings	60.0
Sandstone, white to light gray in lower portion grading up into brown, fine- to medium-grained, micaceous, dense, thin-bedded to massive, channeling	48.8
Savanna Formation:	
Shale:	
Shale, green to gray, silty, fissile to blocky	97.7
Sandstone, buff, fine grained, micaceous, dense, undulating bedding planes	29.6
Shale, dark gray to green, silty, blocky to clayey	59.9
Sandstone (IPsv-3):	
Sandstone, buff, fine grained, silty, ferruginous, ripple marks, fucoids, thin-bedded with thin, silty shale partings	80.6
Shale, green to gray, fissile to blocky, interbedded with thin, silty sandstone stringers	43.5
Sandstone:	
Sandstone, buff, fine grained, micaceous, dense, thin-bedded	4.0
Shale, green, clayey to blocky	21.7
Sandstone, buff, fine grained, micaceous, dense, thin-bedded	32.7
Shale:	
Shale, gray to green, mottled, silty to clayey	49.2
Sandstone, buff, fine grained, thin-bedded	19.9
Shale, green to brown, mottled, silty, clayey to blocky, interbedded with thin, silty sandstone stringers in upper part	89.9
Sandstone, buff, fine grained, silty, thin-bedded	21.8
Shale, covered	60.3
Sandstone (IPsv-1a)	
Sandstone, buff, fine grained to silty, micaceous, dense, thin-bedded	3.5
Shale, green, silty, fissile	10.9
Sandstone, buff, fine-grained, silty, thin-bedded to massive, with thin, silty shale partings	7.5
Shale, black to dark gray, silty, firm, micaceous, fissile to blocky	5.5
Sandstone, buff, fine-grained, dense, thin-bedded, with thin, silty shale partings	5.5
Shale, dark gray to black, silty, micaceous, fissile to blocky	10.9

Shale, green to black, silty, fissile, with trace of coal in thin, black, carbonaceous shale at base	11.0
Shale, gray to green to brown, silty, fissile	5.5
Siltstone, brown, micaceous, dense, interbedded with thin, silty shale partings, trace of coal at base	5.5
Shale:	
Shale, gray, micaceous, fissile, interbedded with thin siltstone stringers	5.4
Shale, covered	54.8
Sandstone, buff, fine-grained, micaceous, dense, thin-bedded	10.9
Shale, green, silty, fissile	5.5
Shale, green, silty, fissile to blocky, plant remains	0.5
Shale, green, silty, blocky, clay ironstone concretions	27.4
Sandstone, brown, fine-grained, silty, micaceous, dense, thin-bedded	5.5
Shale, gray, silty, fissile to blocky	10.9
Sandstone (IPsv-1):	
Sandstone, brown, fine-grained, ripple marks, thin-bedded	1.0
Shale, green, silty, fissile	6.0
Siltstone, brown, dense, thin-bedded	2.0
Shale, green to brown, blocky, clay ironstone concretions	5.0
Sandstone white to tan, fine-grained, dense, massive	10.9
Shale, covered	104.1
Sandstone, buff, fine-grained, dense massive, pronounced undulations in bedding plane	49.3

10. SAVANNA AND PORTIONS OF McALESTER AND BOGGY FORMATIONS. TAKEN FROM ROAD CUT IN CENTER SECTION 31, T. 6 N., R. 19 E. NORTHWARD ALONG STATE HIGHWAY 2 TO VICINITY OF LAKE CARLTON; THENCE WESTWARD THROUGH ROBBERS CAVE UTILITY YARD TO TOP OF ESCARPMENT IN VICINITY OF NW¼ SE¼ SE¼ SW¼ SECTION 13, T. 6 N., R. 18 E.

Formational Description	Thickness in feet
Boggy Formation:	
Bluejacket sandstone, not measured.	
Savanna Formation:	
Shale:	
Shale, covered	220.0
Coal, shaly	0.5
Shale, green, fissile, to blocky, clay ironstone concretions	2.8
Sandstone (IPsv-3):	
Sandstone, brown, fine-grained, dense, massive, thin, silty shale partings, undulating bedding plane	19.3
Shale, green, blocky, with discontinuous traces and flecks of coal in middle portion	16.5
Sandstone, white to tan, fine-grained, massive, undulating bedding plane	17.2
Shale, green to brown, silty to blocky, partly covered	25.5
Sandstone, buff, fine-grained, silty, dense, massive	27.2
Shale, black to dark gray, firm, blocky, channeling, fossil tree stump with coalified bark on roots in middle part	13.5
Sandstone, buff, fine-grained, dense, massive undulating bedding plane, contains clay pellets of underlying shale	14.0
Shale:	
Shale, dark gray to green, silty, fissile to blocky, clay ironstone concretions, interbedded with thin siltstone and silty sandstone stringers	231.6

Siltstone, brown, dense, with thin, silty shale partings	21.5
Shale, dark gray, silty, fissile to blocky, interbedded with thin, silty sandstone stringers	85.9
Sandstone (IPsv-2), buff, fine-grained silty, thin-bedded	16.0
Shale:	
Shale, dark gray to green, blocky, interbedded with thin sandstone stringers, abundant clay ironstone concretions	129.0
Limestone, yellowish-brown, badly weathered, fossiliferous	0.6
Shale, dark gray to black, carbonaceous	1.0
Coal, shaly	0.08
Shale, dark gray to green, blocky	38.0
Sandstone (IPsv-1):	
Siltstone, brown, dense, micaceous, with thin silty shale partings	19.5
Shale, dark gray to green, silty, fissile to blocky	14.6
Sandstone, buff to brown, fine-grained, silty, thin-bedded to massive, undulating bedding plane	84.4
Shale, dark gray to green, fissile to blocky, interbedded with thin, silty sandstone stringers	17.8
Sandstone, buff, fine-grained, silty, micaceous, stringers 1 inch to 2 feet thick interbedded with silty green shale	17.9
Shale, dark gray to green to black, silty, fissile to blocky	40.2
Sandstone, buff, fine-grained, silty, micaceous, dense, stringers 1 inch to 1.5 feet interbedded with thin, silty, green shale partings	15.9
Shale, dark gray to green, silty, firm, blocky, covered in lower portion	116.0
Sandstone, brown, fine-grained, silty, dense, thin-bedded with thin, silty shale partings	21.2
Shale, covered	162.1
Sandstone, brown, fine-grained, silty, ripple marks, thin-bedded to massive, with thin, silty shale partings	41.8
Shale, dark gray to black, firm, blocky, abundant clay ironstone concretions	87.7
Sandstone, brown, fine-grained, silty, stringers 1 inch to 1 foot interbedded with thin shale partings containing plant remains	12.4
Shale, green, silty, fissile to blocky	10.4
Sandstone, light tan to white, fine-grained, thin-bedded in lower portion grading up into massive beds up to 2 feet thick	36.6
Shale, green to brown, firm, blocky	31.8
Sandstone, brown, fine-grained, silty, ripple marks, with thin, silty shale partings in lower 3 feet, grades up into more massive beds in upper part	10.4
Shale, gray to green, silty, fissile	56.8
Sandstone, brown to gray, fine-grained, silty, dense, 2 inch to 8 inch beds separated by thin green, silty shale partings	15.4
Sandstone, buff, fine-grained, silty, dense, thin-bedded to massive, with thin, green, silty shale partings, clay ironstone concretions	72.0

Formational Description	Thickness in feet
McAlester Formation:	
Shale:	
Shale, brown to gray, silty, blocky, interbedded with siltstone stringers, 1 inch to 2 feet thick, clay ironstone stringers, grades into darker gray, fissile shale in upper 5 feet	20.7
Siltstone, brown, micaceous, dense, beds 1 inch to 3 inches separated by thin, silty, gray shale partings, clay ironstone concretions	10.3
Sandstone, buff, fine-grained, ripple marks, dense, beds 1 inch to 3 feet separated by thin, silty shale partings	10.2
Shale, brown to gray, firm, blocky, clay ironstone concretions, grading up into middle and upper portions to darker gray, blocky, with abundant clay ironstone concretions	108.8
Sandstone, (Keota sandstone ?), brown, fine-grained, silty, beds 1 inch to 3 feet thick separated by thin, brown, silty shale partings containing clay ironstone concretions	36.5
Shale, brown, silty, fissile to blocky, interbedded with clay ironstone concretions aligned in stringers	9.3
Coal, trace.	
Shale, dark gray to black, carbonaceous	1.0
Shale, dark brown to gray, firm, blocky	3.0
Shale, brown, silty, fissile to blocky, interbedded with brown siltstone stringers 1 inch to 6 inches thick, clay ironstone concretions	10.3
Shale, dark gray to black, carbonaceous in lower 6 inches grading up into brown, silty, blocky shale interbedded with clay ironstone concretions aligned into stringers	10.3
Coal	0.08
Clay, gray	0.2
Coal	0.08
Shale, dark gray, silty	5.0
Coal	0.06
Shale, covered	262.6
Shale, dark brown to gray, blocky, clay ironstone concretions	30.7
Shale, green to brown, silty, fissile to blocky	62.0
Shale, brown, silty, fissile	9.7
Siltstone, buff, micaceous, dense	9.0
Coal, Upper McAlester (?)	0.06
Shale, gray, clayey, plant remains	1.0
Shale, green to brown, silty, blocky	74.9
Coal, Lower McAlester (?)	0.4
Clay, gray	0.5
Shale, green to brown, silty, fissile to blocky	64.3
Cameron sandstone:	
Sandstone, brown, fine-grained, silty, dense, thin-bedded with thin, silty shale partings	10.7
Sandstone, brown, fine-grained, silty, micaceous, thin-bedded to massive with thin, silty shale partings	26.7
Sandstone, gray to grown, fine-grained, silty, dense, massive, grading up into darker gray, silty sandstone	10.7
Shale:	
Shale, dark gray to black, firm, blocky	26.8
Shale, gray to green, fissile to blocky, interbedded with thin siltstone stringers, clay ironstone concretions, plant remains	21.4
Shale, gray to brown, mottled, partly covered	20.9
Shale, covered, not measured.	

11. PORTION OF McALESTER FORMATION, TAKEN ON ROAD CUT SOUTH OF AREA OF THIS REPORT ON HIGHWAY 2, CENTER NORTH ½ SECTION 6, T. 5 N., R. 19 E.

Formational Description	Thickness in feet
McAlester Formation:	
Warner sandstone, brown, fine-grained, dense, massive, not measured.	
McCurtain shale:	
Shale, dark brown, silty, firm, blocky, undulating bedding planes	84.8
Shale, dark gray to black, hackly, blocky	58.3
Shale, brown to green, silty, blocky, clay ironstone concretions	79.5
Shale, dark gray to black, firm, hackly, blocky	5.3
Shale, covered, unmeasured.	

12. PORTIONS OF BOGGY AND SAVANNA FORMATIONS, TAKEN FROM NW¼ SE¼ SW¼ SECTION 12, T. 6 N., R. 19 E. IN A SOUTHEAST DIRECTION ALONG TRAIL TO THE TOP OF YANCEY MOUNTAIN IN VICINITY OF CENTER-WEST BOUNDARY LINE OF SECTION 18, T. 6 N., R. 20 E.

Formational Description	Thickness in feet
Boggy Formation:	
Sandstone (IPb-3):	
Sandstone, brown, fine-grained, micaceous, dense, massive	27.5
Shale, covered	22.0
Sandstone, brown, fine-grained, micaceous, dense, massive	38.5
Shale Covered	66.0
Sandstone (IPb-2), brown, fine-grained, ripple marks, dense, massive	22.0
Shale, covered	186.5
Sandstone (IPb-1), brown, fine-grained, dense massive	21.6
Shale:	
Shale, covered	192.7
Sandstone, brown, fine-grained, dense, massive, contacts covered	15.2
Shale, covered	38.8
Bluejacket sandstone:	
Sandstone, tan to brown, fine-grained, silty, micaceous, dense, massive	109.4
Shale, covered	54.7
Sandstone, buff, fine-grained, dense, massive	53.9
Savanna Formation:	
Shale, covered	218.8
Sandstone (IPsv-3), not measured.	

13. SAVANNA AND PORTIONS OF BOGGY AND McALESTER FORMATIONS, TAKEN FROM NW¼ SE¼ SW¼ SW¼ SECTION 33, T. 6 N., R. 20 E. IN A NORTHWEST DIRECTION ALONG TRAIL TO ESCARPMENT IN VICINITY SW¼ NE¼ SE¼ SE¼ SECTION 19, T. 6 N., R. 20 E.

Formational Description	Thickness in feet
Boggy Formation:	
Bluejacket sandstone, buff, fine-grained, dense, massive, with thin, silty shale partings, not measured.	

Savanna Formation:	
Shale:	
Shale, covered	71.5
Sandstone, brown, fine-grained, silty, micaceous, dense, massive	16.5
Shale, covered	96.0
Sandstone (IPsv-3):	
Sandstone, brown to buff, fine-grained, silty, micaceous, dense, thin-bedded to massive, with thin, silty shale partings	200.0
Shale, covered	20.0
Sandstone, brown, fine-grained, micaceous, dense, thin-bedded with thin shale partings	32.4
Shale, covered	150.2
Sandstone, brown, fine-grained, thin-bedded to massive	32.4
Sandstone, shaly, covered	64.8
Shale covered	16.2
Sandstone, brown to buff, fine-grained, silty, micaceous, dense, massive	38.5
Shale:	
Shale, covered	89.5
Sandstone (IPsv-2). forms topographic bench, covered	21.6
Shale:	
Shale, covered	98.2
Sandstone, buff, fine-grained, silty micaceous, dense, massive	32.4
Shale, covered	222.6
Sandstone (IPsv-1a), brown fine-grained, silty micaceous, dense, massive	75.6
Shale, covered	140.4
Sandstone (IPsv-1):	
Sandstone, brown, fine-grained, silty, dense, massive	64.8
Shale, covered	118.8
Sandstone, brown, fine-grained, silty, micaceous, dense, massive	43.2
Shale, covered	108.4
Shale, sandy, covered	32.0
Shale, covered	16.2
Sandstone, brown, fine-grained, ripple marks, dense, thin-bedded to massive	10.8
Shale, covered	10.7
Sandstone, brown, fine-grained, micaceous, dense	1.0
Shale, covered	48.6
Sandstone, brown, fine-grained, silty, micaceous, dense, thin-bedded to massive, fucoids	32.4
Shale, covered	52.5
Sandstone, brown, fine-grained, micaceous, ripple marks, dense, thin-bedded to massive, interbedded with thin, silty shale partings	32.1
McAlester Formation:	
Shale, covered	237.6
Keota sandstone, light tan to white to brown, fine-grained, dense, thin-bedded to massive with thin, silty shale partings	16.2
Shale, covered, not measured.	

14. PORTIONS OF BOGGY AND SAVANNA FORMATIONS, TAKEN FROM A POINT 179 PACES NORTH OF INTERSECTION OF TRAIL WITH ABANDONED PIPELINE RIGHT OF WAY IN SE¼ NW¼ NW¼ SECTION 28, T. 7 N., R. 20 E. SOUTHEASTWARD ALONG PIPELINE RIGHT OF WAY TO TOP OF MOUNTAIN IN VICINITY SE¼ NW¼ SW¼ SW¼ SECTION 34, T. 7 N., R. 20 E.

Formational Description	Thickness in feet
Boggy Formation:	
Sandstone (IPb-5), buff, fine-grained silty, micaceous, dense massive	22.0
Shale, covered	137.5
Sandstone, (IPb-4), covered, forms topographic bench	38.5
Shale, covered in upper and lower portions, exposed 100 feet above base as gray to brown, blocky, clay ironstone concretions	455.8
Sandstone, (IPb-3), buff, fine-grained, micaceous, ferruginous, dense, massive	38.4
Shale, with sandstone (IPb-2 ?) at base covered	322.7
Shale, covered	169.2
Sandstone (IPb-1), tan to white, fine-grained, micaceous, dense, massive	48.9
Shale:	
Shale, covered	49.0
Sandstone, buff, fine-grained, micaceous, dense	8.2
Shale, covered	398.3
Bluejacket sandstone:	
Sandstone, buff fine-grained, silty, dense, massive	94.1
Shale, covered	47.1
Sandstone, buff, fine-grained, dense, massive in lower 5 feet grading up into thin, silty beds with silty shale partings	26.2
Savanna Formation:	
Shale, covered	408.4
Sandstone (IPsv-3), brown, fine-grained micaceous, thin-bedded massive, interbedded with thin, silty shale partings	167.4
Shale, covered, not measured.	

15. PORTION OF McALESTER FORMATION, MEASURED NORTHWESTWARD ALONG ROAD FROM NW¼ SE¼ SE¼ NW¼ SECTION 18, T. 6 N., R. 21 E. TO TOP OF FIRST PROMINENT SAVANNA HOGBACK.

Formational Description	Thickness in feet
Savanna Formation:	
Sandstone (IPsv-1), not measured.	
McAlester Formation:	
Shale, dark brown to gray, fissile to blocky, clay ironstone concretions, plant remains in upper 40 feet	210.9
Keota sandstone, light tan to white, fine-grained to silty, dense, massive in lower 4 feet, grading up into shaly siltstone	10.8
Shale:	
Shale, gray to brown, silty, interbedded with thin, silty sandstone stringers, clay ironstone concretions, plant remains	10.5
Coal, shaly, plant remains at base	1.0
Clay, gray	0.5
Coal, shaly	0.4
Clay, dark gray	1.0
Shale, brown to gray, silty, fissile, interbedded with clay ironstone concretions aligned in stringers 1 to 2 inches thick	6.4
Shale, gray, silty, fissile to blocky, clay ironstone concretions	54.1
Shale, covered, not measured.	

16. SAVANNA AND PORTION OF BOGGY FORMATION, TAKEN FROM CENTER EAST BOUNDARY LINE SECTION 8, T. 6 N., R. 21 E. NORTHWARD ALONG HIGH-LINE RIGHT OF WAY TO TOP OF MOUNTAIN IN VICINITY OF NW CORNER SECTION 28, T. 7 N., R. 21 E.

Formational Description	Thickness in feet
Boggy Formation:	
Sandstone (IPb-7), brown, fine-grained dense, massive	90.0
Sandstone (IPb-6), brown, fine-grained, micaceous, dense, massive	31.8
Shale, covered	210.4
Sandstone (IPb-5), brown, fine-grained, dense massive	37.0
Shale, covered in lower and upper portions, exposed in middle portion as gray to brown, fissile, with clay ironstone concretions	98.6
Sandstone (IPb-4):	
Sandstone, brown, fine-grained, dense, massive	15.6
Shale, covered	36.6
Sandstone, brown, fine-grained, dense, massive	20.8
Shale, covered	104.0
Sandstone (IPb-3), brown to buff, fine-grained, silty, dense, massive	77.8
Shale:	
Shale covered in upper portion, exposed in lower portion as gray to green to brown, fissile, clay ironstone concretions	212.6
Shale, brown, silty, fissile, interbedded with thin, silty sandstone stringers	52.0
Sandstone (IPb-2), brown to buff, fine-grained, micaceous, dense, massive, with thin, silty shale partings	181.8
Shale:	
Shale, covered	104.0
Sandstone, covered, forms topographic bench	4.0
Shale, covered	41.6
Sandstone, covered, forms topographic bench	15.8
Shale, covered	36.6
Shale, sandy, covered	26.2
Shale, covered	72.8
Sandstone (IPb-1), buff, fine-grained, silty, micaceous, dense, massive	52.0
Shale:	
Shale, covered	66.5
Sandstone, covered, forms topographic bench	5.2
Shale, covered	20.4
Sandstone, covered, forms topographic bench	15.3
Shale, covered	5.3
Sandstone, covered, forms topographic bench	5.3
Shale, covered	30.6
Sandstone, covered, forms topographic bench	15.3
Shale, covered	122.4
Sandstone, buff, fine-grained, dense, massive	25.3
Shale, covered	16.0
Bluejacket sandstone:	
Sandstone, buff to brown, fine-grained, silty, dense, massive	112.2
Shale, gray to green, fissile to blocky, clay ironstone concretions	61.2
Sandstone, buff, fine-grained, dense, massive	93.1

Formational Description	Thickness in feet
Savanna Formation:	
Shale:	
Shale, covered	197.9
Sandstone, brown, fine-grained, dense	1.0
Shale, covered	229.2
Sandstone (IPsv-3): brown to buff, fine-grained to silty, thin-bedded to massive, interbedded with covered silty shale intervals, forms long dip slope	255.8
Shale, covered	197.9
Sandstone (IPsv-1a), brown, fine-grained, silty, dense, massive	57.9
Shale:	
Shale, covered	57.8
Sandstone, covered, forms topographic bench	10.5
Shale, covered, thickness indeterminate; Sandstone (IPsv-1), brown, fine-grained, dense, thin-bedded upper contact covered, thickness indeterminate	246.8
Shale, covered	173.3
Sandstone, buff to brown, fine-grained, silty micaceous, thin-bedded	31.5
Shale, covered	126.0
Sandstone, brown, covered	26.3
Shale, covered	21.0
Sandstone, brown, fine-grained, silty, dense, thin-bedded to massive, interbedded with thin, silty, shale partings	15.8

17. PORTION OF BOGGY FORMATION, TAKEN FROM BASE OF BLUEJACKET SANDSTONE ESCARPMENT NEAR A LOG CABIN NE¼ SW¼ SW¼ SECTION 34, T. 7 N., R. 21 E. NORTHWARD ALONG ROCK CREEK ⅛ MILE TO OUTCROP OF SECOR COAL IN CREEK BED.

Formational Description	Thickness in feet
Boggy Formation:	
Shale:	
Shale, not measured.	
Sandstone, gray to brown, fine-grained, dense, massive	5.3
Shale, dark to black, silty	0.7
Coal, Secor	0.9
Clay, gray	0.5
Shale, covered	15.9
Sandstone, brown, fine-grained, thin-bedded	5.3
Shale, covered	10.6
Sandstone, brown, fine-grained, thin-bedded	5.3
Shale, covered in upper and lower portions, exposed in middle portion as gray to green, firm, blocky, clay ironstone concretions	135.0
Bluejacket sandstone, buff to brown, fine-grained, silty, dense, massive in upper and lower portions with covered silty shale in middle portion	153.9

18. PORTION OF McALESTER FORMATION, MEASURED FROM NE¼ SE¼ NW¼ SECTION 12, T. 6 N., R. 21 E. IN VICINITY OF LODI SCHOOL NORTHWARD ALONG BEAR CREEK TO FIRST SAVANNA ESCARPMENT IN VICINITY NE SW NW SECTION 1, T. 6 N., R. 21 E.

Formational Description	Thickness in feet
Savanna Formation:	
Sandstone (IPsv-1), not measured.	
McAlester Formation:	
Shale:	
Shale, covered	90.1
Sandstone, brown, fine-grained, silty, micaceous, thin-bedded	5.3
Shale, covered	37.1
Keota sandstone, brown, fine-grained, silty, dense, massive	16.2
Shale:	
Shale, covered	599.0
Shale, dark gray to brown, firm, fissile to blocky, abundant clay ironstone concretions	22.0
Coal, Upper McAlester	1.5
Clay, gray	2.0
Shale, dark gray, silty, fissile to blocky, abundant clay ironstone concretions	63.0
Coal, Lower McAlester	1.7
Clay, gray	1.0
Shale, dark gray to black to brown, silty, firm, fissile to blocky, abundant clay ironstone concretions	96.5
Siltstone, brown, micaceous, dense, thin-bedded	5.4
Shale, dark gray to brown, silty, fissile to blocky, clay ironstone concretions	10.7
Cameron sandstone, brown, fine-grained, silty, micaceous, ripple marks, thin-bedded with thin, silty shale partings, not measured.	

19. PORTION OF UPPER SAVANNA FORMATION, TAKEN ALONG JEFFERSON CREEK IN VICINITY NE¼ SW¼ SECTION 28, T. 7 N., R. 22 E.

Formational Description	Thickness in feet
Boggy Formation:	
Bluejacket sandstone, not measured.	
Savanna Formation:	
Shale, brown to gray, silty, fissile	82.5
Shale, brown, silty, micaceous, fissile, interbedded with thin, silty sandstone stringers	16.5
Shale, brown, silty, fissile	22.0
Shale, brown, sandy, micaceous, with thin, silty sandstone stringers	44.0
Shale, brown to maroon, silty, fissile to blocky	99.0
Shale, brown to maroon, firm, blocky, clay ironstone concretions	71.5

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