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GEOLOGY AND MINERAL RESOURCES (EXCLUSIVE OF PETROLEUM) OF MUSKOGEE COUNTY, OKLAHOMA

MALCOLM C. OAKES

Assisted by Walton Bell, David G. Campbell, Walter F. Coleman, William Gregware, Jimmy T. Lontos, Robert A. Meek, Francis Stewart, Jr., and Joseph G. Stine

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Title Page Illustration

Ink drawing by Roy D. Davis of the massive Bluejacket Sandstone, the basal member of the Boggy Formation of Pennsylvanian (Desmoinesian) age, overlying shale of the Savanna Formation at the top of an escarpment in sec. 19, T. 12 N., R. 19 E., Muskogee County. Drawn from a photograph by William Gregware (1958, p. 61).

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GEOLOGY AND MINERAL RESOURCES (EXCLUSIVE OF PETROLEUM) OF MUSKOGEE COUNTY, OKLAHOMA

MALCOLM C. OAKES[1]

Assisted by Walton Bell, David G. Campbell, Walter F. Coleman, William Gregware, Jimmy T. Lontos, Robert A. Meek, Francis Stewart, Jr., and Joseph G. Stine

Abstract—Rocks belonging to the Ordovician and Devonian Systems crop out in sec. 15, T. 15 N., R. 20 E., in the northeast corner of Muskogee County. Other than those, the rocks that crop out in the County are Mississippian and Pennsylvanian; only parts of each system are represented. Most Mississippian outcrops are east of the Arkansas River and consist of shale, siltstone, sandstone, and limestone. Pennsylvanian outcrops cover most of that part of the County west and south of the Arkansas River; a few of the oldest are east of the river. Throughout they consist largely of shale, silty to sandy, and dark gray to black, weathering to shades of brown and yellow. Next in abundance is sandstone, conspicuous out of all proportion to its amount; it crops out over wide dip slopes, caps long escarpments, and, as debris, litters much of the area where shale crops out. Most of the sandstone is medium grained to fine grained to silty and weathers to shades of red or brown. Limestone is least in abundance. In Morrowan rocks limestone occurs in several beds 10 or more feet thick. In higher Pennsylvanian strata there are only a few limestone beds of considerable extent, and these are silty, sandy, shaly, and only a few feet thick at most. A few local thin lenses of impure limestone are scattered throughout the Pennsylvanian.

Pennsylvanian rocks at the surface contain two unconformities, at the base of the Atoka Formation and at the top of the Boggy Formation. It is possible, however, that the Boggy is gradational at places into overlying formations and that an unconformable relationship at this horizon is largely local.

The Quaternary System is represented by unconsolidated deposits associated with earlier streams and present streams.

Surface structures in the Boggy and older rocks of Muskogee County are dominated by several westward-trending folds and faults. Among these are the Porum syncline, the Warner uplift, the Rattlesnake Mountain syncline, and the Muskogee fault, the latter being associated with an unnamed asymmetric syncline whose north flank extends northward to the Arkansas River. North of the Muskogee fault, structures in Boggy rocks trend southwestward and are complex. Structures in post-Boggy rocks of western Muskogee County are more simple; dips are low and westward, with local variations to the northwest and southwest. The few small faults trend northeastward. The one anticline is broad and trends westward; it probably represents a rejuvenation of more pronounced folding in underlying Boggy and older rocks.

The chief mineral production has been petroleum and coal. Only one coal seam, the Stigler, in the southern part of the County, has been of commercial importance. Other mineral assets are limestone, building stone, clay shale, water, and sand and gravel.

INTRODUCTION

Purpose

The primary purpose in preparing this bulletin was to bring together, in one volume, the knowledge of the geology and mineral resources (except for petroleum) of Muskogee County. The purpose of the field investigations was to study the character, distribution, thickness, and continuity of the rocks exposed in Muskogee County. This is intended to help in the classification and nomenclature of equivalent rocks in other parts of eastern Oklahoma. It is hoped that the information will be useful for correlations with rocks in the subsurface.

[1]Geologist, Oklahoma Geological Survey, retired.

Location

Muskogee County is in the eastern part of Oklahoma (fig. 1). Muskogee, the County seat, is just south of the Arkansas River, the north boundary of the County, and approximately equidistant from the east and west boundaries. It is also roughly equidistant from Tulsa, Oklahoma, to the northwest, and Fort Smith, Arkansas, to the southeast. Muskogee County is about 820 square miles in area.

Accessibility

Most section-line roads are open to travel. Few of these are primitive, as most are drained and have gravel; many are paved or are well graveled. Muskogee, the only city of appreciable size, can be reached from points outside the County via several State and federal highways.

Previous Investigations

Nuttall (1821) made several excursions across what is now eastern Oklahoma to study its botany and geology, and in the course of one of these excursions he crossed part of what is now Muskogee County. Marcou (1855) and Whipple (1855) made explorations in a search for a feasible route for a railroad from the Mississippi River to the Pacific Ocean. They worked as far north as the Arkansas and Canadian Rivers, but probably did not enter Muskogee County. Chance (1890) studied the coal fields of the Indian Territory, now eastern Oklahoma, but confined his work to the coal measures along the south side of the Arkoma basin. Drake (1897) made a geological reconnaissance of the coal fields of eastern Oklahoma, including Muskogee County. Taff (1899, 1901, 1902, 1906) and Taff and Adams (1900) classified the rocks that crop out in the coal fields of eastern Oklahoma south of the Canadian and Arkansas Rivers into formations which they mapped, named, defined, and described. Of these coal-bearing formations, the Atoka, Hartshorne, McAlester, Savanna, Boggy, Stuart, and Senora have since been traced and mapped northward into Muskogee County.

Gould and others (1910) proposed that the rocks that crop out in eastern Oklahoma be subdivided into several named groups, but that proposal was not generally followed by geologists who subsequently worked in the area.

Snider (1914) wrote on the geology of east-central Oklahoma, including southeastern Muskogee County, with special reference to the occurrence of oil and gas. Snider (1915) also made a field study of the Chesterian rocks of northeastern Oklahoma and their relationship to overlying Pennsylvanian rocks. The area included that part of Muskogee County east of the Arkansas River.

The Oklahoma Geological Survey (1917) published on the oil and gas fields of the State by counties, including the development in Muskogee County up to 1917 (p. 331-339). Soyster and Taylor (1928) wrote the section on Muskogee County in a later series. They discussed briefly the surface and subsurface geology and wrote a detailed discussion of oil and gas development by fields.

Wilson and Newell (1937) investigated the Muskogee-Porum district, which included a large part of Muskogee County. Wilson mapped the district, and Newell supplemented his field work, having measured and described many stratigraphic sections in detail and identified some of the fossils; he also wrote the chapter on Carboniferous stratigraphy (p. 18-57).

Incident to the preparation of the *Geologic Map of Oklahoma* (Miser, 1954), the author did field reconnaissance over much of northeastern Oklahoma to supplement available geologic mapping. In the course of that work, he crossed and recrossed Muskogee County several times. The reconnaissance was no more detailed than necessary to delineate formation boundaries and was published only on the *Geologic Map of Oklahoma*.

Present Investigation

The present work is a compilation of material from previously published works and unpublished results of field investigations. In that part of Muskogee County east and north of the Arkansas River, the mapping of the Atoka Formation and older rocks is copied from Huffman and others (1958, pls. 3, 4). On these plates the Atoka Formation is undifferentiated. One may see from a study of aerial photographs that the Atoka in this

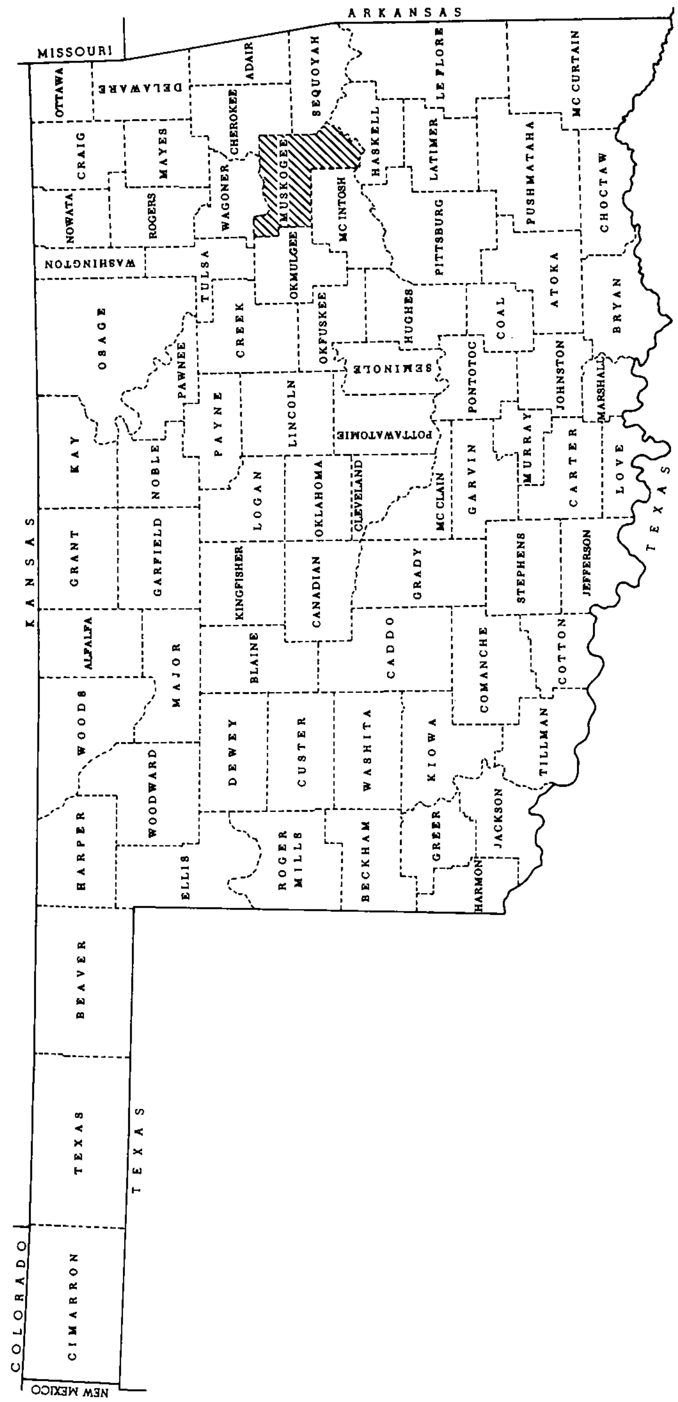

Figure 1. Index map of Oklahoma showing location of Muskogee County.

area contains several scarp-forming units, presumably sandstones.

Wilson (Wilson and Newell, 1937) mapped the Muskogee-Porum district, part of which lies in Muskogee County, south and west of the Arkansas River. Much of Wilson's mapping in Muskogee County resembles that shown in the same area on plate 1 of this report. However, his map units commonly consist of a sandstone and overlying shale and are shown as extending from the base of one sandstone unit to the base of the next higher, without differentiation into sandstone and shale.

Later investigations, here reported, cover that part of Muskogee County south and west of the Arkansas River. They are a part of a continuing cooperative project of the Oklahoma Geological Survey and the School of Geology and Geophysics of The University of Oklahoma.

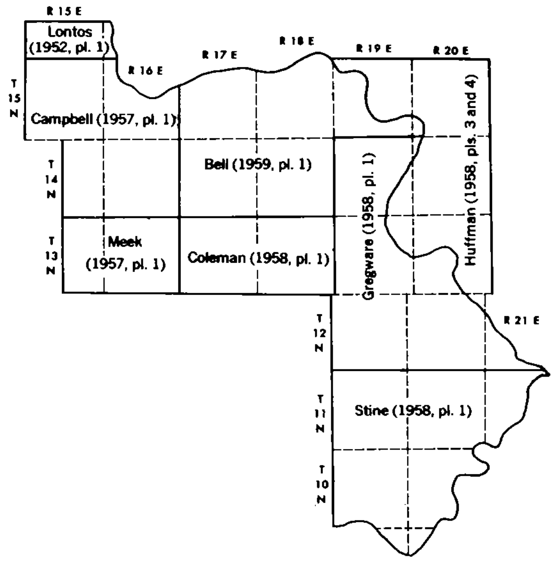

Figure 2. Index to geologic mapping in Muskogee County.

Walton Bell, David G. Campbell, Walter F. Coleman, William Gregware, Robert A. Meek, and Joseph G. Stine mapped parts of the County, as shown in figure 2, under the supervision of the author in partial fulfillment of the requirements for the degree of Master of Science. Earlier, Francis Stewart, Jr. (1949), had mapped Tps. 13-15 N., R. 17 E., under the supervision of the author, with special reference to the Secor coal and the Inola Limestone, at a time when little was known about equivalent rocks in adjoining areas. Coleman and Bell restudied Stewart's area because of new knowledge and availability of aerial photographs. Jimmy T. Lontos (1952) mapped a part of northwestern Muskogee County as a part of his study of the Coweta area.

Field work was done as time was available during the period 1956-58: by Meek, in June and July 1956; by Campbell, in the summer and fall of 1956; by Stine, in February through July 1957; by Coleman, in February to September 1957; by Gregware, in the winter of 1957-58; and by Bell, in the summer and fall of 1958.

The Oklahoma Geological Survey purchased the aerial photographs used for the geologic mapping from the U.S. Department of Agriculture. Prior to 1958, full stereoscopic coverage was available for Muskogee County. The scale of the photographs is about 1:20,000, or about 3.25 inches per mile. The photographs show little tilt, and the relief is small, so that the resulting distortion is negligible. Thus the resultant map is more accurate than a plane-table map.

The usual procedure is to mark directly on the photographs all geologic and cultural features that appear on the stereoscopic image. This marking is done in the office and is checked and corrected later in the field. All verifiable and useful features, such as outcrops, streams, and roads, are transferred to township plats of approximately the same scale as that of the photographs, principally by tracing. The plats are used in compiling the final map.

A somewhat different procedure was followed in making the geologic map (pl. 1) of this report. New stereoscopic prints were made available from the U.S. Department of Agriculture in 1964. These prints are more legible and show greater detail than the earlier prints. The author studied these prints in the office, compared the results with previous work, and where differences were noted adopted whatever version seemed most tenable. Many details that are clear in the field cannot be seen on the best of aerial photographs by even the most skillful interpreter. On the other hand, many details, especially details of stratigraphy, that are virtually unnoticeable in the field can be seen readily on the photographs. The value of the photo-interpreter's work depends not only upon his ability to see what is in the photographs but also to interpret what he sees based upon abundant field experience in similar areas.

GEOGRAPHY

The Arkansas River forms part of the north boundary of Muskogee County and is about 550 feet above sea level on the north side of sec. 19, T. 16 N., R. 16 E. From that point, it trends eastward and southward to the east side of sec. 1, T. 11 N., R. 21 E., which is about 450 feet in elevation, the lowest point in the County. The Canadian River forms the southeastern boundary of the County, being about 500 feet above sea level in sec. 31, T. 10 N., R. 19 E., and 450 feet at the confluence with the Arkansas River.

The highest point in the County (almost 1,100 feet) is north and east of the Arkansas River, near the northeast corner, on hilltops formerly contained in the Camp Gruber Military Reservation. The total relief of the County is about 650 feet. The area west of the river is mostly flat to rolling, but even here a few high points are between 800 and 1,000 feet above sea level. In the vicinity of Greenleaf Lake, in Tps. 13-14 N., R. 20 E., the hills on both sides of the Arkansas River rise 300 to 400 feet above the water level.

By far the greater part of Muskogee County is drained by tributaries of the Arkansas River. The northwestern part is drained by Concharty Creek, by Ash Creek, by Cloud Creek with its tributary Cane Creek, and by Pecan Creek. The north-central part is drained by Coody Creek with its tributary Sam Creek, by Spaniard Creek, and by Dirty Creek with its tributary Butler Creek. The southeastern part is drained almost entirely by Georges Fork, by South Fork of Dirty Creek, and by Sulphur Creek. The northeastern part, north and east of the Arkansas River, is drained by Bayou Manard, by Greenleaf Creek, by the Verdigris River, by the Neosho (Grand) River, and by several smaller tributaries of the Arkansas River. Belle Starr, Briartown, and Possum Hollow Creeks drain into the Canadian River along the south boundary.

The climate of Muskogee County is mild. The mean annual temperature is 62°. The average length of the growing season is 223 days. The average date of the last killing frost in the spring is March 31. The average date of the first killing frost in the fall is November 11. This information is based on records of the U.S. Weather Bureau.

STRATIGRAPHY

Regional Setting

In order to understand the stratigraphy and structural geology of Muskogee County, a brief review is presented for eastern Oklahoma, southeastern Kansas, southern Missouri, and northwestern Arkansas, following Oakes (1963, p. 17-20).

This wider region consists of two areas: the northern and western area, commonly called the shelf or platform, and the southern area, generally called the Ouachita geosyncline. The shelf is commonly subdivided into two parts, based upon the present attitude of the rocks. One includes the Ozark uplift, or Ozark dome, in northeastern Oklahoma, southwestern Missouri, and northwestern Arkansas; the other includes the central Oklahoma arch, which rims the Ouachita geosynclinal area on the north and northwest and extends northward beyond the borders of Oklahoma and westward to the Anadarko basin, west of the longitude of Oklahoma City.

Sedimentary rocks range in age from Cambrian to Pennsylvanian. Limestones are conspicuous among the rocks on the shelf; the clastics are shales, siltstones, and fine-grained sandstones. The many unconformities indicate repeated withdrawal of the sea, erosion, and repeated submergence. Many of the rocks, notably Pennsylvanian rocks, are cyclic.

The rocks of the geosyncline are mostly clastic; nearly all units are thicker southeastward. The evidence indicates that the source of the clastic sediments was an ancient landmass somewhere to the southeast, now buried beneath Cretaceous and younger rocks. However, some of the clastics on the shelf may have come from the east, north, and west. Traced northward, many of the sandstones in the geosyncline are thinner and pinch out before reaching the shelf area, but some clastic units extend northward over the shelf with much thinning, convergence of beds, and gradual change of facies. Thus, the shelf area changed little with respect to sea level during the depositional sinking of the geosyncline. Probably the geosyncline was filled with clastic sediments much of the time so that the water was shallower there than over the shelf area. Furthermore, Pennsylvanian coal beds of the shelf extend to the geosyncline, indicating that the swamps extended over parts of both areas.

Mississippian rocks crop out around the Ozark dome, except where covered, and outliers of Mississippian rocks are on the Ozark dome, indicating that part of the dome was below sea level in Mississippian time. Also, outliers of probable Desmoinesian and later age are in sinkholes in the dome, indicating that the Ozark dome was probably part of the shelf area.

Most of the Ouachita rocks have been folded and faulted, being bounded on the north by the Choctaw fault. The forces that formed the northern Ouachita Mountains were compressive, probably from the south and southeast, and most of the large faults are reverse faults, upthrown on the south side in the northern area. The rocks in the geosyncline north of the Choctaw fault have been squeezed into an east-west syncline between the Ouachita Mountains and the shelf. The syncline is termed variously the McAlester coal basin, the Arkansas-Oklahoma coal basin, and, lately, the Arkoma basin (Branson, 1956, p. 83).

In the subsurface of Oklahoma, most folds and faults persist to great depths, being more intense in the older rocks, as if older structures were later rejuvenated. Structures may even extend into the basement rocks. By analogy we may assume that the Ouachita Mountains had their beginning with gentle folds and small faults in pre-Mississippian time. Post-Atoka rocks have been eroded from the Ouachita Mountain area, but some of their equivalents have been preserved in the Arkoma basin and on the shelf. Hendricks (1939, p. 271) found that the thickest part of the McAlester Formation is in the deepest part of the Arkoma basin and that it is thinner southward, toward the Choctaw fault. On the other hand, the McAlester, in common with other units, is thinner northward out of the basin; many of the sandstone units pinch out in that direction, others converge, and at least two merge. The McAlester sediments probably came from the south, spilling northward into the Arkoma basin across an arch in the bottom of the sea at about the position of the Choctaw fault. Thus it appears that the squeeze which formed the Arkoma basin was already operating, making it at once a structural and a depositional basin; however, it still remained part of the Ouachita geosynclinal area.

The youngest rocks cut by the Choctaw fault belong to the Atoka Formation, but an earlier uplift of considerable magnitude is indicated by chert pebbles in the Atoka Formation on the south side of the Lehigh syncline in Atoka County, west of Stringtown (Taff, 1902, p. 5). It is not possible to date the end of major folding and faulting in the Ouachita Mountains more exactly than post-Atoka, pre-Cretaceous. However, from a study of the structure of the rocks north of the mountains, in the Arkoma basin and on the shelf, the author suspects that much of the movement in the Ouachita Mountains and most of that on the Ozark dome was over by post-Boggy time.

Boggy and older rocks in the Arkoma basin and on the shelf west of the Ozark dome are folded and faulted. The character, distribution, and orientation of these folds and faults indicate a relationship to the Ouachita compressive forces and Ozark vertical forces. Some of these structures are discernible in rocks younger than the Boggy Formation, but in these rocks the amplitude is much smaller. One exception is the Ahloso fault, south of Ada, in Pontotoc County. It cuts units younger than the Boggy and has a maximum throw of more than 2,000 feet, up on the south side. It is probably associated with movement in the Arbuckle Mountain area.

Chert pebbles in post-Boggy rocks seem to have come from the southeast, and their presence indicates recurrent uplift in the Ouachita Mountains (or Llanoria), but lack of evidence of pronounced movement in rocks younger than Boggy indicates that these later stresses in the Ouachita Mountains (or Llanoria) were not transmitted northward across the Choctaw fault with any considerable strength. However, such things as pressure ridges in the soil, straight lines of leaning trees, offset sewers (in Atoka), and occasional weak tremors (near Hugo, e.g.) indicate that some faults in the Ouachita Mountains and in the Arkoma basin are still slightly active (Knechtel and Rothrock, 1935; Sellards, 1935).

Ordovician System

Rocks of Ordovician age crop out in only one place in Muskogee County, in sec. 15, T. 15 N., R. 20 E.

Cincinnatian Series

Fernvale Limestone

According to Huffman and others (1958, p. 26), the Fernvale was named by Hayes and Ulrich (1903) for exposures near Fernvale, Tennessee. The limestone is massive, coarsely crystalline, fossiliferous, crinoidal, and light gray to pink; it weathers lead gray. It is a cliff former but is less than 20 feet thick in Muskogee County. The base is not exposed. It is overlain unconformably(?) by the Sylvan Shale.

Sylvan Shale

The Sylvan Shale was named by Taff (1902) for the village of Sylvan in T. 3 S., R. 4 E., Johnston County, Oklahoma. The Sylvan Shale ranges from dark green and fissile to brown and silty. Its thickness in Muskogee County is not known, but Huffman and others (1958, p. 28) indicated 12 to 36 feet. The Sylvan, in this exposure, rests unconformably(?) upon the Fernvale Limestone and is overlain unconformably by the Chattanooga Formation.

Devonian and Mississippian Systems

Rocks of late Devonian and (or) early Mississippian age crop out in only one locality in Muskogee County, in sec. 15, T. 15 N., R. 20 E.

Chattanooga Formation

Sylamore Sandstone Member.—Huffman and others (1958, p. 38), following Penrose (1891, p. 113-114), stated: "The Sylamore was named by Branner for exposures in the vicinity of Sylamore Creek, Stone County, Arkansas." They also stated that the Sylamore is a white phosphatic sandstone, shaly and limy at the base. It is probably not more than 20 feet thick in Muskogee County, and it overlies the Sylvan Shale unconformably. It is overlain conformably by the black shale member.

Black shale member.—Huffman and others (1958, p. 39) stated: "C. W. Hayes (1894) named the Chattanooga shale from exposures of black, fissile shale near Chattanooga, Tennessee. The term was extended into Arkansas and Oklahoma to replace the local terms 'Eureka' and 'Noel.' " In Muskogee County, as elsewhere, the black shale member is fissile, pyritic, carbonaceous, and bituminous. Its thickness at this exposure is not known. It lies conformably upon the Sylamore Sandstone Member and is overlain unconformably by the Moorefield Formation of Early Mississippian age.

Mississippian System

The middle and upper parts of the Mississippian System crop out in Muskogee County east of the Arkansas River. Huffman and others (1958) mapped four formations: Moorefield, Hindsville, Fayetteville, and Pitkin (ascending). Two, the Fayetteville and Pitkin, crop out in a limited area along the west side of the river in secs. 28, 33, and 34, T. 13 N., R. 20 E., where they were mapped by Gregware (1958).

Meramecian Series

Moorefield Formation

Nomenclator.—According to Huffman and others (1958, p. 49), the term Moorefield was proposed by Adams and others (1904) for beds between the Boone Chert and the Batesville Sandstone at Moorefield, Arkansas. The Moorefield in Muskogee County consists of limestone, shale, and minor amounts of sandstone and siltstone. Huffman and others (1958) subdivided the Moorefield of northeastern Oklahoma into four facies of member rank. They are, in ascending order, the Tahlequah, the Bayou Manard, the Lindsey Bridge, and the Ordnance Plant. They were not mapped by Huffman but were identified in some of the measured sections. Only the Bayou Manard and Ordnance Plant Members have been recognized in Muskogee County.

Bayou Manard Member.—Huffman and others (1958, p. 51) wrote: "The Bayou Manard member is named for exposures along Bayou Manard, a tributary stream to the Arkansas River. The type locality is southeast of Muskogee and Fort Gibson in the SE¼ sec. 19, T. 15 N., R. 20 E. just southwest of the bridge over Bayou Manard."

The distribution of the member was described by Huffman and others (1958, p. 51): "The Bayou Manard member is best developed in the Braggs Mountain area southeast of the South Muskogee fault where it floors the valley below the Braggs escarpment."

With regard to its thickness and character, Huffman and others (1958, p. 51-52) wrote:

> The Bayou Manard member has a maximum thickness of 65 feet along Bayou Manard southeast of Muskogee. Here the base is not exposed and the top has been removed by erosion. . . . At the type locality the Bayou Manard member is composed of black, argillaceous limestones and interbedded black, calcareous shales. The limestones vary from lithographic to medium crystalline. They weather white on the exposed surface and split into thin, black, platy layers. The Bayou Manard strata are commonly jointed in proximity to major faulting, forming large, rectangular blocks. The formation is highly fossiliferous and has a strong bituminous odor. Pyrite is commonly present and upon oxidation, yields a strong odor of hydrogen sulphide. Small cavities and hollow fossil interiors have yielded traces of live, green oil. Leaching of some of the more silty beds produces a light-weight, porous rock locally known as "light-rock."

Ordnance Plant Member.—The type locality of this member is characterized by Huffman and others (1958, p. 57-58) as follows.

> The Ordnance Plant member is named for exposures along Pryor Creek within the Oklahoma Ordnance Plant area and at the west end of the Low Water Dam, secs. 11 and 14, T. 20 N., R. 19 E.), where all but the uppermost beds are completely exposed in the quarry. Uppermost beds are well developed along the west side of Grand River below its confluence with Pryor Creek in sec. 27, T. 20 N., R. 19 E. The Ordnance Plant member takes its name from the Oklahoma Ordnance Plant located on the west side of Grand River southeast of the town of Pryor [Mayes County, Oklahoma].

According to Huffman and others (1958, p. 58), the Ordnance Plant Member in Muskogee County is well developed near the base of Braggs Mountain escarpment on State Highway 10, southeast of Muskogee. It is thinner southeastward from Braggs Mountain. It has been identified along Cedar Creek, in sec. 36, T. 13 N., R. 20 E.

Near the base of Braggs Mountain, southeast of Muskogee, in secs. 21 and 29, T. 15 N., R. 20 E., the Ordnance Plant Member is shale, about 30 feet thick, with the upper part gray to black, jointed, and fissile, and the lower part buff, weakly indurated, jointed, and calcareous.

Chesterian Series

Hindsville Formation

Nomenclator.—Huffman and others (1958, p. 61) wrote:

> The Hindsville limestone was named by Purdue and Miser (1916) for exposures near Hindsville, Arkansas, where it was considered to be a calcareous facies or member of the Batesville sandstone. The Hindsville equivalent was recognized by Siebenthal (1907) in Ottawa County, Oklahoma, where it was mapped as the lower member of the Batesville formation. Following Miser's suggestion, the Hindsville of Ottawa County has been ranked as a formation (Reed, Schoff, Branson, 1955). . . .
>
> The term Hindsville is herein applied to the limestone strata between the Moorefield and Fayetteville in northeastern Oklahoma. It is the equivalent of the Grand River of Brant (1941).

Distribution, thickness, and character.—According to Huffman and others (1958, p. 61-62), the Hindsville Formation is widespread in northeastern Oklahoma but is thinner southward, and apparently it is almost absent in Muskogee County south of Braggs Mountain, where it is 5 feet thick and consists of medium-crystalline limestone.

Fayetteville Formation

Nomenclator.—According to Huffman and others (1958, p. 66), the Fayetteville Formation was named by Simonds (1891) from exposures in the vicinity of Fayetteville, Arkansas.

Distribution.—Huffman and others (1958) said that the Fayetteville Formation crops out widely in northeastern Oklahoma. It crops out in narrow bands following the drainage pattern in that part of Muskogee County east of the Arkansas River. Gregware (1958) mapped the Fayetteville Formation west of the Arkansas River, along the bluffs of secs. 28, 33, and 34, T. 13 N., R. 20 E., where the base is not exposed.

Thickness and character.—Concerning the Fayetteville Formation in Muskogee County, east of the Arkansas River, Huffman and others (1958, p. 66) wrote:

> The Fayetteville formation is typically developed on the Braggs Mountain escarpment southeast of Fort Gibson (secs. 21-29, T. 15 N., R. 20 E.) along Highway 10 where a thickness of 110 feet is developed. There the lower 95 feet is composed largely of black, fissile shale with occasional thin interbeds of blue-black, lithographic limestone. Large septarian concretions are common. The upper part of the Fayetteville consists of interbedded limestone and shale. The limestone ledges are in most cases less than one foot thick and are separated by black, fissile shale. The Fayetteville grades upward into the overlying Pitkin through a 6.5-foot transition zone of rubbly, nodular-weathering, black to gray, lithographic limestone.

Gregware described the Fayetteville Formation along the west side of the Arkansas River in secs. 28, 33, and 34, T. 13 N., R. 20 E., as mostly dark or black, fissile shale with scattered beds of limestone, many of them lithographic.

Stratigraphic relationships.—In eastern Muskogee County, the Fayetteville Formation rests conformably upon the Hindsville Formation and is overlain conformably by the Pitkin Formation. The contact with the Pitkin is gradational.

Pitkin Formation

Nomenclator.—"The Pitkin formation was named by Adams and Ulrich (1904) for exposures near Pitkin postoffice in Washington County, Arkansas. The Pitkin is the 'Archimedes limestone' of early workers" (Huffman and others, 1958, p. 71).

Distribution.—The Pitkin Formation outcrops in Muskogee County are distributed widely east of the Arkansas River, where the formation was mapped by Huffman and others (1958), and are exposed along the river bluffs west of the Arkansas in secs. 28, 33, and 34, T. 13 N., R. 20 E., where they were mapped by Gregware (1958).

Thickness and character.—The Pitkin Formation in Muskogee County is variable in thickness. This is accounted for in part, at least, by pre-Pennsylvanian erosion. The formation is about 60 feet thick on Braggs Mountain, in secs. 21-29, T. 15 N., R. 20 E.; more than 50 feet thick in sec. 27, T. 13 N., R. 20 E.; and reaches its maximum reported thickness of 82 feet in sec. 32, T. 15 N., R. 20 E. Gregware (1958) reported that it is about 30 feet thick along the river bluffs west of the Arkansas in secs. 28, 33, and 34, T. 13 N., R. 20 E.

The Pitkin consists generally of massive gray to blue-gray beds of crystalline limestone, interspersed with a few beds of gray to black shale.

Stratigraphic relationships.—The Pitkin Formation in Muskogee County is conformable with the Fayetteville Formation, below, and unconformable with the Hale Formation of Pennsylvanian age, above.

Pennsylvanian System

Pennsylvanian rocks of northern Oklahoma have been included in three main divisions: Desmoinesian Series, Missourian Series, and Virgilian Series, in ascending order. South of the latitude of central Mayes County, including Muskogee County, are Pennsylvanian rocks older than Desmoinesian.

By the time preparation of the second geologic map of Oklahoma (Miser, 1954) was nearing completion, it seemed fairly certain that future usage would arrange Pennsylvanian rocks in Oklahoma older than the Desmoinesian in one or more series and that the youngest would include the Atoka Formation. Accordingly, Oakes (1953) placed the base of the Desmoinesian Series in Oklahoma at the top of the Atoka Formation, or at the top of older rocks in areas where the Atoka is not present. Anticipated subdivision of the older Pennsylvanian rocks in Oklahoma into two or more series has not yet been made. Palynological work by L. R. Wilson (1976) now shows that the Atoka Formation is Desmoinesian in age. Therefore, the Atoka is placed in the Desmoinesian in this report.

These older Pennsylvanian rocks in Oklahoma fall naturally into two divisions. The older of the two divisions is characterized by its content of limestone and calcareous shale and was long known as the Morrow Group, comprising in northeastern Oklahoma two formations, the Hale and the Bloyd. In this report the term Morrow is reserved for series designation only (Morrowan). The younger of the two divisions is characterized by its content of sandstone and arenaceous shale. Because of its great maximum thickness, some geologists have referred to it as a group or even a series, but there seems to be no widespread basis for its subdivision into parts and it has long been called the Atoka Formation.

Plate 2 (in pocket) shows representative outcrop sections of Pennsylvanian rocks in Muskogee County.

Morrowan Series

The Morrowan Series now comprises two formations, the Hale, below, and the Bloyd, above. They are shown separately on plate 1 east of the Arkansas River but are mapped together west of the river, where both upper and lower parts contain much shale and limestone. The presence of shale in the upper part has led to difficulty in mapping the upper limit. For instance, Taff (1906) did not show Morrowan rocks cropping out in T. 13 N., R. 20 E., farther north than the southern part of sec. 28; Wilson and Newell (1937, pl. 1) extended them into the northern part of sec. 28; Gregware (1958, geologic map) extended them into the southern part of sec. 16. P. K. Sutherland, The University of Oklahoma, and students under his supervision (Bowlby, 1968; Haugh, 1968; Henry, 1970, 1973; Rowland, 1970) agreed essentially with Taff's version; the writer (pl. 1, this report) follows Gregware.

Hale Formation

Nomenclator.—A. H. Purdue (1907, p. 3) is usually credited with naming the Hale, but he said that J. A. Taff named it from Hale Mountain, in the western part of the Winslow quadrangle of Arkansas.

Original description.—According to Purdue (1907, p. 3):

> Its basal portion, usually about 50 feet thick, consists of sandy shale interbedded with thin layers of ripple-marked sandstone. The sandstone is variable in amount, and at some places is almost entirely wanting. Above its basal portion the Hale consists of more or less massive calcareous sandstone. The relative amounts of sand and lime are by no means constant, nor are the beds persistent in character, but change within short horizontal distances. Small lenses of rather pure limestone are common in the sandy layers; and throughout most of the sandstone, especially in its massive portion, there are spherical masses of calcareous material, the size of a walnut or smaller, which weather out, leaving the stone full of cavities and giving it a characteristic pitted appearance.

Distribution.—Outcrops of the Hale Formation are widely distributed in northwestern Arkansas and in northeastern Oklahoma. In Muskogee County, the formation crops out northeast of the Arkansas River and is mapped with the Bloyd Formation west of the river (pl. 1).

Thickness and character.—The Hale Formation ranges in thickness from about 100 to 200 feet in Arkansas; it is about 90 feet thick on Hale Mountain. It thins northward in Oklahoma to extinction in Mayes County, north of Muskogee County. In Muskogee County, the Hale is about 60 feet thick in outcrops on Braggs Mountain in secs. 21 and 28, T. 15 N., R. 20 E., and in sec. 28, T. 13 N., R. 20 E., west of the Arkansas River, where Gregware (1958) said that it is composed of discontinuous, fossiliferous, blue-gray limestones and gray, laminated shales.

Stratigraphic relationships.—The Hale Formation rests unconformably upon the Pitkin Formation of Mississippian age and is succeeded conformably by the Bloyd Formation. At some places it contains a basal conglomerate composed of fragments of older rocks.

Bloyd Formation

Nomenclator.—A. H. Purdue (1907).

Type locality.—Vicinity of Bloyd Mountain, Washington County, Arkansas.

Original description.—Purdue (1907, p. 3) wrote:

> The thickness of the Bloyd shale ranges from 100 to 220 feet. Its thinnest part is in the northeastern portion of the quadrangle. The thickest exposure noted is on the western slope of Hale Mountain, though it approximates 200 feet in all the ravines of the southern slope. With the exception of the Brentwood and Kessler limestone lentils and a bed of coal which is present in places, this formation consists almost entirely of black, thin-fissile, carbonaceous clay shale of uniform character. . . .
>
> The coal occurs between the Brentwood and the Kessler limestones. It rarely exceeds 12 inches in thickness and is generally found not far above the Brentwood limestone. As a distinguishable vein it is only local, but streaks of coal ranging in thickness from a fraction of an inch to 2 inches are seen in fresh exposures.

Distribution.—The Bloyd Formation crops out widely in northwestern Arkansas and northeastern Oklahoma. It is beveled to extinction near the Mayes-Wagoner County line, north of Muskogee County, by pre-Atoka erosion.

Thickness and character.—Of the Bloyd Formation in northeastern Oklahoma, including Muskogee County east of the Arkansas River, Huffman and others (1958, p. 80-81) wrote:

> The Bloyd formation is best described as a sequence of alternating shales and limestones. The lithology of the limestone is variable, ranging from blue-gray to black, from fine to coarsely crystalline in texture, and from massive- to thin-bedded.
>
> The shale is black, brown or greenish-gray, normally noncalcareous, fissile, and it contains limestone concretions. A few beds are calcareous; these range in color from brown to gray.
>
> Sandstones or sandy limestone occur near the base and top of some sections. Occasional siltstones are present, in most cases near the top. These are brown to gray, micaceous, and thin-bedded. A thin bed of coal (0.8 feet) exposed along Highway 10, sec. 20, T. 15 N., R. 20 E. has been placed in the Bloyd by Moore (1947) and tentatively correlated with the Baldwin coal of Arkansas. It

is possible that this coal is in the lower Atoka inasmuch as it is associated with sandstones, shales, underclay, and conglomerates which closely resemble those in the overlying Atoka.

The Bloyd reaches a maximum thickness of 225 feet in the Stilwell area on North Double Head Mountain, NE¼ sec. 23, T. 15 N., R. 25 E. It thins westward toward Muskogee with only 58 feet present at Braggs Mountain, secs. 21 and 29, T. 15 N., R. 20 E. It thins northward to extinction near the Mayes-Wagoner County line.

Gregware (1958) found that the Bloyd Formation is 70 feet thick in exposures in sec. 28, T. 13 N., R. 20 E., west of the Arkansas River. Moore (1947) found it to be 67 feet thick at virtually the same place. Moore also found the Bloyd to be 120 feet thick in his Goose Neck Bend section west of the Arkansas River, in sec. 26, T. 15 N., R. 19 E.; 107 feet in the River Bluff section in sec. 21, T. 15 N., R. 20 E.; 68 feet in the Braggs Mountain section along old State Highway 10, in sec. 29, T. 15 N., R. 20 E.; and 55 feet along new State Highway 10 in secs. 21 and 28, T. 15 N., R. 20 E.

Stratigraphic relationships.—The Bloyd Formation is conformable with the Hale Formation, below, but unconformable with the Atoka Formation, above.

Desmoinesian Series

In Iowa, Missouri, and Kansas, the base of the Desmoinesian Series is generally placed at the unconformity between the Pennsylvanian and pre-Pennsylvanian rocks. But owing to the presence of older Pennsylvanian rocks in Oklahoma south of central Mayes County (north of Muskogee County), which attain thicknesses of thousands of feet in the Arkoma basin, Oakes (1953, p. 1523) placed the base of the Desmoinesian Series in Oklahoma at the top of the Atoka Formation or at the top of the older rocks in areas where the Atoka is absent. L. R. Wilson (1976) now has evidence, based upon palynology, that the Atoka Formation is Desmoinesian in age, and in this report the Atoka is considered the basal Desmoinesian unit. At the top of the series is the obscure but extensive and important pre-Missourian unconformity at the base of the Seminole Formation.

Atoka Formation

Nomenclator.—J. A. Taff and G. I. Adams (1900).

Type locality.—The name is no doubt from the vicinity of Atoka, Atoka County, Oklahoma, but no type locality has been designated.

History of usage.—Subsequent usage of the term Atoka Formation has followed the intent of Taff and Adams.

Distribution.—The Atoka Formation crops out in the Ouachita Mountains of southeastern Oklahoma, on the northeast flank of the Arbuckle Mountains, along the south side of the Arkoma basin in Oklahoma and Arkansas, on Milton and Backbone anticlines in the Arkoma basin in northern Le Flore County, and around the south and west flanks of the Ozark uplift in Arkansas and Oklahoma. Patches of probable Atoka rocks have been mapped as far north as southern Craig County, Oklahoma.

Thickness and character.—The Atoka Formation on the flanks of the Ozark uplift, north of the Arkoma basin, was described by Huffman and others (1958, p. 85). They stated that in most of the area the true thickness cannot be ascertained because it is the youngest unit present, the upper part having been removed by erosion. They mentioned a maximum thickness of 600 feet southeast of Muskogee.

The Atoka Formation was mapped in that part of Muskogee County south and west of the Arkansas River by Gregware (1958), Bell (1959), and Stine (1958). Gregware gave about 600 feet as the thickness in the northern part and 975 feet in the southern part. A limited amount of black clay shale has been reported from this part of the County, but, as a whole, the formation can be best described as dark-gray or dark-brown, predominantly sandy to silty, locally calcareous shale that grades almost imperceptibly into silty, shaly, locally calcareous sandstone or limestone that may be consolidated, forming an escarpment. Nineteen such units have been mapped, numbered, and described, in ascending order (pl. 1). These numbered units are not continuous throughout the area, and they are so much alike that the various outcrops cannot be correlated by physical or paleontological characteristics alone but can be correlated by using relative stratigraphic relationships.

Unit ℙat$_1$ is the oldest unit of the Atoka Formation that crops out in that part of Muskogee County west and south of the Arkansas River. It crops out along the bluffs of the river in T. 13 N., R. 20 E., where it is a light-brown, medium-grained, cross-bedded, massive sandstone that attains a maximum thickness of about 30 feet. Outcrops are also present in the northeastern part of T. 14 N. and the southeastern part of T. 15 N., R. 19 E., where it is commonly light gray, fine grained, well indurated, and compact and contains marine fossils, being about 15 feet thick; it contains a basal conglomerate where it rests unconformably upon Morrowan rocks.

Unit IPat$_2$ is mostly a gray to brown, fine-grained, massive sandstone about 17 feet thick in Tps. 12-13 N., R. 20 E. In the southwestern part of T. 15 N., R. 19 E., it is a very light-gray or cream-colored well-indurated, compact, fairly thin-bedded, ripple-marked sandstone, calcareous in the upper part, and about 18 feet thick.

Unit IPat$_3$ is at the surface over a considerable area on the Warner uplift in Tps. 12-13 N., R. 20 E., where it is generally a light-reddish-brown, fine- to very fine-grained, massive sandstone 15 to 20 feet thick. It also crops out in the northeastern part of T. 14 N. and in the southeastern part of T. 15 N., R. 19 E., where it is a light-brown to light-gray, well-cemented, nonfossiliferous sandstone, being generally massive but thin bedded at some localities.

Unit IPat$_4$ is an extremely erratic sandstone with patchy outcrops around the Warner uplift in Tps. 13-14 N., R. 20 E., where it is fine grained, massive to thin bedded, and probably does not exceed 5 feet in thickness. Similarly, patchy outcrops occur in the northeastern part of T. 14 N. and in the southeastern part of T. 15 N., R. 19 E., where it is light brown, calcareous, micaceous, well cemented, and blocky to thin bedded and contains fossil molds, being about 8 feet thick.

Unit IPat$_5$ crops out in the same general area as unit IPat$_4$ and is also erratic in occurrence. In Tps. 12-13 N., R. 20 E., it is commonly a brown, fine-grained, massive sandstone, which attains a thickness of 10 feet in some localities. In Tps. 14-15 N., R. 19 E., it is a medium-gray to greenish-gray, calcareous, well-cemented sandstone, about 3 feet thick; it contains marine fossil impressions and has clay balls embedded in it.

Unit IPat$_6$ crops out at a few places around the Warner uplift in Tps. 12-13 N., R. 20 E., where it is commonly a thin-bedded, very fine-grained sandstone. It is generally 3 to 4 feet thick, but it attains a maximum thickness of 10 feet. Specimens of

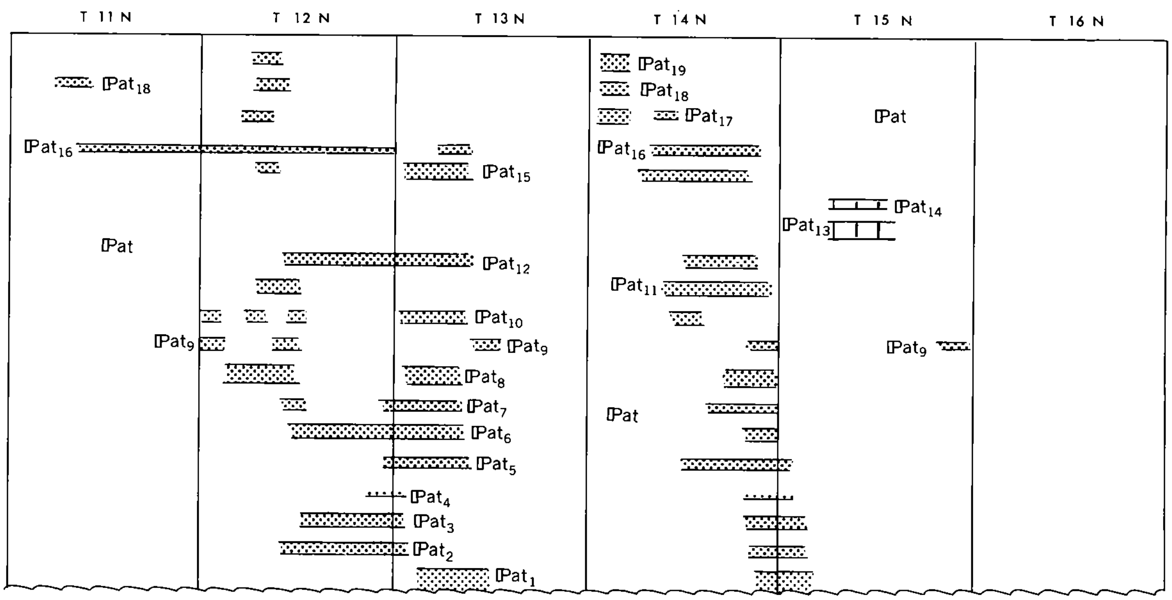

Figure 3. Section diagram, not to scale, of Atoka Formation as it crops out in Muskogee County. Illustrated is south-to-north distribution of 19 mapped units (see pl. 1). Units 13 and 14 are thin limestones; others are sandstones. Remainder of Atoka consists mostly of silty to sandy shale. Atoka Formation is unconformable with rocks of Morrowan Series, below, but conformable with Hartshorne Formation, above.

Taonurus are abundant. In the northeastern part of T. 14 N. and the southeastern part of T. 15 N., R. 19 E., it is a light-brown or grayish-brown, calcareous, well-cemented, fine-grained sandstone 4.5 feet thick; it contains abundant fossil molds.

Unit ℙat$_{7}$ is patchy in outcrops around the Warner uplift in Tps. 12-13 N., R. 20 E., where it is mostly a greenish-brown to brown, thin-bedded to massive, fine-grained, shaly, weakly resistant sandstone more than 20 feet thick. Molds and casts of marine invertebrates are abundant in some parts. The unit occurs over a large hilltop in the northeastern part of T. 14 N., R. 19 E., where it is a light-brown to light-green, well-cemented, fine-grained, micaceous sandstone about 8 feet thick.

Unit ℙat$_{8}$ crops out on the southeastern and northwestern flanks of the Warner uplift, in Tps. 12-13 N., R. 20 E., and in the Rattlesnake Mountain syncline in T. 13 N., R. 19 E. It is a light-gray to brown, fine-grained sandstone with a maximum thickness of more than 20 feet. It weathers characteristically into small angular fragments. As mapped, it is probably part of the Webbers Falls Sandstone of Wilson and Newell (1937).

Unit ℙat$_{9}$ crops out on the flanks of the Warner uplift and in the Rattlesnake Mountain syncline in Tps. 12-13 N., Rs. 19-20 E., and in sec. 4, T. 14 N., R. 19 E. It is a greenish-brown to brown, thin-bedded, very fine-grained, weakly resistant sandstone with a maximum thickness of more than 5 feet. It forms a prominent escarpment in T. 14 N., R. 19 E.

Unit ℙat$_{10}$ is a sandstone unit. Its outcrops are patchy and widely distributed. In Tps. 12-14 N., Rs. 19-20 E., it is mostly light gray or greenish gray, very fine grained, micaceous, and thin bedded, being about 3 feet thick.

Unit ℙat$_{11}$ crops out most prominently in T. 14 N., R. 19 E., but farther south it is so shaly and weakly resistant that there are few outcrops. It is mostly a brown, fine-grained, thin-bedded to massive sandstone about 3 feet thick.

Unit ℙat$_{12}$ is a sandstone unit. The following description is from Gregware (1958, p. 23):

> This unit forms a continuous band of outcrop around the Rattlesnake Mountain Syncline, and is also found in the central and northwestern part of T. 14 N., R. 19 E. It is generally a fine-grained, thin-bedded sandstone which is only locally massive. It caps a relatively prominent escarpment around the Rattlesnake Mountain Syncline, and in sec. 26, T. 13 N., R. 19 E., a thin coal smut is present just below the sandstone. This is the only coal found in the Atoka formation of this area [McLain area]. Wilson (1937) had mapped the [ℙat$_{12}$] sandstone as the Hartshorne formation throughout T. 13 N., R. 19 E., but the stratigraphic position of the unit suggests that it is well down in the Atoka formation. . . . The maximum thickness of the [ℙat$_{12}$] sandstone is more than 20 feet.

Units ℙat$_{13}$ and ℙat$_{14}$ are limestone units. The following is from Gregware (1958, p. 23, 25):

> The mapping of the Atoka limestones found in secs. 14, 22, 23, and 24, T. 14 N., R. 19 E., is only tentative. It appears, in general, that there are two different beds of limestone separated by about 15 feet of dark gray shale. These beds have been mapped as the [ℙat$_{13}$] and [ℙat$_{14}$] limestones, and because of their similarity they will be discussed together. The limestones are mostly dark gray to brown, medium-crystalline, shaly, and fossiliferous. Specimens of "*Marginifera*" are the most abundant fossils, but other fossils are also common in the limestones. The limestones are generally about 2 feet thick, but in places where they have some interbedded shales, they may be as much as 8 feet thick.

Concerning unit ℙat$_{15}$, Gregware (1958, p. 25) wrote:

> This sandstone is found in scattered outcrops in T. 14 N., R. 19 E., and also in secs. 20 and 21, T. 13 N., R. 19 E. It is generally a brown, fine-grained, thin-bedded sandstone with a maximum thickness of about 5 feet. Locally it is resistant and forms relatively prominent escarpments as in sec. 8, T. 14 N., R. 19 E.

The base of sandstone unit ℙat$_{16}$ corresponds in a general way with the base of Wilson's Blackjack School Sandstone and overlying shale, which he extended up to the base of his Hartshorne Sandstone (Wilson, 1935). In the central part of T. 14 N., R. 19 E., unit ℙat$_{16}$ is a greenish-brown, fine-grained, massive to thin-bedded sandstone with a maximum thickness of about 20 feet. In Tps. 11-13 N., R. 19 E., it is finer grained, more shaly, and more lenticular. Although it forms conspicuous escarpments of some length, its stratigraphic position probably varies.

Units ℙat$_{17}$ through ℙat$_{19}$ are thin, extremely lenticular sandstones that crop out in the central and southern parts of T. 14 N., R. 19 E., in the southwest corner of T. 12 N., R. 19 E., and in the western part of T. 11 N., R. 19 E. They are mostly shades of brown and are very fine grained and thin bedded.

None is more than 3 or 4 feet thick. Their stratigraphic occurrence probably varies by tens of feet and represents only the most resistant parts of thick, weakly indurated sandstone lenses otherwise concealed in the sandy shale.

Newell (*in* Wilson and Newell, 1937, p. 159, 165-167, 170, 171, 175-179, 181) measured a number of sections in the Atoka Formation in detail and related them to the mapping done by Wilson (pl. 1, *in* Wilson and Newell, 1937). Wilson's mapping does not correspond to that done by Gregware (1958), Stine (1958), and Bell (1959), which are the main sources of mapping of the Atoka Formation used in compiling this report.

From these and other sources, the writer attempted to assemble enough data to construct a representative outcrop section of the Atoka Formation for each township across Muskogee County, from south to north, but without success. Outcrops of the numbered resistant units are too sparse to permit measurement, or even a close estimate, of the thicknesses of the shale units between them.

Hartshorne Formation

Nomenclator.—J. A. Taff (1899).

Type locality.—Although not mentioned by Taff, the type locality presumably is in the vicinity of Hartshorne, Pittsburg County, Oklahoma, which is partly encircled by the outcrop of the formation.

Original description.—Taff (1899, p. 436-437) wrote of this formation:

> This is a brown to light gray sand rock which has an extreme thickness of about 200 feet. Near the top the beds are very thick and some are massive. Upon the surface they occur as roughly rounded masses and thick ledges. Below, and especially in the lower part, many of the beds are thin and slabby and are associated with sandy shales. . . . The Hartshorne coal lies above this sandstone and is separated from it by a thin but variable bed of shale. The indicative value of this sandstone should be appreciated by the coal prospector, since wherever the sandstone can be traced coal may be expected to occur.

Taff and Adams (1900, p. 274-275) wrote concerning the Hartshorne Formation in the area east of Hartshorne:

> An aggregation of brown, gray, and usually thin-bedded sandstones which locally become shaly constitutes this formation. The upper beds are in places thick, and even massive, while the lower ones are generally thin and grade into shale toward the base. In places the sandstone beds are thin and shaly throughout; at others—for instance, in the railroad cut south of Petros switch, on the Kansas City, Pittsburg and Gulf Railroad—the sandstone is separated into three beds, with shale intervals, each containing a thin coal seam. . . .
>
> The thickness of this sandstone could not be accurately determined. . . . Estimates were made, which varied from 100 feet to a little less than 200 feet. . . .
>
> There are two coal beds associated with the Hartshorne sandstone, known as the upper and lower Hartshorne coals. The upper bed is above the sandstone and is separated from it by a thin bed of shale, which is variable in thickness. Locally this coal bed rests almost upon the sandstone. It properly belongs in and at the base of the McAlester shale, which overlies the Hartshorne sandstone. The contact line at the top of the Hartshorne sandstone is drawn approximately upon the crop of this coal. The lower Hartshorne coal bed is separated from the upper by nearly 50 feet of sandstone and shaly strata.

History of usage.—Hendricks and Parks (1950, p. 73) wrote:

> The Hartshorne sandstone has been defined in earlier work in Arkansas as the first continuous sandstone underlying the Lower Hartshorne coal, and that definition is adopted in the present report. Taff and Adams [1900, p. 274-275], on the other hand defined the Hartshorne sandstone in Oklahoma as extending from the top of the first sandstone below the Upper Hartshorne coal to the base of the first continuous sandstone below the Lower Hartshorne coal. It is thus evident that the sandstone lying between the Upper and Lower Hartshorne coals in Oklahoma is not a part of the Hartshorne sandstone as mapped in Arkansas.

The dominantly sandstone interval between the Lower and Upper Hartshorne coals is thinner northwestward in northern Le Flore County, until the interval is represented by only a sandy-shale parting. Finally, the two coals are represented by one seam composed of upper and lower parts that readily split apart in mining. In view of this situation, the top of the Upper Hartshorne coal was taken to mark the boundary between the Hartshorne Formation and the overlying McAlester Formation in Haskell and northern Le Flore Counties (Oakes and Knechtel, 1948, p. 25). That usage is here extended to apply to Muskogee County.

Distribution.—In Muskogee County and farther north, the Hartshorne Formation is represented by lenticular sandstones with a thin coal seam at the top, at about the stratigraphic position of the Hartshorne Formation as mapped in Haskell and northern Le Flore Counties.

Character and thickness.—The Hartshorne Formation in Muskogee County is ex-

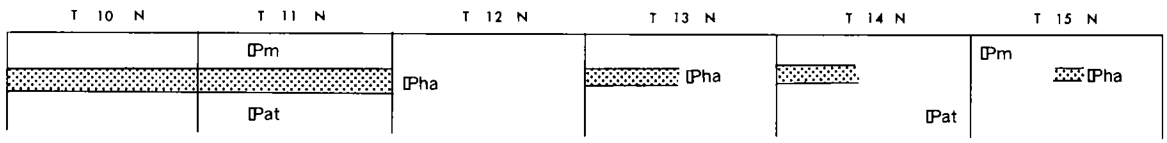

Figure 4. Section diagram, not to scale, illustrating south-to-north distribution of Hartshorne Formation as it crops out in Muskogee County. See plate 1 for explanation of symbols. Hartshorne is conformable with Atoka Formation, below, and with McAlester Formation, above.

tremely variable in continuity and thickness. The most prominent outcrop, about 50 feet thick, extends in a northeasterly direction through Tps. 10-11 N., R. 20 E., roughly parallel to the Canadian River. It is a greenish-gray, fine- to medium-grained sandstone, with small-scale cross-bedding. It is a prominent scarp former, comparable in this respect to the Warner Sandstone Member of the overlying McAlester Formation.

The Hartshorne Formation crops out along the south side of the Warner uplift. This line of intermittent outcrops extends in a northeasterly direction diagonally across T. 11 N., R. 19 E., and into the southwest corner of T. 12 N., R. 20 E. In these outcrops, the Hartshorne is a greenish-brown, fine-grained, finely cross-bedded, thin-bedded sandstone. It grades into shale both above and below. The Hartshorne Formation is absent over most of the Warner uplift. However, there is no indication of an unconformity. Stine reported that he found a little coal in the northeast corner of sec. 2, T. 11 N., R. 20 E., in external molds of fossil plants, as if formed from the organic material of those individual plants, and that otherwise he found no coal in the Hartshorne Formation in Tps. 10-11 N., Rs. 19-20 E.

The Hartshorne Formation crops out sparsely in Tps. 13-15 N., Rs. 19-20 E. It is not more than 17 feet thick anywhere and is most commonly 3 or 4 feet thick. In most exposures it is a brown, fine- to very fine-grained, thin-bedded to massive sandstone, which commonly forms a low bench wherever it crops out. At some places, 5 feet or less above the sandstone and separated from it by dark sandy shale, is a coal seam 1 foot thick or less which is here considered to represent both the Upper and Lower Hartshorne coals of the Arkoma basin.

A coal seam about 3.5 feet below the sandstone and separated from it by sandy shale is exposed only in sec. 15, T. 14 N., R. 19 E.; the coal is about 0.5 feet thick. This coal is here included in the coal-bearing Hartshorne Formation rather than in the non-coal-bearing Atoka Formation, below.

McAlester Formation

Nomenclator.—J. A. Taff (1899).

Type locality.—Taff did not formally designate a type locality for the McAlester Formation, but the name was probably first applied to outcrops of the formation in the vicinity of McAlester, Pittsburg County, Oklahoma.

History of usage.—Common usage of the

term McAlester Shale or McAlester Formation has been applied to the strata between the top of the Hartshorne Formation, below, and the base of the Savanna Formation, above. Oakes and Knechtel (1948, p. 25) restricted application of the term McAlester to strata above the Hartshorne coal in Haskell County, and that restriction is here extended to Muskogee County (see discussion of Hartshorne Formation, this report). Oakes and Knechtel (1948, p. 51) presented evidence that the base of the Spaniard Limestone of Wilson (1935) is, for all practical purposes, the top of the McAlester Formation in Muskogee County.

Distribution.—Outcrops of the McAlester Formation extend from the northern flanks of the Arbuckle Mountains to the Kansas-Oklahoma line, near the northeast corner of Oklahoma, and eastward in the Arkoma basin to the Arkansas-Oklahoma line. Outcrops of the McAlester Formation extend across Muskogee County, mostly in Rs. 19-20 E. (pl. 1).

Description.—The McAlester Formation in the Arkoma basin consists predominantly of clay shale and silty shale, but at widely spaced intervals are prominent sandstone beds that give rise to conspicuous escarpments. The McAlester also contains some thin, discontinuous limestone beds and several coal seams. The only coal seams that have been much worked are the Lower McAlester, the Upper McAlester, and the Stigler. The Stigler is worked in Haskell County, where it was named from the town of Stigler. Some geologists have equated the Stigler with the Upper McAlester, but others have considered the Stigler to be a somewhat higher seam.

The McAlester Formation, like its individual members, is variable in thickness, dependent in part, no doubt, on structural variations. There is a tendency for Pennsylvanian units in northeastern Oklahoma to be thicker in synclines than in anticlines. Plate 2 represents an attempt to compile the thickness of the McAlester Formation across Tps. 10 to 15 N. Newell (*in* Wilson and Newell, 1937, pl. 3) attempted the same thing with comparable results. In most instances his thicknesses are greater than ours, and he may have used higher estimates of dip.

The McAlester Formation is about 650 feet thick in T. 9 N., Haskell County (Oakes and Knechtel, 1948, pl. 4). In Muskogee County, it is about 400 feet thick in Tps. 10-13 N., about 300 feet in T. 14 N., and 150 feet in T. 15 N.

W. T. Thom, Jr. (1935), made a preliminary investigation of most of Haskell County and northern Le Flore County, in the course of which he applied names to most of the sandstone units of the McAlester Formation and to its lowest shale unit, the McCurtain Shale. C. W. Wilson, Jr. (1935), working under Thom's direction, first applied and published these names of units in Muskogee County. From the base upward, the units are: McCurtain Shale, Warner Sandstone, Lequire Sandstone, Cameron Sandstone, Tamaha Sandstone, and Keota Sandstone.

Even in some parts of Haskell County, the shale intervals between some of the named sandstone units are so sandy that hyphenated names were applied, such as Cameron-Lequire and Lequire-Warner (Oakes and Knechtel, 1948). This practice is extended northward into Muskogee County, where the section is thinner and where it is difficult to identify named units. No unit is continuously mappable across Muskogee County, and not even the upper and lower limits of the McAlester Formation can be indicated exactly at all places.

McCurtain Shale Member.—The shale between the Hartshorne Sandstone, below, and the Warner Sandstone Member of the McAlester Formation, above, was named the McCurtain Shale by Thom (1935), and the name was used by Wilson (1935) and by Wilson and Newell (1937). However, neither the Hartshorne nor the Warner is continuously mappable across Muskogee County. Newell (*in* Wilson and Newell, 1937, p. 37) wrote as follows:

> This unit consists almost entirely of shale, unbroken by resistant beds. The lower half is commonly dark gray to black, slabby and silty, and contains abundant unfossiliferous clay-ironstone concretions. The upper half is argillaceous, and buff to greenish, and concretions are not generally abundant. A thin coal bed ranging from an inch or so to more than one foot occurs at the base of the McCurtain division in Tps. 12 and 13 N. Because of its position immediately above the Hartshorne sandstone this coal is correlated with the upper Hartshorne coal south of Canadian River. Apparently the coal is absent in both the northern and southern parts of the Muskogee-Porum district.
>
> Another thin coal bed locally occurs near the top of the McCurtain shale member in Tps. 13 and 15 N. Probably it is present also in T. 14 N., but suitable exposures below the Warner sandstone were not found in this area. The coal is of no economic importance.

> Like most of the Pennsylvanian divisions in the region the McCurtain shale shows marked northward thinning, decreasing in thickness from 200 feet in T. 10 N., to about 80 feet in T. 14 N. The thickness of the unit in T. 15 N. is not known because the lower boundary, defined by the Hartshorne sandstone, was not recognized that far north.

Stine (1958), Gregware (1958), and Bell (1959) studied this shale in more detail and found local mappable sandstone lenses near the middle. Otherwise, they found the unit to be substantially as that described by Newell. The McCurtain is 100 to 200 feet thick on the south limb of the Porum syncline in Tps. 10-12 N., Rs. 19-20 E., 42 feet thick on the Warner uplift in T. 11 N., R. 19 E., and 85 to 100 feet thick in T. 14 N.

Warner Sandstone Member.—The name Warner Sandstone was first used in print by Wilson and Newell (1937). The type locality of the member is about ¼ mile east of the northwest corner of sec. 21, T. 12 N., R. 19 E., 1 mile north of Warner, Muskogee County. Newell (*in* Wilson and Newell, 1937, p. 37) gave the following general description of the Warner in Muskogee County:

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

There is a local 5-foot shale interval, with a local coal seam a few inches thick, about 10 feet below the top of the Warner. The same sequence of sandstone and shale with coal occurs in the upper part of the Warner at some places in Haskell County (Oakes and Knechtel, 1948, p. 21).

In Tps. 10-12 N., Rs. 19-20 E., the Warner is a massive to thin-bedded sandstone with a maximum thickness of about 60 feet. Wherever it is massive it is resistant and caps prominent escarpments. Along the east flank of the Porum syncline, this sandstone is thinner southward from the northern part of T. 11 N., R. 20 E., to secs. 17-20, T. 10 N., R. 20 E., where it virtually pinches out. The shale above the Warner almost pinches out in this locality, and the Cameron-Lequire Sandstone unit merges with the thin remnant of the Warner. Farther south, in the vicinity of the northwest corner of sec. 32, T. 10 N., R. 20 E., in an area surrounded by terrace sand and recent alluvium, is an outcrop of sandstone mapped on plate 1 as Warner; it may be

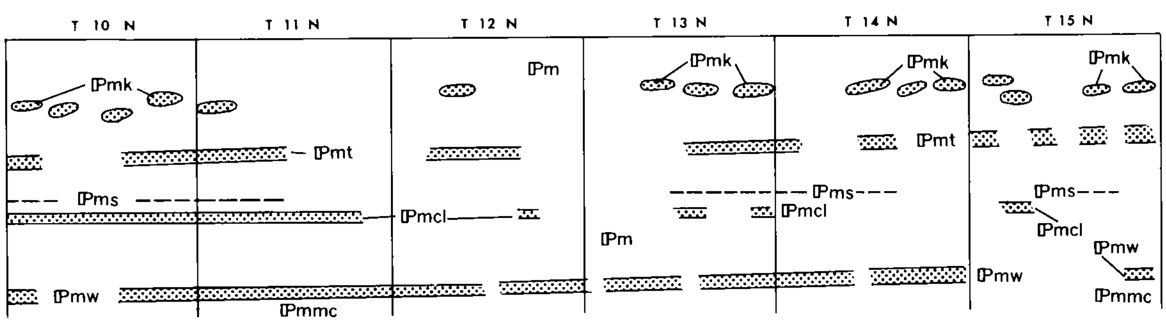

Figure 5. Section diagram, not to scale, illustrating south-to-north distribution of McAlester Formation as it crops out in Muskogee County. See plate 1 for explanation of symbols.

either the Warner, the Cameron-Lequire, or perhaps both.

In the southwestern part of T. 12 N., R. 20 E., the Warner rises up the northwest limb of the Porum syncline and caps a prominent ridge along the line between secs. 29 and 30, known as Rabbit Hill. From here, the Warner trends southwestward toward the west quarter corner of sec. 14, T. 11 N., R. 19 E., where it is possibly cut off by the southwestern fault of the Warner uplift. Isolated outcrops occur along the southeastern side of the Warner uplift, extending to the southwestern corner of T. 11 N., R. 19 E., where there is a large outcrop of Warner Sandstone about 60 feet thick. However, the Warner is thinner a short distance northwestward into McIntosh County and is absent on the Warner uplift north of sec. 26, T. 11 N., R. 18 E.; it may not have been deposited there.

The Warner Sandstone Member crops out on a broad southwestward dip slope in the north-central and northwestern parts of T. 12 N., R. 19 E. Newell (*in* Wilson and Newell, 1937, p. 164) estimated it to be 25 feet thick in secs. 6 and 7. The Warner is the aquifer for most of the domestic water supply in this vicinity.

In T. 13 N., R. 19 E., the Warner crops out just north of the Keefeton fault and caps a prominent south-facing escarpment almost entirely across the central part of the township. Gregware (1958, p. 92) estimated it to be 30 feet thick across the western side of sec. 18.

The Warner crops out on a broad southwestward dip slope in the north-central part of T. 13 N., R. 19 E., and the south-central part of T. 14 N., R. 19 E. Newell (*in* Wilson and Newell, 1937, p. 179) found the Warner to be 50 feet thick on the northeast point of Brushy Mountain in sec. 27, T. 14 N., R. 19 E.

The Warner Sandstone Member is variable in both thickness and character in T. 14 N., Rs. 18-19 E., where it caps an eastward-facing escarpment and at least five outlying hills. In sec. 11, T. 14 N., R. 18 E., the Warner is generally silty to fine grained, micaceous, weakly indurated, thin bedded to blocky, and rust brown on weathered surfaces. A coal seam 10 inches thick was found directly below the sandstone. The shale commonly present in the upper part of the Warner is evident only in sec. 25, T. 14 N., R. 18 E.; the thin coal seam in this shale at some places was not found here. In sec. 36, T. 14 N., R. 18 E., the Warner is fine grained, thin bedded to massive, and ripple marked. The thicker beds contain limonitic concretions and stringers.

In T. 15 N., Rs. 18-19 E., several limited exposures of sandstone have been mapped as Warner Sandstone. This sandstone is generally silty, well indurated, calcareous, light gray, and 4 to 5 feet thick; it overlies a light-gray, calcareous siltstone. In sec. 10, T. 15 N., R. 18 E., a 4-inch coal seam and its underclay lie 2 feet above the top of the sandstone.

The Warner Sandstone Member is correlated with the Booch sand of subsurface terminology and with the Little Cabin Sandstone of the surface in northeastern Oklahoma.

Unnamed shale above Warner Sandstone Member.—The shale between the Warner Sandstone Member and the Cameron-Lequire Sandstone Member in Tps. 10-11 N., Rs. 19-20 E., ranges from extinction up to 60 feet in thickness. At most exposures it is gray and fissile. In secs. 17-19, T. 10 N., R. 20 E., it grades into sandstone that is continuous upward with the Cameron-Lequire Sandstone. This shale forms a broad valley along the axis of the Porum syncline in the northern part of the area, where it is partly surrounded by the Warner Sandstone. The shale is absent on the Warner uplift but is present between the Warner and Cameron-Lequire Sandstones north of the uplift, in the northwestern part of T. 12 N., R. 19 E., where Gregware (1958) described it as being about 100 feet thick. In the syncline in the northwestern part of T. 13 N., R. 19 E., the shale is generally dark gay or greenish gray to light brown, and silty, and in some places it is weakly indurated and somewhat fissile. Two thin, brown, fine-grained, shaly, lenticular sandstones less than 3 feet thick crop out about 25 feet above the Warner and form small benches in sec. 17, T. 13 N., R. 19 E. Near the middle of the shales are two 1- to 2-inch limestones that are 10 to 15 feet apart and crop out in the SE¼ sec. 17 (not shown on pl. 1). They are gray to red, finely crystalline, and very ferruginous at most places and locally so fossiliferous that they might be called coquinites. A coal seam 0.1 inch thick with an underclay occurs between the limestones. The 25-foot shale between the Warner and the Cameron-Lequire in secs. 1 and 11, T. 13 N., R. 18 E., is not well exposed and is not mapped separately in Tps. 14-15 N.

Cameron-Lequire Sandstone Member.—Both the terms Lequire and Cameron have been applied to certain lenticular sandstone beds and even to extremely sandy shales that crop out below minable coal, here assigned to the Stigler coal seam of Haskell County. Following the precedent set by Oakes and others (1967, p. 16), the term Cameron-Lequire is applied to these beds.

The term Lequire Sandstone was first used in print by Wilson (1935, p. 508). It was named by Thom (1935), and the type locality is in sec. 31, T. 8 N., R. 21 E., 1.5 miles northwest of Lequire, southern Haskell County, according to Oakes and Knechtel (1948, p. 37). Likewise, the Cameron Sandstone was named by Thom, with the type locality being near Cameron, northern Le Flore County. Oakes and Knechtel (1948, p. 39, fig. 5) found that in several localities in Haskell County the Lequire and Cameron almost meet, making one unit of the two.

Stine (1958, p. 29-30) found that the Cameron-Lequire Sandstone Member pinches out against the southeastern flank of the Warner uplift in sec. 12, T. 11 N., R. 19 E. The unit is thicker southward (30 feet) at the expense of the underlying shale, resting upon the Warner Sandstone Member in sec. 20, T. 10 N., R. 20 E. He also found that a few feet of the lower part of the unit crops out on the Warner uplift in the southwest corner of T. 11 N., R. 18 E.

This outcrop extends westward into McIntosh County, where the unit consists of two parts separated by 13 feet of shale. The lower part is 40 feet thick but is thinner northward to extinction in sec. 23, T. 11 N., R. 18 E. The upper part is as thick as 45 feet and continues across the Warner uplift, in McIntosh County, to the north fault.

The unit called the Cameron Sandstone by Gregware (1958, p. 41) is, no doubt, the same unit as the Cameron-Lequire Sandstone of this report. It crops out on a westward dip slope in the west-central part of T. 12 N., R. 19 E., where it is thin bedded and between 2 and 5 feet thick. It consists of about 5 feet of interbedded siltstone and greenish-gray shale, which forms a low bench across the road along the west side of sec. 18, T. 13 N., R. 19 E. Coleman (1958, p. 19) mapped an extension about half a mile westward into sec. 13, T. 13 N., R. 18 E., and mentioned that it crops out in sec. 1. Coleman (1958, p. 19) described the Cameron-Lequire as a 4- to 6-foot bed of weakly-indurated, brown, fine- to medium-grained, thin-bedded, cross-bedded, ripple-marked sandstone containing carbonized plant impressions at the top. An 8- to 10-inch coal seam, which he correlated as Stigler, lies a short distance above the sandstone and has been mined in sec. 1.

Unnamed shale above Cameron-Lequire Sandstone Member.—Stine (1958, p. 31) described the shale that crops out between the Cameron-Lequire and the Tamaha Sandstone Members in Tps. 10-11 N.:

> It ranges from about 50 to 80 feet in thickness, being thickest to the south. The distribution of this shale roughly straddles the east boundary of townships 10 and 11 N., R. 19 E. . . . Along the road on the west side of sec. 27, T. 11 N., R. 19 E., in the south creek bank of the east side of the road, the Stigler coal is 1.5 feet thick with an underclay below and gray shale above.
>
> In sec. 35, T. 10 N., R. 19 E. another thin coal is present about 4 feet above the Stigler coal. The shale between these two coals is highly carbonaceous. Above the upper coal is a zone containing a molluscan fauna. The . . . shale is present on the uplift west of this area where the total thickness could not be observed owing to its base being covered by terrace sand. . . .
>
> Over the rest of the area where the coal has been stripped the pits were flooded with water and the coal could not be observed. The Stigler coal is used as a key bed because it is the only coal in this area of such thickness and continuity.

The shale between the Cameron-Lequire and the Tamaha Sandstone Members crops out in sec. 18, T. 12 N., R. 19 E., where Newell (*in* Wilson and Newell, 1937, p. 162) found it mostly covered and about 50 feet thick. Gregware (1958, p. 91) measured one of the few well-exposed sections from the top of the Warner Sandstone Member to the top of the McAlester Formation, along the west line of sec. 18, T. 13 N., R. 19 E. The 33-foot shale between the Cameron-Lequire and the Tamaha is green or blue gray and partly covered; the 56-foot shale between the top of the Tamaha and the base of the Keota Sandstone Member is greenish, greenish gray, or bluish gray, silty, and fissile and contains some thinly interbedded siltstone. Shale occurs from the top of the Warner to the base of the Keota in the southern part of T. 13 N., R. 18 E., but it is mostly covered by recent alluvium. The Cameron-Lequire Sandstone, the Stigler coal seam, and the Tamaha Sandstone crop out in sec. 1, T. 13 N., R. 18 E., but the shales between crop out poorly and have not been measured.

Tamaha Sandstone Member.—The Tamaha Sandstone was named by Thom (1935) from the town of Tamaha in northern Haskell County. Oakes and Knechtel (1948, p. 40) found that his type locality is, in fact, on the outcrop of the Lequire-Warner sandstone interval, and they designated a new type locality in sec. 30, T. 11 N., R. 22 E., some 2 miles west of Tamaha. Over much of Haskell County, the Tamaha is absent, and the same is true of the Tamaha in Muskogee County.

Stine (1958, p. 33, pl. 1) mapped the Tamaha in Tps. 10-11 N., R. 19 E., a short distance above the minable coal here correlated with the Stigler coal seam of Haskell County. The Tamaha is cut off by the southern fault of the Warner uplift in sec. 15, T. 11 N., R. 19 E. It ranges greatly in thickness in short distances. For example, it is 1 foot thick in the northwest corner of sec. 35, T. 10 N., R. 19 E., and 24 feet thick along the east line of the same section. Along most of this outcrop, it is 4 to 7 feet thick, and it ranges from massive where thick to flaggy where thin. Outcrops of the Tamaha have not been found on the Warner uplift; it was probably not deposited there.

Gregware (1958, p. 43) mapped an outcrop of Tamaha Sandstone that forms a wide southwestward dip slope in the west-central part of T. 12 N., R. 19 E., and traced it around the faulted syncline in the northwestern part of T. 13 N., R. 19 E., to sec. 31, T. 14 N., R. 19 E., where it caps a prominent hill. He stated that the Tamaha in these outcrops is primarily siltstone and only locally sandstone, that it is normally olive green or light brown, thin bedded, shaly, generally 3 to 5 feet thick, and forms small benches where it crops out.

Coleman (1958, p. 19) found an outcrop of a sandstone in secs. 1 and 11, T. 13 N., R. 18 E., which is here considered to be the Tamaha Sandstone.

Bell (1959, p. 29) reported sandstone that he correlated with the Tamaha in two localities: secs. 23, 24, and 36, T. 14 N., R. 18 E., and sec. 34, T. 15 N., R. 18 E. It is tan to gray, silty to fine grained, and micaceous and has a maximum thickness of 10 feet.

Unnamed shale above Tamaha Sandstone Member.—Bell (1959) mapped the McAlester Formation in Tps. 14-15 N., Rs. 18-19 E., learning little about the shales. The 55-foot shale between the Tamaha and the lowest Keota lens along the south side of sec. 36, T. 14 N., R. 18 E., is grayish brown and silty and contains clay-ironstone concretions. Along the north third of the east line of sec. 23, T. 14 N., R. 18 E., Bell (1959, p. 27) stated that the Tamaha lies 42.5 feet above the Warner, with a 5-inch coal seam (Stigler?) 18.1 feet below the top.

Keota Sandstone Member.—The Keota Sandstone was named by Thom (1935) from outcrops in the vicinity of Keota, Haskell County. The name was first used in print by Wilson (1935). Oakes and Knechtel (1948, p. 43) described the Keota in Haskell County as erratic in the number and thickness of its beds and stated that this poses problems, locally, as to what should be included in the Keota. The result is that the measured sections may range from 20 to 200 feet or more in thickness.

The Keota in Haskell County, to the south, is a sequence of sandstone lentils in sandy shale and includes local coal seams of no economic value. These lentils grade through siltstone into shale and are more sandy than most McAlester shales. However, the unit does have great lateral continuity and is therefore useful as a persistent, if inexact, marker. Much the same is true of the Keota in Muskogee County, but the Keota is thinner northward and sandstone lenses are fewer in number and are finer grained; they grade into poorly exposed siltstones, which are almost impossible to map. Only the sandstone lentils and some thin limestones and coal seams are shown on plate 1. The upper limit is marked at the Spaniard Limestone, the basal unit of the overlying Savanna Formation. The Spaniard is exposed as sparsely as the Keota.

Stine (1958, p. 34) mapped the Keota Sandstone in Tps. 10-11 N., R. 19 E., Muskogee County. The outcrop is covered by Quaternary deposits in some areas in the south part of T. 10 N. and is cut off by the south fault of the Warner uplift in sec. 28 of T. 11 N. The sandstone is 30 feet thick in the south part of T. 10 N. but less than 1 foot thick in sec. 27 of T. 11 N. It is fine to medium grained, thin bedded, and ripple marked.

Gregware (1958, p. 45) mapped the sandstone lenses of the Keota in Tps. 12-13 N., R. 19 E. He stated that they crop out through about 30 feet of section and individually attain a maximum thickness of about 20 feet.

In general, the sandstone is light brown, fine grained, and interbedded with a large amount of siltstone and shale. He found only one small sandstone lentil in sec. 20, T. 12 N. He mapped the Keota Sandstone around the syncline in the northwestern part of T. 13 N. The sandstone on the south flank is flaggy and well ripple marked and is probably the lower Keota. That on the north flank has numerous *Lepidodendron* and other plant fossils and is probably the upper Keota.

Coleman (1958) mapped several lenses of sandstone in T. 13 N., R. 18 E., which he considered to be Keota. The sandstone weathers brown, is medium to fine grained, silty, and irregularly bedded. The most conspicuous of these lenses crops out in secs. 1 and 2 and is an extension of beds mapped by Gregware (1958) on the northern flank of the syncline in the northwestern part of T. 13 N., R. 19 E. This lens extends northward about ¾ mile into an area mapped by Bell (1959), where it is cut off by a fault. It is 16 feet thick at some places, but mostly it consists of 3 or 4 feet of weakly indurated sandstone. Three small Keota Sandstone lentils crop out east-west across the middle of sec. 13. Below the base of the Bluejacket escarpment in secs. 19-20, Coleman mapped outcrops of thin sandstone that probably are upper Keota.

Bell (1959) mapped several sandstone lenses and some thin limestones and coal seams in T. 14 N., R. 18 E., which he arbitrarily assigned to the Keota as described by Newell (*in* Wilson and Newell, 1937). They are designated IPmk on plate 1. There is an upper and a lower sandstone lens, with a limestone commonly a few feet below the upper sandstone, and a coal bed a short distance below the limestone. The limestone is designated IPml on plate 1. Certainly none of these rocks crop out continuously, and the beds may not be precisely equivalent.

The Keota crops out at several places in T. 14 N., R. 18 E. Probably the lower Keota crops out in the southwestern part of sec. 36, where it is grayish brown, well cemented, and silty and about 5 feet thick. Probably the upper Keota crops out along the east side of sec. 35. A lens in a comparable stratigraphic position crops out in the southeastern part of sec. 22, the southwestern part of sec. 23, and the northwestern part of sec. 26. A thin bed of limestone is exposed a few feet below this sandstone, in the bed of the stream in the northwest corner of sec. 26. Sandstone and limestone of the upper Keota crop out similarly on Sam Creek on the west side of sec. 14. Probably the best exposure of Keota beds is along a stream near the middle of the north half of sec. 2, where the Spaniard Limestone is exposed. Four or 5 feet below the Spaniard is a silty, micaceous, 3-foot sandstone that weathers light rust brown and contains abundant marine fossils. The sandstone is underlain by 3 feet of grayish-brown silty shale containing clay-ironstone concretions. Next below is a thin ferruginous limestone filled with *Marginifera*, underlain by a foot of medium-gray, fossiliferous shale resting upon a 1-foot coal seam.

Bell (1959) mapped several outcrops of sandstone lenses as Keota in T. 15 N., R. 18 E. Upper Keota outliers cap hills on either side of the road between secs. 33 and 34, just north of the south line.

A 5-foot upper Keota outlier caps a hill in the NW¼ sec. 34, and a 2-foot sandstone, considered to be Tamaha, crops out 38 feet lower along the north side of the stream. No lower Keota was found at this place. The lower Keota, together with a thin underlying coal seam, crops out in the NW¼ sec. 8. The sandstone is grayish brown, silty, and at least 8 feet thick. It is shaly in the upper 2 feet; otherwise it is well cemented.

The following stratigraphic section is condensed from Bell (1959, p. 92) and is 60 feet west of the east quarter corner of sec. 17, T. 15 N., R. 18 E., and may contain most of the Keota beds in that vicinity:

	Feet
Sandstone: upper part of Keota	7.0
Shale	3.5
Limestone	.5
Coal	.3
Shale	5.0
Limestone	.5
Shale	20.0
Sandstone: base not exposed	8.0
Total	44.8

The upper beds in this section, down through the coal, are exposed 160 feet west of the northeast corner of sec. 16, T. 15 N., R. 18 E.

Unnamed shale above Keota Sandstone Member.—A sandy to silty shale occurs above the youngest Keota Sandstone lenses, up to the base of the Spaniard Limestone, the basal member of the overlying Savanna Formation. This shale is 10 feet thick in T. 10 N., R. 19 E., with a 2-inch coal seam just below the top. This coal seam occurs with the

Spaniard over a wide area in northeastern Oklahoma, including Muskogee County. Coleman (1958, p. 24) found that in T. 13 N., R. 18 E., the upper shale is brown to gray, silty, and fossiliferous and contains a 1-inch coal seam 0.5 to 1.5 feet below the Spaniard Limestone. Gregware (1958, p. 46) reported that this shale crops out on the flanks of the syncline in the northeastern part of T. 13 N., R. 19 E., where it is 5 to 25 feet thick, gray to greenish gray, and silty and contains marine fossils near the top and a 1-inch coal seam 2 feet below the Spaniard Limestone. Bell (1959, p. 35) reported that this shale is 2 to 5 feet thick in a few localities in Tps. 14-15 N., where both the Spaniard and the Keota are identified. The thin coal near the top, just below the Spaniard, is found in sec. 2, T. 14 N., R. 18 E., and in sec. 18, T. 15 N., R. 18 E.

Savanna Formation

Nomenclator.—J. A. Taff (1899).

Type locality.—Taff (1899) did not mention a type locality, but probably he meant the vicinity of Savanna, Pittsburg County, Oklahoma.

History of usage.—For many years, usage of the term Savanna Sandstone or Savanna Formation followed that of Taff (1899). However, because of the variable nature of individual beds, difficulties of precise correlation, and lack of detailed mapping, writers differed in usage from that of Taff. For instance, the upper part of the McAlester Formation and the lower part of the Boggy Formation in Muskogee County were tentatively included in the Savanna Formation by Wilson (1935, p. 509) when detailed mapping of the intervening territory was incomplete.

On the *Geologic Map of Oklahoma*, Miser (1954) classified the Savanna top to be at the base of the Bluejacket Sandstone. The Bluejacket was the longest continuously mappable boundary available, and seemed suitable and acceptable.

Thereby, an 800-foot shale unit, containing a variable amount of sandstone, was reassigned from the Boggy Formation to the Savanna Formation, including the Doneley Limestone and subjacent Rowe coal seam (lower Boggy coal of Wilson and Newell, 1937, p. 53).

Distribution.—The Savanna Formation crops out along the northern flank of the Arbuckle Mountains to the Kansas-Oklahoma line near the northeastern corner of Oklahoma and eastward in the Arkoma basin to the Arkansas-Oklahoma line. It crops out across central Muskogee County from the Canadian River to the Arkansas River.

Thickness and description.—The Savanna Formation of present usage consists mostly of sandstone and shale in the Arkoma basin. The sandstones are highly variable in both thickness and character from place to place and from bed to bed. The Savanna Formation in the basin contains a few disconnected thin limestone beds and numerous coal seams too thin to be worked. Like other Pennsylvanian formations, the Savanna is thinner markedly northward out of the Arkoma basin. It is about 450 feet thick in T. 10 N. and about 170 feet thick in T. 15 N., in Muskogee County. It contains one named and mapped sandstone unit, three named and mapped limestone units, and one coal seam, the Rowe, called the lower Boggy coal by Wilson and Newell (1937, p. 53).

Spaniard Limestone Member.—The Spaniard Limestone Member, at the base of the Savanna Formation in Muskogee County, was named from Spaniard Creek in the NE¼ sec. 11, T. 13 N., R. 18 E., Muskogee County, by S. W. Lowman in an unpublished manuscript, from which Wilson (1935, p. 510) quoted the following measured section:

	Ft.	*In.*
Limestone: dark-gray, fine-grained, weathers brown	1	2
Shale: dark to black, fossiliferous, weathers buff	0	6
Shale: blue-gray, fossiliferous, calcareous	1	6
Total	3	2

Oakes and Knechtel (1948, p. 51, fig. 7) showed that the Spaniard Limestone Member in the vicinity of the Canadian River occupies substantially the same stratigraphic position as does the base of the lowest sandstone of the Savanna Formation in Haskell County. The Spaniard is probably not continuous with that sandstone, but it is certainly the most suitable marker that we have for the base of the Savanna Formation in Muskogee County.

In T. 10 N., R. 19 E., the Spaniard is 2 to 9 inches thick. It is exposed in the isolated hills north of the Canadian River. Farther north, it is seen only in the beds of the larger streams that cut across the strike of the rocks. In most exposures, it consists of a coquina of *Marginifera* and is reddish gray, dense, finely crystalline, and impure. It contains a considerable amount of silt and clay, and where deeply weathered the calcium carbonate is leached out, leaving a porous, ferruginous siltstone containing molds of *Marginifera* and other fossils. The Spaniard has not been found on the Warner uplift in Muskogee County. Outcrops of the Spaniard are probably beneath talus debris in secs. 18-19, T. 12 N., R. 19 E., but exposures have not been found.

Newell (*in* Wilson and Newell, 1937, p. 46) found that in T. 13 N., R. 18 E., fusulinids and the horn coral *Campophyllum* are common but not abundant in the Spaniard Limestone. The Spaniard is 10 to 12 inches thick there. Coleman (1958, p. 28) found that the Spaniard in this township differs greatly in appearance, depending upon, in part, the environment of weathering. In a dry environment, the rock is light gray and may resemble a coquina, but in streams it appears dark gray, smooth, and dense. The Spaniard crops out in the syncline in the northwestern part of T. 13 N., R. 19 E. It is especially evident on the northern flank, where it reaches a maximum thickness of about 2 feet, weathers light gray to light brown gray, and is gray, finely crystalline, shaly, and fossiliferous and contains numerous brachiopods, crinoids, and bryozoans that weather to smooth, rounded surfaces.

Bell (1959) mapped the Spaniard across Tps. 14-15 N., R. 18 E. It is probably a continuous bed but weathers so readily that exposures are mostly in stream beds. Bell stated (p. 39):

> The Spaniard is exposed in sec. 14, T. 14 N., R. 18 E., in Sam Creek, and is 1.5 feet of dark gray ferruginous dense jointed limestone, that weathers to maroon on the outer surface, and contains abundant fossils of brachiopods and crinoids, and a few corals. There are hard calcareous siltstone nodules, as much as one foot long and five inches wide, embedded in the top of the limestone. The Spaniard is well exposed in sec. 18, T. 15 N., R. 18 E., and generally is a hard dense medium gray microcrystalline limestone filled with a large coral, *Caninia torquia,* which constitutes about one-third the volume of the rock. In sec. 18, T. 15 N., R. 18 E., a 4.5-inch coal occurs about three feet below the Spaniard, and is separated from it by deeply weathered fossiliferous shale. About 150 yards north of this exposure in sec. 7, a one-inch coal is exposed about a foot above the Spaniard. Fusulinids have been collected from the Spaniard south of Muskogee a few miles, but none was found by the writer.

Unnamed shale above Spaniard Limestone Member.—In T. 10 N., R. 19 E., gray, weakly indurated, fissile shale occurs from the top of the Spaniard Limestone up to the base of the Sam Creek Limestone, the next higher named unit of the Savanna Formation. It is about 30 feet thick in the south part of the township, where the upper few feet

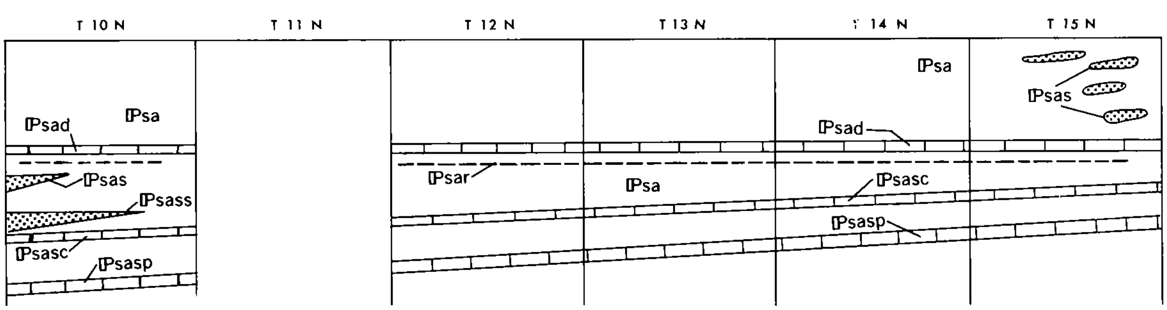

Figure 6. Section diagram, not to scale, illustrating south-to-north distribution of Savanna Formation as it crops out in Muskogee County. See plate 1 for explanation of symbols.

contains a thin coal seam and a thin, unnamed limestone, which have been mistaken for the Rowe coal and the Doneley Limestone.

In T. 11 N., R. 19 E., on the Warner uplift, there are no outcrops of Savanna rocks in Muskogee County.

In T. 12 N., R. 19 E., Savanna rocks crop out only in sec. 19, and surficial cover precludes complete detailed descriptions of the shales. The total thickness of the Savanna Formation is about 225 feet, according to Newell (*in* Wilson and Newell, 1937, p. 164).

In T. 13 N., R. 18 E., in the southwestern part of the township, about 30 feet of somewhat sandy shale lies between the Spaniard and the Sam Creek. Three separate bands of fossiliferous, concretionary limestones occur in the upper half of this shale. No coal seams have been reported, but Newell (*in* Wilson and Newell, 1937, p. 48) mentioned a dark to black underclay at the top.

In Tps. 14-15 N., R. 18 E., the few exposures and the character of the topography indicate that the Savanna Formation is mostly shale. The prevalence of surficial cover precludes much subdivision or detailed description. In T. 15 N., the shale between the Spaniard and the Sam Creek is about 20 feet thick.

Sam Creek Limestone Member.—The Sam Creek Limestone was named by S. W. Lowman (unpublished manuscript) from the type locality on Sam Creek in the eastern part of sec. 15, T. 14 N., R. 18 E., Muskogee County. Wilson (1935, p. 510) quoted the following measured section from the manuscript:

	Ft.	*In.*
Gray limestone; weathers brown; contains so many *Marginifera muricata* that it is almost a coquina	0	6
Gray, fossiliferous shale	3	6
Alternation of gray limestone and gray, fossiliferous shale, the former essentially a reef composed of *Campophyllum torquium*	0	11
Gray limestone, with layers of gray shale	3	8
Total	8	7

Newell (*in* Wilson and Newell, 1937, p. 49) restricted application of the term Sam Creek to the limestone directly below the Spiro Sandstone and redescribed the restricted Sam Creek, at the type locality, as consisting, in ascending order, of 9 inches of reddish-brown limestone filled with *Campophyllum* (most persistent bed), 9 inches of gray and buff silty shale, and 5 inches of sparsely fossiliferous rusty and silty limestone.

According to Stine (1958, p. 42), the Sam Creek Limestone Member is exposed on a hill isolated by terrace sand and recent alluvium in secs. 33 and 34, T. 10 N., R. 19 E., and also in secs. 15 and 22, of the same township. It consists of dark-gray dense, fine- to medium-crystalline limestone that weathers reddish brown. The Sam Creek has not been found farther north in this township nor in Tps. 11-12 N. in Muskogee County.

Coleman (1958) mapped one exposure of Sam Creek near the center of the east line of sec. 31 and several others in secs. 1-2, 11-12, T. 13 N., R. 18 E., but described none of them. Gregware (1958) found the Sam Creek exposed at one place, along a creek bank in the northwestern part of T. 13 N., R. 19 E., where it is about 0.9 foot thick and consists of two dark-gray, extremely fossiliferous, ferruginous, brown-weathering limestone beds separated by a thin bed of dark-gray, calcareous, fossiliferous shale.

Bell (1959, p. 41) mapped the Sam Creek across Tps. 14-15 N., R. 18 E., and stated (p. 41, 43):

> The type locality was found in this investigation, but the exposure was poor due to the relatively high water in the creek. The shales exposed at this outcrop are more abundantly fossiliferous than the limestones, and there are numerous marine invertebrates represented. It crops out in five places in T. 14 N., R. 18 E., and the writer found, as did Newell previously, that the upper limestone alone is persistent.
>
> The other beds are confined to the type section. In sec. 26, T. 14 N., R. 18 E., the Sam Creek crops out in a gully at the edge of the Davis Field airbase, and is eight inches thick, medium- to dark-gray, dense, and contains abundant "*Marginifera.*" Exposures of limestone in T. 15 N., R. 18 E., are sporadic and variable in lithology. At the southeast corner of sec. 15, T. 15 N., R. 18 E., is an exposure of limestone which the writer thinks is Sam Creek, but it can be identified only by similar characteristics and the fact that it crops out below the Bluejacket sandstone. Thickness of the Sam Creek is from six to eight inches in the Muskogee area.

Unnamed shale above Sam Creek Limestone Member.—In the southern part of T. 10 N., R. 19 E., about 15 feet of gray silty shale lies above the Sam Creek Limestone Member and below the Spiro Sandstone Member. The shale is thinner in the northern part of the township and grades upward through sandy shale into the Spiro.

In T. 13 N., R. 18 E., in the southwestern part of the township, the interval from the

Sam Creek Limestone to the Rowe coal is brown to gray silty shale, about 25 feet thick, that contains minor amounts of siltstone streaks and concretions.

In T. 15 N., R. 18 E., the shale between the Sam Creek Limestone and the Doneley Limestone, above the Rowe coal, is about 25 feet thick.

Spiro Sandstone Member.—Wilson (1935, p. 509) mentioned that the Spiro Sandstone Member caps the ridge in secs. 13-14, T. 9 N., R. 25 E., just north and northeast of Spiro, Le Flore County, Oklahoma, in an area mapped by W. T. Thom, Jr. (unpublished map). Thom was no doubt the nomenclator. At about the same time that Thom advised Wilson to apply the name to a sandstone in Muskogee County, Knechtel (1949) found that the Savanna Formation north and northeast of Spiro consists of two sandstone units and an intervening shale unit that Knechtel mapped together as a synclinal outlier of the Savanna Formation. It seems reasonable to conclude that the Spiro Sandstone of Thom was the lower unit, but Thom's Spiro may have included the upper as well. Elsewhere in northern Le Flore County, and in Haskell County, the Savanna consists essentially of two sandstone zones, upper and lower, and an intervening shale zone that contains locally mappable sandstone beds. Both sandstone zones are divided locally into separate mappable sandstone and shale units.

Along State Highway 2 north of Tucker Knob in southern Haskell County, the upper sandstone zone of the Savanna is about 200 feet thick and contains 50 feet of shale near the middle. It has this tripartite character northward to the Canadian River in secs. 5-6, T. 9 N., R. 19 E., northwest of Hoyt, Haskell County, where the upper unit is 15 feet thick, the lower is 20 feet thick, and the intervening shale is 25 feet thick. This locality is directly across the river from the one in which Newell (*in* Wilson and Newell, 1937) measured the thickest Spiro Sandstone of Muskogee County. Sandstone assignable to the lower zone of the Savanna has not been found farther north than sec. 18, T. 9 N., R. 19 E.

The correlation of Newell's 20-foot Spiro Sandstone in the extreme southern part of Muskogee County with the 20-foot massive, fine-grained, resistant sandstone of the upper zone of the Savanna Formation capping the Canadian River bluffs northwest of Hoyt, Haskell County, is based on the fact that each is about 400 feet below the base of the Bluejacket Sandstone, the basal member of the Boggy Formation, which is easily traced across the river. Newell described one Spiro sandstone, but there is topographic evidence of a higher bed, probably thin, about 20 feet above his Spiro, in sec. 33, T. 10 N., R. 19 E. This may well be the northernmost occurrence of the upper unit of the upper sandstone zone of the Savanna Formation of Haskell County.

The term Spiro Sandstone was not used by Oakes and Knechtel (1948) in Haskell County nor by Knechtel (1949) in northern Le Flore County, but it is used in Muskogee County because of popularity in the literature and in discussions for the last 40 years.

Stine (1958) mapped the Spiro in T. 10 N., R. 19 E., and described it as a fine-grained, thin- to massive-bedded sandstone. It is 20 feet thick in a hill just north of the Canadian River but 5 feet thick half a mile north, being thinner and weakly resistant northward to the north line of sec. 22, where it forms a topographic break which is traceable to Porum in the northeastern part of sec. 10, T. 10 N., R. 19 E.

The Spiro of Webb (1957, 1960) in T. 10 N., Rs. 17-18 E., McIntosh County, is about 180 feet below the top of the Savanna and about 75 feet above the base. Stine (1958) mapped one 30-foot exposure of Webb's Spiro across the south part of sec. 6, T. 10 N., R. 19 E., Muskogee County.

Newell (*in* Wilson and Newell, 1937, p. 50-51) stated:

> The heaviest development of the sandstone [Spiro] in the area studied [Muskogee-Porum district] occurs in the river bluffs in sec. 33, T. 10 N., R. 19 E., where the Spiro sandstone consists of 20 feet of massive, cliff-forming sandstone. Within a fourth of a mile to the northward, the unit is only 4 feet thick and is reduced to about 2 feet of soft sandstone in section 15 of the same township. To the northward the Spiro retains a fairly constant thickness of 2 to 4 feet, and across all the remaining part of the area is non-resistant and shaly. The sandstone generally grades downward into the Sam Creek limestone, and contains fossils, especially fenestellid bryozoans, in the lower more calcareous layers.

Newell's statement agrees well with what the writer saw in the course of field reconnaissance for completion of the *Geologic Map of Oklahoma* (Miser, 1954).

Coleman (1958), Gregware (1958), and Bell (1959) did not map the Spiro Sandstone Member separately from the intergrading Sam Creek Limestone Member below. The

Spiro is not shown on plate 1 farther north than sec. 6, T. 10 N., R. 19 E.

Unnamed shale above Spiro Sandstone Member.—In the southern part of T. 10 N., R. 19 E., about 150 feet of shale occurs above the Spiro Sandstone Member to the Rowe coal. It is in general sandy with a few lenticular, fossiliferous limestones less than 1 foot thick and a few coal seams generally less than 1 inch thick. One conspicuous band of sandstone lenses 2 to 10 feet thick lies 20 to 25 feet below the Rowe coal.

Doneley Limestone Member.—A description of the Doneley Limestone Member was first published by Branson (1954, p. 192):

> Seventy feet below the base of the Bluejacket sandstone, and thus in the Savanna formation is a limestone which is the cap rock of a persistent, thin, but locally workable coal. This limestone has been mapped from the Kansas line south to beyond Warner in Muskogee County. Howe [1951] found a locality in Kansas where what is probably the same limestone is sporadically developed in a strip pit and is the cap rock of the Rowe coal. The limestone was referred to as the "Lower Boggy lime" by Wilson and Newell [1937]. The distinctness of this limestone and its usefulness as a mapping horizon over a wide area make it desirable to give it a name. The limestone is here named the Doneley limestone member of the Savanna Formation. The name is derived from the Doneley School . . . in the NW¼ sec. 27, T. 26 N., R. 20 E. [Craig County, Oklahoma]. This school has been replaced by the Pleasant Hill school which is at the same location. The type section is one mile north of the school building, in the NW¼ sec. 16, T. 26 N., R. 20 E. in the south bank of the creek which crosses the north-south section line road and the exposure is about 100 feet east of the road. The name first appeared in the unpublished Master of Science thesis of Louie P. Chrisman [1951]. At the type section, the Doneley is a calcareous clay ironstone three inches thick, lying eight inches above a thin coal and its underclay.

The Rowe coal and the superjacent Doneley Limestone are closely associated in most exposures, being indicated on plate 1 by *x*'s with a single dashed line between exposures. The line of outcrop is taken mostly from Wilson and Newell (1937, pl. 1). Newell (*in* Wilson and Newell, 1937, p. 53) said of the Rowe coal and Doneley Limestone:

> The coal is overlain by a thin, but exceedingly persistent limestone, which is ordinarily somewhat non-resistant and carbonaceous. The common occurrence of *Neospirifer cameratus* and a broad and sulcate *Marginifera* like *M. muricatina* in this limestone is noteworthy, because these fossils appear to be either rare or lacking in lower horizons. The limestone rarely exceeds 6 inches in thickness.

In T. 10 N., R. 19 E., the Rowe is about 1 foot thick, and the Doneley is about 1.5 feet thick. They lie about 250 feet below the base of the Bluejacket Sandstone (basal Boggy) and about 25 feet above an unnamed lenticular sandstone 5 to 15 feet thick, shown on plate 1 as IPsas. The Rowe and Doneley have been found in the NW¼ sec. 18, T. 12 N., R. 19 E., where the coal is 1 foot thick and has been stripped. The limestone is carbonaceous, contains *Marginifera muricatina* and *Neospirifer cameratus*, and is 1 foot thick, being about 180 feet below the base of the Bluejacket Sandstone. According to Coleman (1958, p. 30-32) the Rowe coal in T. 13 N., R. 18 E., ranges from 6 to 17 inches in thickness, and the Doneley Limestone averages 0.5 foot. Each bed is 0.5 foot thick in an exposure 150 feet below the base of the Bluejacket in sec. 20.

In exposures near the center of the east line of sec. 10 and in the SE¼ sec. 15, T. 14 N., R. 18 E., the Doneley and the Rowe are each about 0.5 foot thick. They are exposed in a small northeastward-flowing stream in the NE¼ sec. 18, T. 15 N., R. 18 E. Here the Doneley is shaly, carbonaceous, and nodular and is 0.8 foot thick; it contains abundant marine fossils. It is separated from the Rowe by 0.3 foot of shale, and the Rowe is 1 foot thick. This exposure is about 120 feet below the base of the Bluejacket Sandstone.

Unnamed shale above Doneley Limestone Member.—In the southern part of T. 10 N., R. 19 E., above the Doneley Limestone, is 15 to 20 feet of black, flaky, well-indurated shale filled with light-gray calcareous concretions and bedded fossiliferous limonite. The overlying 230 feet of shale is dark gray and silty. At some places, this shale grades upward through sandy shale into the basal Bluejacket Sandstone Member of the Boggy Formation without a definite break. At other places, there is local channeling, with a sharp line between the shale and the overlying cross-bedded sandstone. Of course, this is a common feature at the base of thick sandstone units.

In sec. 19, T. 12 N., R. 19 E., the Savanna is about 225 feet thick, according to Newell (*in* Wilson and Newell, 1937, p. 164), and the Doneley Limestone is about 180 feet below the top. Gregware (1958, p. 56) stated that the total thickness is 180 to 190 feet and that the Doneley Limestone lies about 160 feet below the Bluejacket, the interval being green-gray to dark-gray silty shale that weathers somewhat fissile locally.

In the southwestern part of T. 13 N., R. 18 E., the 150-foot interval from the Doneley to the base of the Bluejacket is commonly covered, but there is evidence that the lower 30 to 50 feet contains black fissile shale that grades upward through black to dark-gray flaky shale into brown silty to sandy shale. At some places, this shale grades into the lower part of the Bluejacket Sandstone; at other places, the contact is sharp because of channeling.

In T. 15 N., R. 18 E., the shale between the Doneley and the base of the Bluejacket is about 120 feet thick.

In T. 15 N., R. 19 E., east and northeast of Muskogee, the units previously mapped as Atoka, Hartshorne, Warner, Cameron-Lequire, and Tamaha are here mapped as the Savanna Formation undifferentiated (pl. 1). Soyster and Taylor (1928) showed the base of the Booch sand (=Warner) to be about 125 feet deep in C NW¼NW¼ sec. 28 (elevation 510 feet) and about 290 feet deep in C SE¼NE¼ sec. 30 (elevation 610 feet), with about 50 feet per mile west-southwest dip. Bell (1959) described an 18-inch light-gray sandstone, overlain by 5.5 feet of shale, with an 18-inch siliceous, fossiliferous limestone at the top, on the west side of the Arkansas River about half a mile north of the bridge in sec. 16, T. 15 N., R. 19 E. This upper limestone has many brachiopods and crinoid fragments and may be close to the Sam Creek Limestone stratigraphically. About 1 mile farther south along the river bank in sec. 21 is a 17-foot siltstone and shale with a thin ½-inch coal streak at the top. About a quarter of a mile west of this coal exposure, along strike, in the NE¼SE¼SE¼ sec. 20, Wilson (*in* Wilson and Newell, 1937, p. 99 and map) mentioned that a 4-inch coal bed had been locally mined. The coal bed in these two exposures may be close to the Rowe horizon. Three local sandstones occur in the overlying 135-foot interval that extends to the base of the Bluejacket in sec. 20 and adjacent areas: shale (10 feet), sandstone (10 feet), shale (15 feet), sandstone (20 feet), shale (35 feet), sandstone (10 feet), and shale (35 feet) (ascending).

Boggy Formation

Nomenclator.—J. A. Taff (1899).

Type locality.—Taff did not formally designate a type locality, but the formation was probably named from extensive outcrops in the valley of Clear Boggy Creek in Pontotoc, Coal, and Pittsburg Counties, Oklahoma.

History of usage.—Subsequent usage of the terms Boggy Shale and Boggy Formation followed the intent of Taff until Wilson (1935) inadvertently included the Bluejacket Sandstone and the shale below it in his Savanna Formation, the result of miscorrelation.

In the course of preparation of the *Geologic Map of Oklahoma,* Miser (1954) found that the base of the Bluejacket Sandstone Member of the Boggy Formation is the only horizon sufficiently extensive to serve conveniently to separate the Savanna Formation, below, from the Boggy Formation, above. Taff placed the upper limit of the Boggy Formation at the base of the Thurman Sandstone. Oakes (1953) recognized the base of the Thurman as marking an obscure but extensive unconformity along which each successively younger post-Boggy stratum overlaps the next older one northward and rests upon Boggy rocks. He therefore placed the top of the Boggy at this unconformity. Hare (1969), however, noted an interfingering of the Boggy with the Thurman at some localities. The present writer has not recognized the Thurman at the surface in Muskogee County; it is probably overlapped by the Stuart Shale beneath surficial deposits associated with the Canadian River. As here used, the Boggy Formation extends from the base of the Bluejacket Sandstone Member to an obscure but extensive unconformity at the base of younger strata.

Distribution.—Outcrops of the Boggy Formation extend from the north flank of the Arbuckle Mountains northeastward across Pontotoc, Coal, Pittsburg, Haskell, McIntosh, Muskogee, Wagoner, Rogers, Mayes, and Craig Counties to the Kansas-Oklahoma line just west of the Neosho (Grand) River. Outcrops of the Boggy Formation are also present in synclinal hills in the Arkoma basin in Pittsburg, Haskell, and Le Flore Counties. Boggy rocks constitute most of the bedrock outcrops of Rs. 15, 16, and 17 E. in western Muskogee County.

Thickness and description.—In general, the Boggy, like other Pennsylvanian formations, thins northward out of the Arkoma basin; the thinning affects all units. However, along with the northward thinning, Boggy units younger than the basal Bluejacket Sandstone Member tend to be unexpectedly thick in local basins, such as the Porum and Rattlesnake Mountain synclines, and surprisingly thin over such structurally high areas as the Warner uplift. Hendricks (1937, p. 24-25) found the Boggy Formation of present usage to be about 2,500 feet thick in the southeastern part of T. 4 N., R. 13 E., Pittsburg County. The Boggy is about 1,500 feet thick in T. 8 N., Rs. 13-18 E., Pittsburg and Haskell Counties. The Boggy is about 1,400 feet thick in T. 9 N., 800 feet in T. 10 N., 530 feet in T. 11 N., and 730 feet in T. 12 N., McIntosh County (Oakes and others, 1967, p. 21).

The following quotation is from Dane and others (1938, p. 160-161) and describes the Boggy between the area mapped by Hendricks and the south line of McIntosh County.

> The formation is predominantly shale but contains a variable number of sandstone beds or zones in which sandstone is equal to or predominant over shale in thickness. These zones of sandstone are as much as 100 feet thick. Where the dips are relatively steep, as in the southern part of the area of exposure, the thicker sandstone beds and such sandstones as are separated by thick shale intervals make topographic ridges that are traceable with some degree of assurance over most of the district. Where the dips are gentle the degree of exposure is not sufficiently good to permit tracing of individual beds for more than short distances. Accordingly an attempt has been made to show . . . the extent and persistence of zones within the Boggy in which sandstone makes up the predominant or conspicuous part of the section. . . . The lenticularity of the individual beds is well established by field observation, and individual lenses may reach 20 feet or more in thickness but do not have great lateral extent. Examples of the fusion of two or more beds to form a single thicker bed are also common. Lateral changes in lithology of the individual beds from thin-bedded and even shaly sandstones to massive and cross-bedded sandstones or to sandstones that exhibit contorted or deformed bedding are the rule rather than the exception.

In McIntosh County, south and west of Muskogee County, the Boggy Formation is thinner northward and comprises a different facies. In the southern part of the Porum syncline, the Boggy consists of an orderly arrangement of thick sandstone units separated by thicker shale units that can be correlated with Boggy units mapped by Dane and others (1938) to the south. But this orderly, progressive, northward change in thickness and character extends only to the Canadian River area. Only the Bluejacket Sandstone Member of the Boggy can be traced across the Canadian River.

On and north of the Warner uplift in Tps. 11 and 12 N., rocks of the Boggy Formation belong to the shelf facies of northeastern Oklahoma. In contrast to the thicker, more massive sandstones of the basin facies, the shelf sandstones are finer grained, more shaly, and more lenticular. In some places sandstone bodies grade imperceptibly—vertically

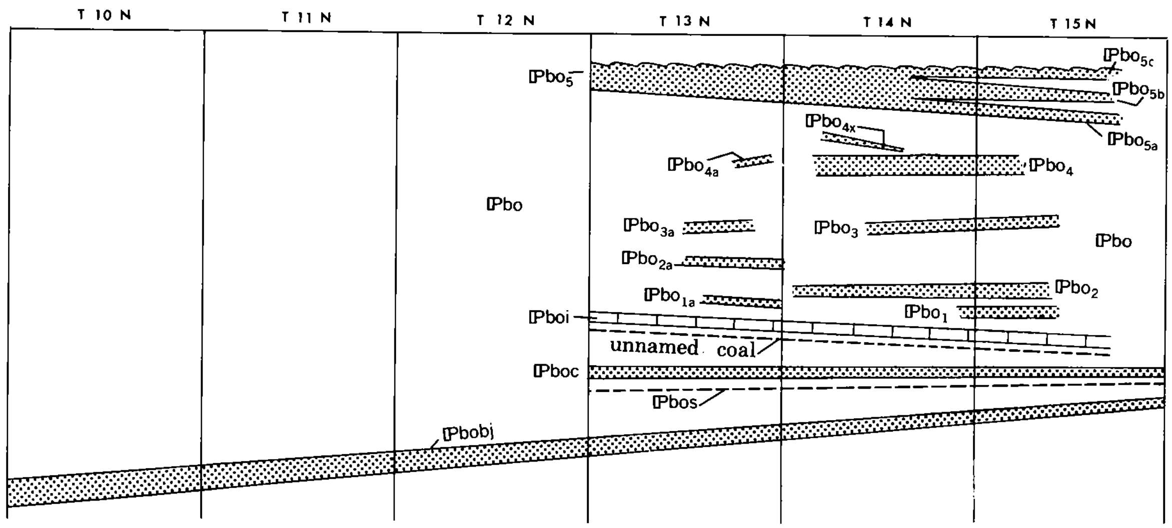

Figure 7. Section diagram, not to scale, illustrating south-to-north distribution of Boggy Formation as it crops out in Muskogee County. See plate 1 for explanation of symbols.

and laterally—into sandy shale. Even the upper part of the Bluejacket Sandstone Member consists of such rocks; they were mapped with the lower, more massive part only because there was no mappable stratigraphic boundary to separate them. Another distinguishing shelf feature of the Boggy Formation is outcrops of thin limestones of considerable length, commonly associated with coal seams; these do not extend southward into the basin.

Bluejacket Sandstone Member.—Most thick sandstone units that crop out in the northeastern part of Oklahoma, including the Bluejacket Sandstone Member, are composed of many sandstone and shale lenses. Rarely does a single massive bed crop out for many miles. Wherever such a unit is underlain by thick, deeply eroded shale there is a high escarpment that is easily identified and useful for correlation. This situation was well understood by the pioneer geologists who first mapped and applied names to these obvious but inexact stratigraphic markers. The base and top were generalized, including all lenses.

The Bluejacket Sandstone Member was named by D. W. Ohern in an unpublished manuscript from outcrops in the hills west of the town of Bluejacket, Craig County, Oklahoma (1914, "Geology of the Nowata and Vinita Quadrangles": Oklahoma Geological Survey). He described it as follows.

> A second sandstone, whose base lies about 150 feet above the top of the Little Cabin [Warner] sandstone, is the most salient feature of the stratigraphy of the Cherokee from the Kansas line southward to the limits of the Vinita-Nowata area. In places its total thickness of 50 to 60 feet is a solid mass of sandstone, but usually it is broken up into several beds by intervening shales. This sandstone is well exposed on the west bank of Neosho River a mile south of the Kansas line, where more than 30 feet is seen above the river surface. It forms the escarpment in the eastern part of T. 28 N., R. 21 E., and is widespread east of Welch. It extends southward past Bluejacket, and its typical development is found in the hills west of the town, from which it is proposed to name it the Bluejacket Sandstone member.

Owing to miscorrelation across faults, McCoy (1921) applied the name Bluejacket by inference to the Warner Sandstone Member of the McAlester Formation in the vicinity of Warner, Muskogee County. Wilson (*in* Wilson and Newell, 1937) mapped the Bluejacket Sandstone across Muskogee County by tracing and by correlation across faults and found it to be the massive sandstone on Rattlesnake Mountain in T. 10 N., R. 18 E., which Taff (1906, p. 4) had described as the lowest sandstone unit of the Boggy Formation. However, Wilson classified it as the youngest member of the Savanna Formation. Dane and Hendricks (1936) completed the tracing of the Bluejacket Sandstone into the Quinton-Scipio district and found it to be the same as the lowest sandstone unit of the Boggy Formation, as mapped there by Dane and others (1938). Pierce and Courtier (1938, p. 27-30) applied the name Bluejacket to a similar sandstone in the same stratigraphic position in southeastern Kansas. Howe (1951, p. 2089-2090) measured and published a type section of the Bluejacket at Ohern's type locality in the hills west of Bluejacket in Craig County and found that the Bluejacket is practically continuous along the belt of outcrop of Cherokee rocks in Kansas.

Branson and others (1965, p. 31) described the Bluejacket in Craig County, Oklahoma:

> The Bluejacket Sandstone, which ranges in thickness from 0 to 50 feet, rests upon an undulating surface and in channels which cut into older rock units. The lower part is a buff to tan, heavy-bedded, cross-laminated, medium-grained, well-sorted, micaceous, ferruginous sandstone ranging in thickness from 20 to 30 feet. Locally within the lower 15 feet are beds of conglomerate. The lower part of the Bluejacket is resistant and locally forms a prominent escarpment. The upper 15 to 20 feet of the Bluejacket is thin-bedded, fine-grained, tan, micaceous sandstone and shale. The upper part is weak and weathers back from the face of the escarpment.

Govett (1959, p. 71-72) wrote of the Bluejacket Sandstone in Wagoner County, Oklahoma, just north of Muskogee County:

> The greater part of the Bluejacket sandstone consists of massive to cross-bedded, fine-grained, tan sandstone that weathers brown. In the vicinity of the town of Porter, T. 16 N., R. 17 E., the Bluejacket consists of three sandstones separated by black shale. Northward these sandstones coalesce into one and the section becomes thinner. Shales and siltstones are generally found interbedded with the sandstone in the Bluejacket.
>
> Thickness of the Bluejacket varies from 16.5 to 37.5 feet. The average thickness is about 20 feet.

Visher (1968, p. 32-44) treated the Bluejacket Sandstone Member as a sheet of coalescing deltas laid down by streams flowing in various directions. Saitta and Visher (1968) published a subsurface study of the "Bluejacket delta" in Tps. 7 to 21 N., Rs. 7 to 20 E.

The Bluejacket is represented in Muskogee County by a single continuous sandstone unit that fills channels and grades into the underlying shale. Bell (1959, p. 48) mapped the Bluejacket across Tps. 14 and 15 N., Rs. 17 and 18 E. His description follows.

> In the Muskogee area the Bluejacket ranges from 10 to 65 feet in thickness. It is generally a silty to fine-grained cross-bedded sandstone, and weathers to tan or light rust brown. A few calcareous layers may be found in some exposures, but iron oxide is generally the cementing material.. . . Identifiable plant fossils were not found in the Bluejacket in the Muskogee area, but fibrous plant material is common.

Coleman (1958, p. 38-39) mapped the Bluejacket across T. 13 N., Rs. 17 and 18 E., Muskogee County, and T. 12 N., Rs. 17 and 18 E., McIntosh County. His description of the Bluejacket in this area follows.

> The Bluejacket is in irregular contact with the underlying silts and shales. At some points channeling is evident, at other points the contact is gradational. The basal units are generally massive, cross-bedded, brown to gray sandstone interbedded with thin silty sandstones, and some silty shales. Small round openings were found at various locations in the lower units of the Bluejacket; the limonite rims of these openings suggests they are probably the result of weathered-out limonite concretions. Scattered plant fossils and local knife edges of coal were observed in the basal Bluejacket. The most massive single unit observed was about 15 feet thick. In the area of its maximum thickness the Bluejacket consists of two sandstone units separated by an interval of thin-bedded sandstones. The upper unit forms several ridges which radiate from the point of its maximum thickness, in sec. 1, T. 12 N., R. 17 E. The rocks composing these ridges exhibit profound cross-bedding and at many places apparent dips which coincide with the slopes of the individual ridge. There is no evidence to support tectonic formation of these ridges; therefore, it is suggested that they represent the sand bars associated with a small delta. Two of these delta-like structures are in evidence; one in secs. 24, 25, and 26, T. 13 N., R. 17 E. [Muskogee County]; the other in secs. 1, 2, 11, 12, and 13, T. 12 N., R. 17 E. and secs. 6 and 7, T. 12 N., R. 18 E. [McIntosh County]. It is noted that both these features are located on the upthrown side of east-west trending faults. They were possibly continuous but have been separated by faulting and subsequent erosion. In secs. 1 and 2, T. 12 N., R. 17 E. the rocks of the interval between the lower unit of the Bluejacket and this upper unit consist of thin, soft, variable-grained, cross-bedded sandstones. No break in sedimentation was observed.

A fault upthrown on the southeast side crosses sec. 19, T. 15 N., R. 18 E., and brings sandstone, possibly a lens of the Keota Sandstone Member of the McAlester Formation, to the surface in sec. 25, T. 15 N., R. 17 E., where the dip is plainly southeastward. On the upthrown side of this fault the Bluejacket crops out along the line between Rs. 17 and 18 E. from the Muskogee fault to the northwest corner of sec. 30, T. 15 N., R. 18 E. Thence the outcrop turns eastward across the city of Muskogee to the southwestern part of sec. 19, T. 15 N., R. 19 E., where it turns southward and extends to the Muskogee fault in the northeastern part of sec. 1, T. 14 N., R. 18 E. There are Bluejacket outliers farther east. Along much of this part of the outcrop the sandstone is not actually seen because of surficial cover, much of it incident to the presence of the city. However, enough is seen to indicate that the Bluejacket is thinner and more shaly eastward. Indeed, in much of the eastern part of the city its presence is indicated only by the topography.

The unnamed shale that overlies the Bluejacket Sandstone Member in Muskogee County is so variable in thickness and character that it might be well to include both it and its overlying sandstone, the Crekola, in the Bluejacket, especially in view of the fact that the term Crekola has not been used outside Muskogee County.

Bell (1959, p. 50) stated:

> It [the shale above the Bluejacket] ranges from 8.8 to 30 feet in thickness in the Muskogee area. Generally it is a light grayish-brown silty micaceous shale that contains clay ironstone concretions and thin wavy sandstone plates in places.

Newell (*in* Wilson and Newell, 1937, p. 55) indicated that this shale is 20 feet thick or more near Summit and Crekola, sec. 29, T. 14 N., R. 18 E., and sec. 10, T. 14 N., R. 17 E., respectively, and about 6 feet thick north of Taft in T. 15 N. The shale is ordinarily sandy throughout but contains a thin carbonaceous and fossiliferous layer near the base in the vicinity of Summit. Coleman (1958) mapped sandy shale that contains coal locally in the northern part of T. 13 N., R. 18 E., between the Bluejacket, below, and the Crekola, above. In the southern part of the same township and in T. 12 N., R. 17 E., McIntosh County, this same shale is probably represented by the weakly resistant, variable-grained, cross-bedded sandstone that lies between the lower and upper units of Coleman's Bluejacket.

In some localities the upper and lower limits of this shale are readily discernible, but in many localities the shale is sandy and the limits are arbitrary.

This shale is mapped separately because locally it contains coal that has been strip mined at a number of places. Newell (*in* Wilson and Newell, 1937, p. 55) stated that the coal occurs 20 feet or more above the top of the Bluejacket in the vicinity of Summit and Crekola but appears to rest almost upon the Bluejacket north of Taft, in T. 15 N. He also mentioned that near the base, in the vicinity of Summit, a thin carbonaceous and fossiliferous layer is present. The writer considers it more than a possibility that coal occurs at more than one horizon in this shale. Wilson (1935, p. 510) called the coal Secor. In the Arkoma basin, where the name Secor was first used, it has long been the practice to apply the name to the most prominent coal seam lying above the Bluejacket Sandstone. The author suspects that from the Arkoma basin northward as far as Muskogee County numerous coal seams were deposited at various horizons in shale that overlies the Bluejacket, each in a swamp or marsh of limited extent, and that the name Secor has been applied to several of them. According to Branson and others (1965), a coal called the Bluejacket occurs just above the Bluejacket Sandstone in Craig County.

Crekola Sandstone Member.—The Crekola Sandstone was named by Wilson (1935, p. 510-511) from the village of Crekola, sec. 10, T. 14 N., R. 17 E., Muskogee County. He described it as a brown, regularly bedded, blocky, medium-textured sandstone 10 feet thick.

Newell (*in* Wilson and Newell, 1937, p. 55) described it as follows: "This unit consists of thin-bedded, soft buff sandstone, ranging from about 4 to 10 feet in thickness at measured outcrops. The sandstone appears to be unfossiliferous."

Bell (1959, p. 52-53) wrote:

> It is best exposed in T. 15 N., R. 17 E., where it may be seen in bluffs above the Arkansas River. It also crops out in T. 14 N., R. 18 E., but not over a wide area.
>
> The Crekola is variable in thickness and character in the Muskogee area. In secs. 33 and 34, T. 14 N., R. 18 E., the Crekola is about four feet thick, thin bedded, silty, micaceous, and 11 feet above the Bluejacket. In sec. 6, T. 14 N., R. 18 E., it is about 20 feet thick, massive, friable, porous, and weathers to a light brown, or reddish brown, and is 30 feet above the Bluejacket. In sec. 17, T. 15 N., R. 17 E., it is silty to shaly, thin bedded to blocky, friable to well cemented, jointed, weathers to a light brown or tan, and is about 30 feet above the Bluejacket.

Coleman (1958, p. 47) mapped the first sandstone above the Bluejacket as Crekola in T. 13 N., Muskogee County, and gave the following brief description: "The Crekola reaches its maximum thickness in sec. 8, T. 13 N., R. 18 E. where it consists of 18 feet of sandstone overlain by 7.7 feet of shale and silt which is overlain by 4 feet of sandstone." The Crekola is probably included in the much thickened upper unit of the Bluejacket in the south part of T. 13 N., which is in turn separated from the lower unit by weakly resistant, variable-grained, cross-bedded sandstone.

A thin shale lies between the Crekola Sandstone Member, below, and the Inola Limestone Member, above. It is variable in thickness but, in general, is thicker southward. At many places a thin coal seam lies a few inches below the top. Bell (1959) extended the Crekola to the tops of the hills in the southeast part of T. 15 N., R. 17 E., but a thin shale is indicated on the aerial photographs of that area by a change in the slopes of the hills. Bell mapped a thin coal seam in this shale in the northwest corner of sec. 25, but outcrops of the Inola Limestone have not been found.

Newell (*in* Wilson and Newell, 1937, p. 56) reported: "Between the Crekola sandstone and Inola limestone above occurs 5 to 10 feet of sandy buff shale, at the top of which, occurs a thin coal and underclay."

Stewart (1949, p. 28) stated that in at least parts of T. 15 N., R. 17 E., the Inola Limestone is less than 3 feet above the top of the Crekola Sandstone.

Bell (1959, p. 53, 91) reported that the shale is fully exposed in the northwest corner of sec. 16, T. 15 N., R. 17 E., where it is gray to brown, silty, calcareous, contains a few marine fossils, and is 5 feet thick; in sec. 17 it is medium-gray argillaceous shale, of which only 3 feet is exposed. Coleman (1958, p. 93) reported that brown and gray silt and shale 15 feet thick, with a much weathered carbonaceous streak at the top, are exposed between the Crekola Sandstone and the Inola Limestone along a stream in the NE¼ sec. 8, T. 13 N., R. 18 E.

Inola Limestone Member.—The Inola Limestone was first mentioned by name in print by Lowman (1932), who stated that it was "named from an outlier on a hill east of the town of Inola, Oklahoma."

Branson (1954, p. 192) stated:

> About the middle of the Boggy formation and a few feet above the Bluejacket sandstone is the Inola limestone of Lowman. The Inola limestone has been found to

consist of four separate fossiliferous beds each lying in a separate cyclothem and with coal seams under the first, third, and fourth. The term Inola is here restricted to the lower limestone of the four. The type locality is Inola Mound, Rogers County, but the type section is here designated as the section exposed in the south road cut on Oklahoma Highway 20 on the west face of the hill just east of the Rogers County—Mayes County line, near the northwest corner of sec. 18, T. 21 N., R. 18 E. The limestone is here 1.9 feet thick and contains *Wedekindellina henbesti* (Skinner), *Fusulina leei* Skinner, and *Eoschubertella gallowayi* (Skinner). Charles Ryniker in a personal communication reports fusulinids from the limestone on Inola Mound. The Inola limestone (restricted) and the immediately superjacent limestones are important in aiding the field geologist to differentiate between the Bluejacket and the Taft sandstones, but their solubility combined with their position between two thick sandstones has resulted in their weathering to unrecognizable soil at most places. One or more of the limestones can be found at scattered localities from the northern edge of Mayes County to northern McIntosh County, but their discontinuity of outcrop precludes use as a mapping horizon.

The following quotation is from Newell (*in* Wilson and Newell, 1937, p. 56).

> The name Inola is applied in this area [Muskogee County] to a blocky, even, bluish-gray bed of fine-grained limestone, 1 foot thick. Recognizable fossils are ordinarily rare except for a sponge which resembles *Heliospongia*. Because of the position in the broad plain at the foot of the Taft sandstone escarpment, outcrops of the Inola bed are discontinuous and located only with difficulty. The southern extent of the bed is unknown, but it is entirely typical in the latitude of T. 13 N., and probably extends considerably farther south.

Stewart (1949, p. 29) wrote the following:

> This fine grained, dark limestone is fossiliferous. The most common fossils are a sponge, *Heliospongia* and some large crinoid stems. Some large pelecypods and fragments of spirifer brachiopods are present in sec. eighteen of township fifteen. The limestone weathers brown or gray where exposed. It appears to dissolve easily; and outcrops are usually lacking, unless there has been rapid recent erosion. Occasionally it weathers into plates about one-half inch thick . . . , and these then are the only surface expression of this bed.

Bell (1959, p. 55) described the Inola Limestone Member in Tps. 14 and 15 N., R. 17 E., Muskogee County, as 6 inches to 1 foot thick and generally dark gray, fossiliferous, hard, dense, and blocky. Coleman (1958, p. 49) found the Inola generally less than 1 foot thick with a coal seam less than 2 inches thick 1 to 3 inches below. A notable exception is a fossiliferous shale and limestone bed 17 inches thick in sec. 32, T. 13 N., R. 17 E., which has no coal below it. It may represent one of the higher limestone beds mentioned by Branson.

The unnamed shale that lies between the Inola Limestone and sandstone unit $\mathbb{P}bo_1$ is dark to black, fissile, and jointed and contains clay-ironstone concretions and limestone septaria. It is 15 to 20 feet thick in the northwestern part of sec. 19, T. 15 N., R. 17 E., and 15 feet thick at the middle of the west line of sec. 3, T. 14 N., R. 17 E.

Unit $\mathbb{P}bo_1$ is present as sandstone lenses in the northwestern part of sec. 19, T. 15 N., R. 17 E., that range from 2 to 4 feet in thickness and are generally silty, micaceous, and thin bedded. It caps hills in secs. 26, 27, and 35, T. 15 N., R. 17 E. It crops out in secs. 3, 4, and 9, T. 14 N., R. 17 E., just south of Pecan Creek, where it is reddish brown, coarse grained, poorly cemented, and 4 feet thick.

The shale between sandstone units $\mathbb{P}bo_1$ and $\mathbb{P}bo_2$ grades upward through dark shale to gray, silty, and argillaceous shale and is about 45 feet thick.

Unit $\mathbb{P}bo_2$, according to Bell (1959, p. 55-56), is the bed Newell (*in* Wilson and Newell, 1937, p. 56) described as "forming an obscure terrace in the Taft sandstone escarpment. It is fairly persistent in outcrop in the northwest part of T. 14 N., R. 17 E., and the southwest part of T. 15 N., R. 17 E. It occurs about 80 feet below the base of the $\mathbb{P}b_4$ sandstone lens, and averages six feet in thickness. . . . It is generally a thin-bedded to massive, light brown or tan, micaceous silty sandstone."

Campbell (1957, p. 15) wrote: "Although it is generally thin and difficult to map continuously in the Jamesville area, this sandstone forms a prominent bluff along the south bank of the Arkansas river in sec. 23, T. 15 N., R. 16 E. where it is about 20 feet thick."

Identifiable equivalents of this sandstone unit have not been found farther south than the northeastern part of sec. 17, T. 14 N., R. 17 E.

The unnamed shale that overlies unit $\mathbb{P}bo_2$ is about 80 feet thick in the southern part of T. 15 N., R. 17 E., according to Bell (1959, p. 56), who wrote the following.

> The best exposures . . . are below outliers, and in road cuts in the southwest part of T. 15 N., R. 17 E., and the northwest part of T. 14 N., R. 17 E. It is generally a micaceous, silty shale, and contains thin lenticular, or platy sandstone beds. Channeling occurs at the top of this shale and is exposed on an outlier in sec. 24, T. 14 N., R. 17 E. The . . . shale is about 80 feet in thickness in the Muskogee area.

Unit IPbo$_3$ contains part or all of Wilson's Taft Sandstone. Wilson (1935, p. 510) characterized the unit as follows.

> Massive gray-to-light brown sandstone; contains small pebbles of quartz in T. 14 N., and large pebbles of sandstone, shale, and quartz in southwest corner of T. 15 N. This conglomerate was not found north of Arkansas River; hence might represent shore phase of the member. . . . 50 [feet].

Newell (*in* Wilson and Newell, 1937, p. 56-57) wrote:

> The Taft sandstone forms a prominent escarpment, ranging up to 200 feet in height above the Crekola-Inola plain. At the type locality in T. 15 N., the unit consists of about 20 feet of coarse-grained massive sandstone. The upper third of the division consists of silty to sandy shale. Farther south, in T. 14 N., a series of massive sandstones and interbedded shales, amounting in aggregate to some 80 feet of beds, surmounts the Taft escarpment. Probably the outcrops around the village of Taft are equivalent only to the lower part of the sandstone section in T. 14 N. Further detailed work along the Taft escarpment is needed to determine the logical boundaries of the Taft member.

The term Taft has been much used in both conversation and writing about sandstones that crop out in the upper part of the Boggy Formation beyond the boundaries of Muskogee County, although the limits of the formation and correlations have never been adequately established. Lontos (1952, p. 24) mapped three sandstone units separated by shale, with a total thickness of 150 feet in his Coweta area, and called each Taft. Govett (1959, p. 79) who mapped Wagoner County, which includes the greater part of the Coweta area mapped by Lontos, wrote:

> The Taft sandstone north of the Arkansas River is here defined as any sandstone between the Inola limestone below and the Tiawah limestone above. Since these sandstones are lenticular and discontinuous, and the upper sandstone may be in the Senora formation, they have no time-stratigraphic significance.

Actually, four sandstone units, each designated Taft, appear on his map; two appear as members of the Boggy Formation, and two as members of the Senora Formation. According to Branson and others (1965, p. 33), three fairly consistent sandstone units separated by shale, with a total thickness of 146 feet, have been mapped as Taft in northern Mayes County; the lower one of the three extends into southern Craig County.

Considering the history of usage, it is deemed inadvisable to use the term Taft formally in this report.

Bell (1959, p. 58) wrote: "In T. 14 N., R. 17 E., the [IPbo$_3$] sandstone may be generally described as silty to fine-grained, slightly calcareous, thin-bedded to massive, and light to medium-brown where weathered." In sec. 30, T. 15 N., R. 17 E., it is a massive, reddish-brown to light-brown, coarse-grained sandstone, with abundant iron oxide cement and plant impressions. The greatest thickness mentioned by Bell is 45 feet, but the top was present in only two small areas in the part mapped by him.

Campbell (1957, p. 19-20) mapped the unit in the area west of that mapped by Bell and stated:

> The IPb$_5$ sandstone [unit IPbo$_3$ of this report] is best exposed along the east boundary of sec. 25, T. 15 N., R. 16 E. where it is buff to coffee-brown, medium-grained, massive-to thin-bedded, and highly ferruginous, and is about 37 feet thick. This sandstone caps a prominent, high escarpment, part of a synclinal ridge, southwest of the town of Taft. The dip is two degrees to the southeast in sec. 25, but westward the base of this unit swings to the north, thus delineating what the writer considers to be the southwestern extension of the Taft anticline as mapped to the east by Wilson and Newell (1937). Just south of the Arkansas River in sec. 23, T. 15 N., R. 16 E., IPb$_5$ member caps an eastward-facing scarp and lies about 40 feet above the IPb$_3$ sandstone. At this point the IPb$_5$ sandstone has thinned to about 8 feet, is thin-bedded, fine-grained, and contains plant fossils, including *Stigmaria*, in the upper part. In addition, there are random ridges of maroon, limy material deposited along the bedding planes. Possibly, these ridges constitute fossilized algae.
>
> An isolated outcrop of gray to tan, fine-grained, massive to thin-bedded sandstone, about 6 feet thick, is present in sec. 6, T. 15 N., R. 16 E. Although the exact stratigraphic position of this sandstone in relation to the Boggy sandstones to the north and south could not be determined due to its isolation, it has tentatively been correlated as IPb$_5$? on the basis of lithologic similarity and inferred stratigraphic position.

Unit IPbo$_3$ is covered by younger beds in a northeastward-trending syncline that crosses the northwestern part of sec. 1, T. 14 N., R. 16 E. South of the syncline it extends southeastward to a fault that crosses the southeastern part of sec. 7, T. 14 N., R. 17 E. It appears around a northwestward-plunging horst between this fault and another in sec. 3, T. 14 N., R. 16 E. Campbell (1957, p. 21) thought it possible that the northwest-trending Muskogee fault brings the unit, here designated IPbo$_3$, into contact with unit IPbo$_4$. This view is tenable. The sandstone along the line of the supposed fault is more deeply weathered than that to the north and south; moreover, that to the south seems to be finer grained. However, there is no indisputable evidence that the Muskogee fault extends that far southwestward in surface rocks; there is even less evidence that it may cut still younger rocks farther southwestward.

The interval between sandstone units $\mathrm{IPbo_3}$ and $\mathrm{IPbo_4}$ is not well exposed and is mainly buff, argillaceous to silty, micaceous shale. Its maximum thickness is estimated to be about 80 feet. According to Campbell (1957, p. 22), a coal seam about 5 inches thick lies about 5 feet above the base in the bank of a stream in the NW¼ sec. 23, T. 15 N., R. 16 E. In this locality the coal seam is overlain by about 13 feet of black, fissile to blocky, carbonaceous shale that grades upward into gray, silty shale. What is probably the same coal seam is exposed in the NW¼ sec. 26, about 2 feet above the base of the shale. Another coal seam about 35 feet below the top of the shale has been strip mined in the NE¼ sec. 3, T. 14 N., R. 16 E. From the middle of the east side of sec. 34, T. 15 N., R. 16 E., to the Arkansas River, the upper part of this shale, along with the overlying sandstone, is concealed by a fault.

Unit $\mathrm{IPbo_4}$ extends southward from the point mentioned previously as a gray to brown, fine-grained, cross-bedded sandstone that probably ranges in thickness from about 5 feet to perhaps 20 feet. Lying as it does above a shale some 80 feet thick, it caps high escarpments and prominent isolated hills. From the northeastern part of sec. 14, T. 14 N., R. 16 E., the outcrop swings 2 miles westward around a westward-plunging anticline that lies in secs. 13, 14, and 15. The unit may be cut off by the Muskogee fault in sec. 26, T. 14 N., R. 16 E., as mentioned in the discussion of unit $\mathrm{IPbo_3}$.

Units $\mathrm{IPbo_1}$ to $\mathrm{IPbo_4}$, inclusive, crop out in northern Muskogee County between the Inola Limestone, below, and unit $\mathrm{IPbo_5}$, above, and none extends far south of the Muskogee fault. The thickness of the interval between the Inola and unit $\mathrm{IPbo_5}$ in northern Muskogee County is probably between 300 and 400 feet. Its thickness is not known in southern Muskogee County, south of the Muskogee fault; it was estimated to be about 300 feet in northern McIntosh County (Oakes and others, 1967, p. 27). In southern Muskogee County, as in northern McIntosh County, this shale interval between the Inola and unit $\mathrm{IPbo_5}$ is occupied by sandy shale containing a minor amount of sandstone. The latter occurs as ill-defined sandstone bodies that grade into the sandy shale, both vertically and laterally, as in McIntosh County. However, the more resistant parts form longer outcrop belts than in McIntosh County; they cap mappable escarpments and, it is felt, indicate strike and dip. On plate 1 they are designated by symbols $\mathrm{IPbo_{1a}}$ to $\mathrm{IPbo_{4a}}$, in ascending order, if the order is discernible; if it is not, they are designated by the symbol $\mathrm{IPbo_{4x}}$, which is also used to designate certain sandstone outcrops slightly younger than $\mathrm{IPbo_4}$ in secs. 16, 21, and 29, T. 14 N., R. 16 E. Outcrops of these sandstones in secs. 23, 26, and 36, T. 14 N., R. 17 E., may be greatly slumped. The outcrop in the southwest corner of sec. 6, T. 13 N., R. 17 E., is little more than a jumbled pile of rocks. It has been worked for road metal.

The shale that lies between sandstone units $\mathrm{IPbo_4}$ and $\mathrm{IPbo_5}$ is more than 70 feet thick in the NE¼ sec. 27, T. 14 N., R. 16 E.; it is about 90 feet thick in sec. 3, where the exposed upper part consists of gray micaceous shale that is progressively more silty and sandy upward. It is probably equally thick farther north, where its lower part has been cut off by a fault, downthrown to the east. A sandstone lens crops out in the lower part of this shale unit in secs. 16, 21 and 28, T. 14 N., R. 16 E.; it is here designated $\mathrm{IPbo_{4x}}$. Campbell (1957, p. 23-24) treated this sandstone as a tongue of unit $\mathrm{IPbo_4}$ and stated that it is gray to buff, lenticular, cross-bedded sandstone with interbedded shale. At its best exposure, in the road cut along the south boundary of sec. 21, it is 15 feet thick and is separated from unit $\mathrm{IPbo_4}$ by 52 feet of gray argillaceous to silty shale that contains clay-ironstone concretions in the upper part. The shale thins abruptly to the north and becomes so sandy that it is indistinguishable from the underlying sandstone along the north side of sec. 21. In sec. 16, three sandstone outliers can be distinguished from the sandy shale and sandstone underlying them because they are more firmly cemented and, therefore, more resistant. They are here designated $\mathrm{IPbo_{4x}}$.

Unit $\mathrm{IPbo_5}$, in southern Muskogee County south of the Muskogee fault, is continuous in outcrop with unit $\mathrm{IPb_5}$? of Oakes (1967) in northern McIntosh County, which is probably nearly or quite the same as unit

IPb-5 in southern McIntosh County and unit 7 of Dane and others (1938, p. 160, pls. 12, 14) in northern Pittsburg County. As across the line in McIntosh County, unit IPbo$_5$ is tan to brown, medium- to fine-grained, ripple-marked, thin-bedded to massive, lenticular sandstone, with a maximum thickness of about 30 feet. In T. 13 N., the unit contains many local lenses of sandy shale, and the lower part grades irregularly into the sandy shale below, posing many a question as to where to draw the lower limit, especially on outliers. The outcrop occupies a large part of T. 13 N., R. 16 E. It enters over the south line of secs. 34 and 35, extends northwestward along the southwestern flank of an anticline, and swings over the crest and back along the northeastern flank. It extends into the northern part of the township and there occupies a nearly east-west syncline that is probably faulted along the axis. In secs. 5 and 6, the outcrop makes an abrupt turn northward over the Muskogee fault with a change of about 70° in strike but with little if any displacement along the fault.

Campbell (1957, p. 79) found about 32 feet of shale and sandstone to represent this unit, IPbo$_5$, in the southeastern part of sec. 32, T. 14 N., R. 16 E.; the top is eroded there, and it is not certain that the base is exposed. The present writer does not think that the main outcrop extends farther northward, owing to post-Boggy erosion. Farther north, east of Cloud Creek and its tributary, Cane Creek, beds occupying the stratigraphic position of IPbo$_5$ crop out around hills and as hilltop outliers.

According to Campbell (1957, p. 27) unit IPbo$_{5a}$ ranges from 3 to 13 feet thick and is best exposed in the road cut in U.S. Highway 64 east of Yahola, where it consists of 13 feet of gray to buff, fine-grained, lenticular sandstone. The shale above ranges in thickness from 10 feet in sec. 9, T. 14 N., R. 16 E., to about 20 feet along the eastern flank of the hill in sec. 27, T. 15 N., R. 16 E. It is mostly covered, but isolated exposures indicate that it is gray, argillaceous to silty, micaceous shale.

Unit IPbo$_{5b}$ is gray to brown, cross-bedded, locally limonitic sandstone and ranges in thickness from 3 to 12 feet. It is best exposed on top of the hill in secs. 27 and 34, T. 15 N., R. 16 E. The overlying shale is gray to buff, silty, micaceous, poorly exposed, and about 28 feet thick in sec. 5, T. 14 N., R. 16 E.

Unit IPbo$_{5c}$ caps three outliers along the top of the hill in secs. 4, 5, and 9, T. 14 N., R. 16 E. According to Campbell (1957), it consists of buff to brown, fine-grained, locally ferruginous sandstone; the outlier near the southeast corner of sec. 5 is capped by thin, much weathered limonitic siltstone that contains fossil casts and molds of brachiopods, corals, and gastropods.

Post-Boggy Unconformity

For more than 50 years, geologists familiar with the Boggy Formation have thought that there is an unconformity within or at the top of the Boggy. Oakes and others (1967, p. 28-30) have reviewed, in some detail, the literature dealing with the development of the concept and described the field conditions that have led to the opinion that there is, indeed, an unconformity at the top of the Boggy Formation, and that post-Boggy beds transgressed from the south, older beds having been successively overlapped by the next younger. Hare (1969), however, uncovered evidence showing an intergradational relationship at some localities between the Boggy and the overlying Thurman Sandstone; the Thurman is not exposed at the surface in Muskogee County, probably having been overlapped by the Stuart Shale beneath surficial deposits.

In the field, it is nearly impossible to find the actual unconformable contact; at most places, shale lies both above and below. In southern Muskogee County, south of the Muskogee fault, as in McIntosh County and farther south, Boggy rocks are noticeably more folded and faulted than are post-Boggy rocks; and this is the main criterion for distinguishing them. North of the Arkansas River, in Oklahoma, in southeastern Kansas, and in southwestern Missouri, differences in the fossils found in Boggy rocks and in post-Boggy rocks are useful in distinguishing them. On this basis the line is drawn at the base of the Weir-Pittsburg coal cycle (Searight and others, 1953, p. 2748; Branson and others, 1965, p. 34 and pl. 2).

Campbell (1957, p. 36-37) placed the unconformity at the top of his unit IPb-11, somewhat higher than unit IPse$_2$ (Senora Formation) of this report, and at the time the writer concurred with his interpretation of the data; however, now, after further field work, and after considering the conclusions of Searight and others (1953) and the work of Branson and others (1965), he now thinks that it is lower in the section. He had previously placed it, somewhat arbitrarily, it is true, at the top of the Boggy Formation in the vicinity of the west side of sec. 13, T. 13 N., R. 15 E. (Oakes, 1953, p. 1525). From that point northward to the middle of the east side of sec. 6, shale, here assigned to the Senora Formation, overlies Boggy unit IPbo$_5$. In that vicinity unit IPbo$_5$ is overlain by shaly, fine-grained, thin-bedded sandstone of uncertain thickness (IPse$_1$ of this report) that extends northward west of Cloud Creek. The base of the thick Boggy unit IPbo$_5$ passes under the alluvium of Cloud Creek at about the middle of the west side of sec. 32, T. 14 N., R. 16 E.; the lower part of the unit is doubtfully represented farther north by two thin sandstone beds and their intervening shale (units IPbo$_{5a}$ and IPbo$_{5b}$ of this report). Shale containing a thin limestone bed and a thin coal seam crops out across secs. 6 and 21, T. 15 N., R. 16 E., west of Cane Creek. The thin coal seam may be the Weir-Pittsburg.

Stuart Shale

The Stuart Shale was named for Stuart, Hughes County, Oklahoma. In the northern part of T. 12 N., R. 15 E., McIntosh County, south of Muskogee County, the Stuart consists of gray silty shale, possibly 80 feet thick. It is thought to rest unconformably upon shale in the upper part of the Boggy Formation, but the contact cannot be mapped with certainty. The upper limit of the Stuart is a thin sandstone at the base of the overlying Senora Formation. This thin sandstone is not mappable in T. 13 N., R. 15 E., Muskogee County, where the Stuart is indistinguishable from similar shale in the Boggy Formation, below, and the Senora Formation, above. Consideration of topography and structure leads to the conclusion that the Stuart Shale is probably overlapped by shale in the lower part of the Senora Formation in sec. 13, T. 13 N., R. 15 E. The approximate upper and lower limits of the Stuart are indicated on plate 1 by dashed lines, an unsatisfactory expedient.

Senora Formation

Nomenclator.—J. A. Taff (1901).

Type locality.—Taff did not formally designate a type locality, but the name is from the old post office of Senora, in southern Okmulgee County, Oklahoma.

History of usage.—Taff's original usage of the term Senora has not been modified.

Distribution.—The outcrop of the Senora Formation extends from the Ahloso fault in T. 13 N., R. 7 E., a few miles southwest of Ada, Pontotoc County, northeastward across Pontotoc, Hughes, Pittsburg, McIntosh, Okmulgee, Muskogee, Wagoner, Rogers, and Craig Counties to the Kansas-Oklahoma line. The maximum width of outcrop is about 20 miles, in McIntosh County.

Thickness and character.—Throughout most of the length of its outcrop the Senora Formation consists of a lower member, in which sandstone is conspicuous, and an upper member, in which shale is the distinguishing element.

According to Morgan (1924, p. 87), the Senora is only 125 feet thick in secs. 3 and 10, T. 13 N., R. 7 [8?] E. The upper member is shale with prominent interbedded brown and yellowish-brown sandstone and is about 95 feet thick. The lower member is sandstone with very little shale and is 35 feet thick.

South of Citra, T. 4 N., R. 9 E., Hughes County, Weaver (1954, p. 44) found the upper member to be 114 feet thick and the lower member 116 feet, for a total thickness of 230 feet.

In the latitude of Stuart, T. 5 N., R. 11 E., Hughes County, Weaver found the upper member to be 150 feet thick and the lower member 350 feet, for a total thickness of 500 feet.

In the latitude of Dustin, T. 9 N., Hughes County, Weaver found the upper member to be 160 feet thick, with 365 feet of the lower member present; and Oakes and others (1967) found an additional 350 feet of the lower member in western McIntosh County, to the east. Thus the total thickness is 875 feet.

In T. 10 N., McIntosh County, Oakes found the upper member to be 350 feet thick and the lower member about 600 feet, for a total thickness of 950 feet.

In T. 11 N., Okmulgee and McIntosh Counties, Oakes (1963) and Oakes and others (1967) found the upper member to be 280 feet thick and the lower member 670 feet, for a total thickness of 950 feet.

In T. 12 N., Okmulgee and McIntosh Counties, Oakes found the upper member to be 210 feet thick and the lower member 700 feet, for a total thickness of 910 feet.

In T. 13 N., Okmulgee County, Oakes (1963) found the upper member to be 250 feet thick and 420 feet of the lower member to be present. About 450 feet of the lower member is present across the southern part of T. 13 N., Muskogee County, as shale. The total thickness in T. 13 N. is about 1,120 feet.

In T. 14 N., Okmulgee County, the upper member is 200 feet thick; 200 feet of the lower member is present, and an additional 420 feet of the lower member crops out in Muskogee County. Thus the total thickness is 820 feet.

In T. 15 N., Okmulgee County, the upper member is 190 feet thick, and 90 feet of the lower member is present. An additional 420 feet of the lower member crops out in Muskogee County.

In the southern half of T. 16 N., Muskogee County, the entire Senora Formation crops out and is 480 feet thick.

According to Govett (1959, p. 84), the total thickness of the Senora Formation ranges from about 245 to about 470 feet across Wagoner County, north of Muskogee County. Branson and others (1965, pl. 2), in a generalized columnar section, gave about 300 feet as the thickness of the Senora Formation in Craig County, Oklahoma. This is about the sum of the maximum thicknesses given by them for the several parts of the formation.

The sandstone that is so conspicuous in the lower part of the Senora in southern McIntosh County and farther south grades into 450 feet of shale northward in the southern part of T. 13 N., Muskogee County. In Tps. 14, 15, and 16 N., Muskogee County, sandstone and extremely sandy shale are again conspicuous.

Just west of alluvium associated with Cloud Creek and the Arkansas River, in secs. 6, 21, and 28, T. 15 N., R. 16 E., a shale sequence crops out that contains a limestone 0.2 feet thick, 6 feet below the top, and a coal seam 0.3 feet thick, about 13 feet below the top. The coal is here rather arbitrarily presumed to represent the Weir-Pittsburg coal of southwestern Missouri, southeastern Kansas, and northeastern Oklahoma. Searight and others (1953, p. 2748) placed the Weir-Pittsburg coal cycle at the base of the Cabaniss Group in southwestern Missouri, and Branson and others (1965) placed it at the base of the Senora Formation in Craig County, Oklahoma. Gray to buff, silty, micaceous shale 28 feet thick crops out in sec. 5, T. 14 N., R. 16 E., between units IPbo$_5$ (Boggy) and IPse$_1$ (Senora), but neither the limestone nor the coal has been found there.

Unit IPse$_1$ crops out in the NE¼ sec. 6, T. 13 N., R. 16 E., as a gray to brown, shaly, fine-grained, thin-bedded sandstone of uncertain thickness and vague upper limit. It was at first thought to be the upper part of unit IPbo$_5$, but the writer now thinks that it is a sandstone in the Senora Formation, resting upon the eroded top of unit IPbo$_5$ at this place. The outcrop extends along the west side of Cloud Creek as thin-bedded, weakly resistant sandstone of varying thickness and indefinite upper limit to alluvium in sec. 8, T. 14 N., R. 16 E. It occurs on the west side of Cloud Creek in sec. 28, T. 15 N., R. 16 E., and continues north to alluvium associated with the Arkansas River. This outcrop is a gray, platy, cross-bedded, micaceous sandstone about 3 feet thick, weathering buff to brown.

The interval that overlies unit IPse$_1$ was described by Campbell (1957). In secs. 29 and 30, T. 14 N., R.16 E., exposures are few and poor but appear to be gray shale about 100 feet thick. The thickness decreases northward to about 15 feet in the vicinity of Jamesville. In sec. 24, T. 15 N., R. 15 E., northwest of Jamesville, the interval is about 13 feet thick and contains, in ascending order: underclay, 3.0 feet thick; coal, 0.4 feet; black fissile shale containing clay-ironstone concretions, 3.5 feet; and gray silty shale, 6.5 feet thick. Campbell found remnants of gray to red fossiliferous limestone in the stream in the SE¼ sec. 24, but the bed was not found in place. In sec. 29, T. 15 N., R. 16 E., southeast of Jamesville, the interval is gray, slightly silty shale about 21 feet thick.

Unit IPse$_2$ was mapped by Campbell (1957, p. 30-31) as four separate sandstone lenses, each lying at different stratigraphic positions in shale that he classified as part of the Boggy Formation, his unit IPb10. But inasmuch as this shale unit is reported to be 138 feet thick in the southern part of his area, north of Boynton, and only 83 feet thick in the northern part, the writer thinks it at least as likely that these sandstone lenses lie near the same position; after studying aerial photographs of the area and examining the field evidence, he has mapped them as a single unit, IPse$_2$, of the Senora Formation.

In the area north and northwest of Jamesville, which is in the northwestern part of sec. 20, T. 15 N., R. 16 E., unit IPse$_2$ consists of gray to gray-brown, buff-weathering, very fine-grained, massive to thin-bedded, shaly, micaceous sandstone about 5 feet thick. In sec. 30, T. 14 N., R. 16 E., it is a gray to brown, buff-weathering, very fine-grained, massive to thin-bedded, shaly, micaceous sandstone 9 feet thick. In this area it contains plant fossils and is channeled into the underlying shale. It does not extend south of sec. 25, T. 14 N., R. 15 E.

The shale unit that lies above unit IPse$_2$ is the upper part of shale unit IPb10 of Campbell (1957). It is gray, silty to sandy, and about 40 feet thick in sec. 24, T. 15 N., R. 15 E., and 35 feet thick in sec. 30, T. 14 N., R. 16 E. Isolated exposures of gray fossiliferous limestone, IPsel, were found in the north-central part of sec. 22, T. 15 N., R. 15 E. A diligent but unfruitful search for other exposures was made by Campbell (1957, p. 33).

Unit IPse$_3$, in the area between Cane Creek and Boynton, is the same as unit IPb11 of Campbell (1957, p. 33). It is a gray to brown, fine-grained, irregularly bedded sandstone about 8 feet thick. It contains abundant plant remains in its upper part, with some coal stringers along bedding planes. The outcrop extends eastward into sec. 30, T. 14 N., R. 16 E., where it caps a high escarpment. The unit is not found south of Boynton.

The area between Cane Creek and Ash Creek was remapped by the writer in the fall of 1967, using new aerial-photograph prints, after Campbell had completed his thesis. The result was far from gratifying, however. In this area, unit IPse$_3$, as here presented, corresponds rather closely to the lower part of Campbell's unit IPb11. The unit consists, at most places, of silty sandstone lenses that grade into silty, sandy shale vertically and laterally; it is probably nowhere more than 10 feet thick. In this part of the area the outcrop lies on the southwestern flank of a low anticline whose axis essentially parallels Ash Creek. North of Ash Creek, unit IPse$_3$ lies on the northwestern flank of the anticline and includes unit IPb11 of Campbell along with some outliers farther east and north, beyond the area mapped by him. The unit appears to be cut off by a fault, downthrown on the northwest side, and is probably nowhere more than 15 feet thick.

Tiawah Limestone Member.—The following quotation is from Branson and others (1965, p. 34-35).

> The Tiawah Limestone was named by Lowman (1932, p. 24) for the village of Tiawah in Rogers County. The limestone is recognized at widely spaced localities from southwestern Wagoner County northward into Missouri. In Wagoner County it grades northward from a myalinid coquinite into a dense, crystalline limestone with abundant fusulinids. In the type section, selected by Tillman (1952, p. 23), which is in the outlier along State Highway 20, 0.1 mile east of SW cor. sec. 12, T. 21 N., R. 16 E., Rogers County, the Tiawah is 6.3 feet thick and is dense, light-gray limestone with small gastropods.

The writer is not acquainted with the Tiawah Limestone Member from field experience, but the literature indicates that the Tiawah and the Tebo coal, a short distance below, are each less than 1 foot thick at most places and that they are generally separated by a few feet of black fissile shale, which may extend somewhat above the Tiawah or below the Tebo. The limestone, black shale, and coal are generally found cropping out together, but all may be absent for long stretches because of patchy deposition, post-Tiawah erosion, or both. The southernmost outcrop previously known was reported by Lontos (1952, p. 22) in sec. 2, T. 16 N., R. 15 E.

In Muskogee County, just such an association of strata is found cropping out in that part of the section where the Tiawah and Tebo would be expected, in the interval above unit IPse$_3$. Directly south of Cane Creek, the interval between IPse$_3$ and IPse$_4$ is estimated to be about 40 feet thick and comprises, in ascending order, gray shale, 9 feet thick, sandy at the base, grading to argillaceous at the top; coal, 6 feet, probably Tebo; shale, 16 feet, black, fissile, containing iron carbonate concretions; limestone, 0.5 foot, dense, fossiliferous, dark gray, weathering reddish brown, probably the Tiawah

Limestone; and shale, weathered, poorly exposed, thickness not known but probably not more than 15 feet.

At most places north of Cane Creek, the interval between IPse$_3$ and IPse$_4$ is composed of silty to sandy shale lenses ranging from siltstone to sandstone. Its thickness is not known, but it is variable and probably thickens northward to as much as 60 feet in sec. 17, T. 15 N., R. 15 E. The overlying sandstone unit, IPse$_4$, could not be recognized farther north. At the middle of the west side of sec. 20, T. 15 N., R. 15 E., the upper part of the interval contains coal, which Campbell (1957, p. 46) referred to the Eram coal of Okmulgee County because of its position below unit IPse$_6$. However, according to the mapping here presented, which admittedly is not all that could be desired, it lies in about the same stratigraphic position as the coal and limestone south of Cane Creek, described previously. From such piecemeal measurements as could be made, the section is about as follows, in ascending order: gray argillaceous shale, 3.2 feet thick; coal, probably representing the Tebo, 0.5 foot; black, blocky to fissile, carbonaceous shale, containing iron carbonate concretions, 6.0 feet; gray, dense, fossiliferous limestone, 0.6 foot, probably representing the Tiawah; and gray micaceous shale, 12 feet.

In secs. 4 and 8, T. 15 N., R. 15 E., along the north side of a fault, downthrown an unknown amount to the northwest, are several exposures of limestone, black fissile shale, and coal thought to represent the Tiawah Limestone and the Tebo coal. From such piecemeal measurements as could be made, the section is about as follows, in ascending order: underclay, gray to blue-gray, carbonaceous, 2.3 feet thick; coal, 0.5 foot, probably representing the Tebo; shale, black, fissile, carbonaceous, containing phosphatic nodules and interbedded ironstone concretions, 5.0 feet; limestone, gray, coquinoid, about 4 inches, probably Tiawah; shale, maroon to light-gray, argillaceous, containing clay-ironstone concretions, 2.5 feet.

Campbell (1957, p. 44) stated that shale, dark to light gray, micaceous, locally silty, and estimated to be 110 feet thick, crops out up the hill to the north to the base of the Chelsea Sandstone Member of the Senora. The same interval is about 80 feet thick along the west side of secs. 20 and 29, T. 15 N., R. 15 E., but contains about 30 feet of sandstone, IPse$_8$, the lower part of which grades northward into shale whereas the upper part is truncated by the unconformity at the base of the Chelsea Sandstone.

Unit IPse$_4$ was mapped from aerial photographs, and the mapping was checked by traversing the roads. Both upper and lower boundaries are indistinct in many parts of the area; moreover, there is a possibility that the unit, as mapped, lies higher in the section in T. 15 N. than in T. 14 N. As here presented, the unit extends from the east side of sec. 26, T. 14 N., R. 15 E., where it grades into shale, to the middle of the west side of sec. 20, T. 15 N., R. 15 E., where it again grades into shale. Its thickness is evidently variable but is not known for any locality; however, it is probably not more than 20 feet.

Campbell (1957, p. 77) described the shale lying above his unit IPb11 (unit IPse$_3$ of this report) across secs. 21 to 24, T. 14 N., R. 15 E., as gray to buff, silty to sandy, and micaceous wherever exposed and about 290 feet thick. Reducing this by 50 feet, the estimated thickness of the interval between the top of unit IPse$_3$ and the top of unit IPse$_4$ in this part of the area leaves about 240 feet for the thickness of shale that the author presumes to lie between units IPse$_4$ and IPse$_5$. Unit IPse$_5$ was not mapped by Campbell, but it was mapped by Manhoff (1957) and by Oakes (1963). It is identical with unit IPsn-1 of Okmulgee County. It consists of fine- to medium-grained sandstone with a maximum thickness of 20 feet in Okmulgee County. Senora units IPsn-1, IPsn-2, and IPsn-3 of Okmulgee County all grade into shale northward and are not present north of T. 14 N. in Muskogee County. Unit IPsn-4a of Okmulgee County is the same as unit IPse$_8$ of Muskogee County.

Campbell (1957, p. 78) gave 237 feet as the thickness of the interval between his unit IPb11 and unit IPse$_6$ of this report from sec. 8 to sec. 1, T. 14 N., R. 15 E. Reducing this thickness by 60 feet, the estimated thickness of strata between the top of his unit IPb11 and the top of unit IPse$_4$ leaves about 180 feet as the thickness of the interval between units IPse$_4$ and IPse$_8$. According to Campbell's description, this interval consists of gray to buff, silty to sandy, micaceous shale wherever exposed. From this locality northward, the thickness of the interval decreases precipitately to about 20 feet along the west side of the SW¼ sec. 20, T. 15 N., R. 15 E. Part of this decrease may be due to a suspected northward rise of unit IPse$_4$ in the section.

Unit IPse$_8$ in Muskogee County is the same as unit IPsn-4a of Okmulgee County, which the writer once thought was a lower tongue of the Chelsea Sandstone, an opinion that he no longer holds. The unit is 85 feet thick along the south line of T. 15 N., R. 15 E., but is only about 30 feet thick 2 miles farther north. The abrupt northward thinning is similar to that of the underlying shale. The following description is largely from Campbell (1957, p. 46-47). This Senora unit consists of gray to buff, fine-grained, lenticular sandstone and interbedded shale. The base is not well defined; in some places it is marked by sandstone lenses and elsewhere by a barely perceptible change from gray silty shale to shaly sandstone. There are three outliers east of the main outcrop, one of which contains, along the south line of sec. 28, T. 15 N., R. 15 E., two small patches of highly weathered, silty, coquinoid limestone, an isolated occurrence designated like all such as IPsel. The unit crops out around the hill in secs. 29, 30, 31, and 32, T. 15 N., R. 15 E., south of Midway, where it is about 30 feet thick and grades upward into sandy shale. The outcrop is more shaly northward to a fault downthrown by an unknown amount to the north, in sec. 7, T. 15 N., R. 15 E. It is still more shaly north of the fault and is truncated by an unconformity at the base of the much coarser Chelsea Sandstone in the northwestern part of T. 15 N. and the southwestern part of T. 16 N., R. 15 E.

Gray to buff, micaceous, silty shale about 30 feet thick overlies unit IPse$_8$ near the top of the hill in secs. 29, 30, 31, and 32, T. 15 N., R. 15 E., south of Midway, and crops out northward along the line between Okmulgee and Muskogee Counties to the southwestern part of sec. 30, T. 16 N., R. 15 E., where it is finally cut off by the unconformity at the base of the Chelsea Sandstone.

Chelsea Sandstone Member.—This member of the Senora Formation was named by D. W. Ohern in an unpublished 1914 report ("Geology of the Nowata and Vinita Quadrangles"; Oklahoma Geological Survey) from exposures in the Vinita quadrangle, east of the town of Chelsea, Rogers County, Oklahoma. It is the same as sandstone unit IPsn-4b of Okmulgee County. Oakes (1963, p. 30) called this unit the upper part of the Chelsea Sandstone, but later evidence shows it to be the entire member. An outlier of the lower part of the Chelsea,

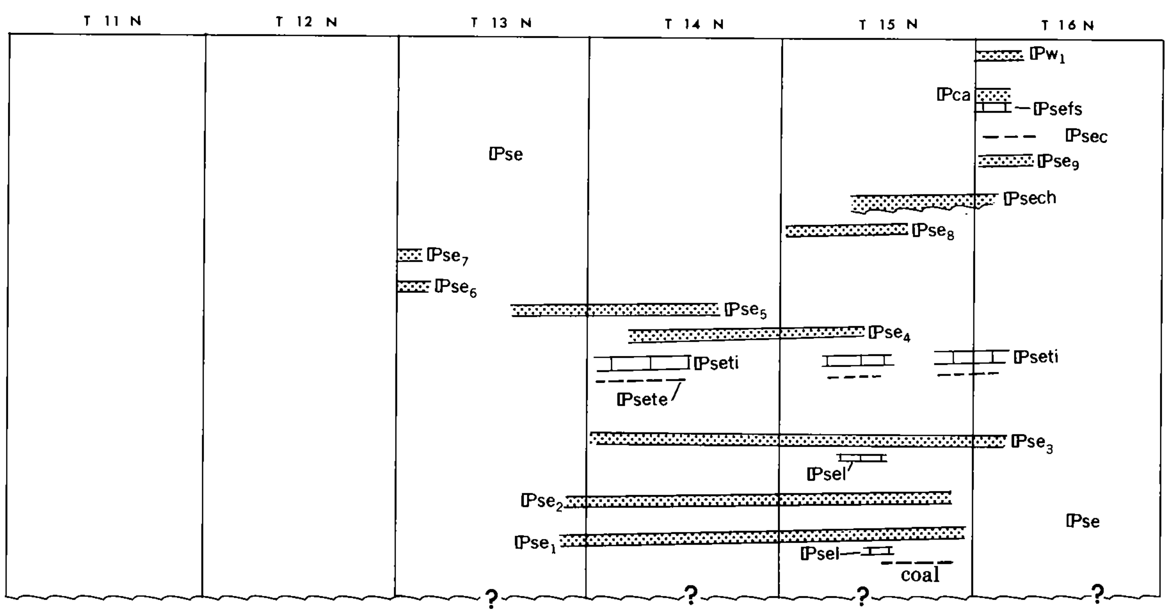

Figure 8. Section diagram, not to scale, illustrating south-to-north distribution of Senora Formation, Calvin Sandstone, and Wewoka Formation as they crop out in Muskogee County. See plate 1 for explanation of symbols.

about 3 feet thick, caps the hill south of Midway. According to Campbell (1957, p. 48), the unit is a yellow to brown, fine-grained, lenticular sandstone. It crops out in the northwestern part of T. 15 N. and the southwestern part of T. 16 N., R. 15 E., where it is probably about 50 feet thick. The lower part is coarse grained, and it rests unconformably upon and finally cuts off sandstone unit IPse$_8$. Evidence of this unconformity has been found from place to place, at least as far north as the Kansas-Oklahoma line; the Chelsea is now known to rest on strata only 5 feet above the Bluejacket Sandstone Member of the Boggy Formation in Craig County (Branson and others, 1965, p. 36).

Strata in Muskogee County younger than the Chelsea Sandstone Member are about 230 feet thick. They crop out across approximately the NW¼ sec. 19, T. 16 N., R. 15 E., in the extreme northwestern part of the County, along and beneath a high escarpment where the terrain is steep. Detrital debris is thick and plentiful, and exposures are scarce. About 50 feet of poorly exposed silty to sandy shale overlies the Chelsea Sandstone conformably.

Unit IPse$_9$ is poorly exposed in Muskogee County. In adjoining Okmulgee County, to the west, it is mapped as IPsn-8 and described as reddish-brown to gray-brown, fine-grained sandstone, 5 to 10 feet thick (Oakes, 1963, p. 30). The overlying silty to sandy shale is about 170 feet thick and contains the Croweburg (Henryetta) coal in the lower part.

Unit IPsefs is composed of limestone, gray calcareous shale, and black fissile shale containing phosphatic nodules. It represents the Fort Scott Limestone and, possibly, the Breezy Hill Limestone farther north (Oakes, 1963, p. 31).

Marmaton Group

Less than 100 feet of the lower part of the Marmaton Group crops out in Muskogee County (see Oakes, 1963, p. 33).

The Calvin Sandstone, at the base of the Marmaton, overlies the Senora Formation conformably. It consists of gray-brown to reddish-brown, fine- to medium-grained sandstone about 30 feet thick; it is overlain conformably by about 50 feet of silty to sandy shale of the Wewoka Formation.

Unit IPw$_1$ is yellowish-brown to brown, fine-grained, thin-bedded sandstone about 10 feet thick in the top part of the exposed Wewoka.

Quaternary System

Terrace Deposits

Unconsolidated deposits of fine-grained sand, silt, and clay occur at greater altitudes than the flood plains of the present Arkansas and Canadian Rivers and their tributaries. The deposits are commonly light red in color, much dissected, and may be 100 feet or more in thickness. They were probably deposited by ancestral streams.

Alluvium

The unconsolidated alluvium of the flood plains of the present Arkansas and Canadian Rivers and their tributaries consists of unconsolidated sand, silty, and clay; in color, these deposits are mostly light brown to grayish brown. Their maximum thickness is unknown.

STRUCTURE

In general, the structure of Muskogee County is dominated by folds and faults that trend southwestward. They are much more numerous and prominent in rocks of Boggy age and older than in rocks of Senora age and younger.

Faults

It is difficult to pinpoint the traces of the faults; most are indicated on plate 1 as being inferred, with varying degrees of uncertainty. Most geologists who have worked in the area have agreed on their trend and general character but not on their exact mapping. The faults are here described in their order of occurrence, from northwest to southeast.

A normal fault, downthrown on the northwest side, passes through secs. 4 and 8, T. 15 N., R. 15 E., and secs. 27 and 34, T. 16 N., R. 15 E. The throw is probably about 20 feet and brings the Tiawah Limestone Member of the Senora Formation down to the base of Senora sandstone unit IPse$_3$.

A small northeastward-trending fault crosses the road between secs. 13 and 24, T.

14 N., R. 15 E. It seems to be downthrown on the southeast side, probably less than 10 feet.

A fault, downthrown to the west, is indicated in the SE¼ sec. 34, T. 15 N., R. 16 E., by unusually steep westward dips and the absence of sandstone unit IPbo$_4$ of the Boggy Formation farther north. It seems to play out in sec. 3, T. 14 N., R. 16 E., but attains a throw of about 50 feet in sec. 23, T. 15 N., R. 16 E.

A fault of small northward displacement is inferred that trends north of east across the line between secs. 1 and 2, T. 14 N., R. 16 E., on the basis of unusually steep dips in Boggy unit IPbo$_3$ in sec. 1 and an offset at the base of Boggy unit IPbo$_4$ in sec. 2.

Both Wilson (*in* Wilson and Newell, 1937, p. 81) and Bell (1959, p. 69) mapped a fault extending southwestward across sec. 14, T. 15 N., R. 17 E., downthrown on the northwest side, which Wilson named the Pecan Creek fault. The writer has, uncertainly, extended it into the northern part of sec. 4, T. 14 N., R. 17 E., and speculatively connected it with the fault that extends through secs. 7, 8, and 13, T. 14 N., R. 17 E., which is downthrown on the northwest side.

An unnamed fault was mapped from northeast to southwest in secs. 25, 35, and 36, T. 15 N., R. 17 E., and secs. 17 and 19, T. 15 N., R. 18 E. The best evidence for this fault is found in sec. 19, T. 15 N., R. 18 E., where the Bluejacket Sandstone Member of the Boggy Formation is displaced, and in secs. 35 and 36, T. 15 N., R. 17 E., where beds are offset. A coal has been mined on the northwest side of this fault (Bell, 1959, p. 70). Sandstone crops out on the southeast side of this fault in sec. 25, T. 15 N., R. 17 E., and dips noticeably southeastward; it is thought to be some part of the Keota Sandstone Member of the McAlester Formation.

The Muskogee fault enters Muskogee County across the east line of sec. 12, T. 15 N., R. 20 E., where it was called the South Muskogee fault by Huffman and others (1958, p. 92, pl. 6), following Wilson (*in* Wilson and Newell, 1937, p. 80, pl. 1), who stated:

> The Muskogee fault (south) enters the area in sec. 26, T. 15 N., R. 19 E., but is covered by the alluvial silt of the Arkansas River from that locality to N½ sec. 2, T. 14 N., R. 18 E., in which section it abruptly dies out. The presence of this fault beneath the alluvium was determined by the study of well logs. The throw is as much as 600 feet, and the downthrown side is to the north. The Muskogee fault (north) probably begins abruptly in the SE¼ sec. 30, T. 15 N., R. 19 E., and extends west-southwest into sec. 8, T. 14 N., R. 17 E., beyond which it could not be accurately traced.

Mapping by Bell (1959, pl. 1) indicates that his Muskogee fault is the same as Wilson's Muskogee fault (north) and is continuous with Wilson's Muskogee fault (south). According to Huffman and others (1958, p. 92), "It trends northeastward parallel to the course of Bayou Manard and Highway 62 to a point one mile southeast of Tahlequah [Cherokee County]. It appears to be continuous with the fault which crosses the Illinois River in secs. 24 and 26, T. 17 N., R. 23 E. northeast of Tahlequah. . . . The fault is downthrown on the north and maximum stratigraphic displacement is 250 to 300 feet." West of the Arkansas River, the present writer has drawn the Muskogee fault along a general southwestward trend to sec. 18, T. 14 N., R. 17 E. Farther southwestward it is no doubt present in the subsurface but probably not at the surface. The throw is probably not more than 40 feet in sec. 9, T. 14 N., R. 17 E.

A fault, downthrown on the north side, is questionably indicated on plate 1 extending in a south of westward direction from the vicinity of the SE¼ cor. sec. 17, T. 14 N., R. 18 E., to sec. 34, T. 14 N., R. 16 E. It is inferred from revised detailed mapping of Bell (1959, pl. 1) and Campbell (1957, pl. 1) by the writer. The trace of this inferred fault marks a conspicuous change in the stratigraphy and structure of the upper part of the Boggy Formation. Northward, the rocks of the Boggy are comparatively well stratified and dip generally westward to northwestward. Southward, such outcrops as could be mapped between the Inola Limestone Member, below, and sandstone unit IPbo$_5$, above, are merely the more resistant parts of poorly resistant sandy shale and sandstone bodies that lie in a large southwestward-plunging syncline several miles wide. It is interesting that this interval has much the same character as it extends southward into northern McIntosh County.

An inferred fault trends eastward through secs. 7, 8, and 9, T. 14 N., R. 17 E. It is downthrown on the north side, but the throw is probably not more than 20 feet. It lies along the axis of a syncline and probably extends no farther westward than sec. 7.

The Dirty Creek fault is named from the water gap through which both the fault and the creek pass. The eastern limits of this fault are unknown, but the fault is believed to diminish to the west in R. 17 E. and result in a small anticline. The fault has a throw of approximately 50 feet, down on the north, measured across Dirty Creek from sec. 35, T. 13 N., R. 17 E., to sec. 1, T. 12 N., R. 17 E., according to Coleman (1958, p. 64). The writer infers that this is the same fault as the one inferred in secs. 22 and 28, T. 13 N., R. 18 E.

Wilson (*in* Wilson and Newell, 1937, p. 80) stated: "The *Coody Creek fault* extends from the NE¼ sec. 5, T. 14 N., R. 19 E., westward to the west line of sec. 11, T. 14 N., R. 18 E. The throw of this fault is down to the north and is about 90 feet. The McCurtain and Warner members of the McAlester shale and the Tamaha and Keota members of the Savanna [McAlester] formation are cut at the surface by this fault." The present writer has found no surface evidence of this fault except in the vicinity of the SE cor. sec. 2, T. 14 N., R. 18 E., where the Warner Sandstone Member of the McAlester Formation appears to be cut by a fault, downthrown to the north. Bell (1959, p. 69) estimated the throw in this locality to be about 30 feet.

Wilson (*in* Wilson and Newell, 1937, p. 79 and pl. 1) mapped and discussed what he called the Sam Creek fault, trending eastward across the middle of T. 14 N., R. 19 E., with a maximum throw of about 150 feet, downthrown on the south side. In mapping this fault, Wilson seems to have relied considerably on subsurface data. Gregware (1958, p. 68-70, pl. 1) mentioned no such fault, but stated:

> Several faults occur in T. 14 N., R. 19 E. A long faulted zone extends through secs. 3, 4, 6, 7, 17, 19, and 20 but the cumulative throw is not great. Apparently, some rotation of the blocks has occurred as the upthrown and downthrown sides are reversed to the north. The fault zone is discontinuous in places to the north. Two faults in the central part of the township form the boundaries of a downthrown block which preserves an outlier of Hartshorne coal and sandstone. The throw along these faults is also relatively small. Two other small faults were mapped in this township; one in secs. 27, 31, 32, and 33, and one in secs. 17 and 18. . . .
>
> The Keefeton Fault extends east to west across the center of T. 13 N., R. 19 E. The maximum throw is probably not over 300 feet. . . .
>
> A faulted zone with a cumulative throw of about 50 feet or less occurs along Spaniard Creek in T. 13 N., R. 19 E. The steep dips associated with these faults and with the Keefeton Fault cause the entire McAlester formation to be exposed in a distance of less than three-fourths of a mile in sec. 18, T. 13 N., R. 19 E. . . .
>
> [The north fault of the Warner uplift] was mapped in the southwest part of T. 12 N., R. 19 E., and also further north in secs. 1 and 2, T. 12 N., R. 19 E., sec. 6, T. 12 N., R. 20 E., and in secs. 29 and 31, T. 13 N., R. 20 E. Between these two regions the fault, if present, is indistinguishable and could not be mapped. In the southwestern part of T. 12 N., R. 19 E., the fault has considerable throw as it brings Atoka rocks in contact with the Savanna formation. At this place the throw is estimated to be more than 500 feet. However, the throw decreases rapidly northward, and the fault probably dies out in sec. 15, T. 12 N., R. 19 E. Where this fault again appears farther north, the throw is probably not over 100 feet at any place. . . .
>
> The South Fault of the Warner Uplift trends diagonally across T. 12 N., R. 20 E. It is a faulted zone rather than a single fault, and appears to fork in several places. The throw may be as much as 300 or 400 feet in places.

Folds

A broad, gentle, ill-defined, westward-plunging anticline with southwestward and northwestward dips of not more than 3° extends across the middle of T. 15 N., R. 15 E. It is typical of the gentle structures that occur in post-Boggy rocks.

The axis of a syncline extends southeastward across secs. 4 and 9, T. 14 N., R. 16 E., along the top of a hill where there are several sandstone outliers.

A southward-trending anticline was mapped by Wilson (*in* Wilson and Newell, 1937, p. 84) in secs. 17 and 19, T. 15 N., R. 17 E. Wilson named it the Taft anticline and stated that it was the site of the Sommerville oil and gas field. Campbell (1957, p. 54, pl. 1) extended the axis into sec. 35, T. 15 N., R. 16 E. Wilson said that dips on the flanks are less than 4°.

A short anticline extends slightly west of south through secs. 10 and 15, T. 15 N., R. 17 E.

A long, unnamed syncline extends southwestward from sec. 12, T. 15 N., R. 17 E.

The axis of an anticline, indistinctly discerned because of much loose sand, passes through secs. 13 and 27, T. 15 N., R. 17 E.

Most geologists who have worked in the area draw a synclinal axis a short distance north of the Muskogee fault; but actually, considering the area on both sides of the fault, the whole feature would be better classified as a faulted syncline.

A faulted, westward-trending syncline occupies the northern part of T. 13 N., Rs. 16 and 17 E., and the axis of an anticline extends across the southwestern part of the same area. Gregware (1958, p. 67-68) stated:

> A large syncline is located in the northwestern part of T. 13 N., R. 19 E. This structure is asymmetrical, with steeper dips on the south flank, and is also faulted along the south limb. The presence of this structure causes the younger Savanna rocks to be exposed in that township.
>
> Two other, smaller synclines were mapped in this area [the area of his thesis]. One occurs in sec. 16, T. 14 N., R. 19 E., and one in sec. 16, T. 12 N., R. 19 E. Both of these features are rather poorly shown, and are relatively gentle structures.
>
> Two small anticlines were also mapped, one in secs. 20 and 21, T. 12 N., R. 19 E., and one in secs. 7 and 8, T. 14 N., R. 19 E. The latter structure is adjacent to the Jolly-Patton oil field and may be the surface expression of the producing structure.

The axis of the Rattlesnake Mountain syncline enters Muskogee County from McIntosh County, to the west, over the top of the high hill in the center of sec. 19, T. 12 N., R. 19 E., and extends to alluvium associated with the Arkansas River in sec. 19, T. 13 N., R. 20 E. It probably extends across the river into eastern Muskogee County, but it has not been indicated there for lack of suitable outcrops. Its course parallels that of the north fault of the Warner uplift.

The syncline is asymmetrical, with the north limb having the steeper dips. Elevations along the axis of the Rattlesnake Mountain syncline are generally higher than those of the surrounding areas, according to Gregware (1958, p. 67).

The Warner uplift extends into Muskogee County from McIntosh County, on the west, and continues eastward into Sequoyah and Cherokee Counties. It is a broad horst between two normal faults called the north and south faults of the Warner uplift. Earlier writers described these two faults as having passed into steep dip slopes locally, but the writer thinks that they may be continuous and has so indicated on plate 1. The uplift was mapped by Wilson (*in* Wilson and Newell, 1937, p. 83, pl. 1), who showed several secondary folds surmounting it. However, Gregware (1958, p. 67) stated that only one fold could be mapped on the Warner uplift in Tps. 12 and 13 N., Rs. 19 and 20 E.; it lies in secs. 13, 23, 24, and 26, T. 12 N., R. 19 E. Stine (1958, p. 61) mentioned an anticline on the Warner uplift in Muskogee County whose axis passes through secs. 28, 29, and 31, T. 11 N., R. 19 E., and whose south limb dips into the south fault of the Warner uplift.

An anticline extends into Muskogee County from McIntosh County, to the west, across sec. 6, T. 10 N., R. 19 E.; its axis is terminated within a mile by the south fault of the Warner uplift.

The Porum syncline lies adjacent to the Warner uplift on the south side. Its axis extends into Muskogee County from McIntosh County through the NW¼ sec. 18, T. 10 N., R. 19 E., and continues northeastward to the Arkansas River alluvium near the northeast corner of sec. 33, T. 12 N., R. 20 E. According to Stine (1958, p. 60):

> The Porum syncline is an asymmetric fold having a dip of less than 2° on the southeast flank and approximately 12° on the northwest where the high dip is associated with the downthrown side of the south fault of the Warner uplift.

On page 62 Stine stated further:

> A syncline with a curved axis extends across the center of T. 11 N., Rs. 20 and 21 E. almost at right angles to the Porum syncline. Just one mile south of the axis of this syncline is the axis of an anticline having the same general trend. The dips associated with these two structures are estimated to be less than 2°.

Also on page 62 Stine wrote:

> An anticline flanked by the Keota sandstone trends in a northeast-southwest direction in sec. 27, 22, and 23, T. 10 N., R. 19 E. The north flank dips to the northwest at about 5°. The south flank is cut by a northeast-trending normal fault. . . .
>
> The outcrops surrounded by alluvium and terrace sand in secs. 28, 29, 30, 31, 32, and 33, T. 10 N., R. 20 E. indicate an anticline whose axis trends nearly east-west. . . .
>
> The Canadian River is thought to conceal a fault along the southeast side of the area. In Haskell County to the southeast the Atoka stands up as a high escarpment but to the northwest the Atoka is at a much lower elevation.

ECONOMIC GEOLOGY

Muskogee County has produced oil, gas, and coal in considerable quantities, but in none of these has it been one of the State's major producing counties. The outcropping rocks are mostly shales and sandstones; sandstone beds as sources of building stone have been used in older buildings when economic conditions warranted the use of that material. There are a few thin, lenticular limestone beds, most of limited extent, and all are too thin and impure to be of commercial value. Sand and gravel are available from the Arkansas River. The consolidated sandstones, alluvium, and terrace deposits contain sufficient ground water at most places for rural domestic requirements. Properly constructed ponds and small lakes are dependable for modest water supplies; the soils are such that ponds and lakes are feasible for most localities. The Arkansas and Neosho (Grand) Rivers are available for really large water supplies. For further information on water resources, the reader is referred to Marcher (1969).

The investigation of petroleum resources and potential was beyond the scope of this report.

Coal

The Hartshorne coal seam is exposed at some places a few feet above the Hartshorne sandstone. Wilson (*in* Wilson and Newell, 1937, p. 86) reported that the coal ranges in thickness from 9 to 12 inches and that it has been strip mined in sec. 35, T. 12 N., R. 20 E.

Bell (1959, p. 75) reported that a coal seam 10 inches thick underlies the Warner Sandstone Member of the McAlester Formation in sec. 12, T. 14 N., R. 18 E., but has not been mined. An unnamed coal seam crops out at some places in the upper part of the Warner Sandstone. Wilson (*in* Wilson and Newell, 1937, p. 86) described it as 9 to 11 inches in thickness and stated that it had been prospected and mined in sec. 13, T. 13 N., R. 18 E., and in sec. 4, T. 13 N., R. 19 E.; Gregware (1958, p. 74) stated that it had been strip mined at two localities in sec. 3, T. 13 N., R. 19 E. All coal produced from this seam has probably been for strictly local use.

The Stigler coal seam crops out in shale between the Cameron-Lequire and the Tamaha Sandstone Members of the McAlester Formation. The Stigler has been strip mined in Tps. 10 and 11 N., Rs. 19 and 20 E., where the most common thickness is 18 inches or less; it is reported to be as thick as 24 inches at some places. It crops out and has been strip mined in secs. 17, 18, and 20, T. 12 N., R. 19 E., where it is as thick as 18 inches. It crops out and has been mined locally at numerous places in the syncline in the northwestern part of T. 13 N., R. 19 E.; we have no data as to thickness there except that it is 18 inches near the W½ sec. 18. Bell (1959) mapped the McAlester Formation in Tps. 14 and 15 N., Rs. 18 and 19 E., and stated on page 27 that along the north third of the east line of sec. 23, T. 14 N., R. 18 E., the shale between the Warner Sandstone Member, below, and the Tamaha Sandstone Member, above, is 42.5 feet thick and contains a coal seam 5 inches thick that is 18.1 feet below the top, which may be the Stigler coal. Bell reported no outcrops of Stigler coal farther north.

Coal seams too thin and erratic to be of commercial importance crop out at many places in the McAlester Formation, especially in the shales of the Keota Sandstone Member.

The Rowe coal seam, and the Doneley Limestone Member, a few inches to a few feet above it, lie in the upper part of the Savanna Formation. Inasmuch as the coal and limestone are closely associated and are nearly always seen together, exposures are indicated on plate 1 by an *x* and a single dashed line representing the outcrop of both between exposures. The mapping is taken mostly from Wilson (*in* Wilson and Newell, 1937, pl. 1). The Rowe was called the lower Boggy coal by Wilson, who stated that it had been mined at many localities in T. 10 N., R. 19 E., and in sec. 2, T. 13 N., R. 18 E.; in secs. 6, 10, and 15, T. 14 N., R. 18 E.; in secs. 21 and 22, T. 15 N., R. 18 E.; and in sec. 13, T. 15 N., R. 17 E. He estimated the average thickness at about 10 inches. Gregware (1958, p. 74) found that the Rowe had been strip mined in the NW¼ sec. 19, T. 12, N., R. 19 E. Coleman (1958, p. 68) found abandoned strip pits in secs. 3, 4, 10, 11, 13, and 14, T. 12 N., R. 18 E. Bell (1959, p. 75) stated that the Rowe coal crops out but had not been mined in sec. 18, T. 15 N., R. 18 E., where it is 12 inches thick.

The Secor coal, so called by Wilson (*in* Wilson and Newell, 1937, p. 85, 86), lies in shale between the Bluejacket and Crekola Sandstone Members of the Boggy Formation. Wilson stated (p. 86):

> It has . . . been mined in sec. 3, T. 13 N., R. 18 E., where it is 16 inches thick. This coal also crops out in sec. 9, T. 13 N., R. 18 E. It has been mined and prospected in secs. 19 and 31, T. 14 N., R. 18 E.; sec. 25, T. 15 N., R. 17 E., where it is 12 inches thick; and secs. 8, 9, 11, 14, and 16, T. 15 N., R. 17 E., where it is 11 inches thick.

Coleman (1958, p. 68-69) wrote, of a higher coal in the Boggy: "Abandoned strip-mines are located in secs. 17, 18, 19, 20, T. 13 N., R. 17 E. The coal found here is in a faulted area and occurs discontinuously and with varying dips." This quotation summarizes the little that is known about it; the present writer quizzed local residents with no results. The coal lies in the shale that crops out between the Inola Limestone Member, below, and sandstone unit IPbo$_5$, above, south of the Muskogee fault, where sedimentation was extremely variable from place to place; the coal is probably not to be correlated with any named coal seam elsewhere in the Boggy Formation.

Limestone

Huffman and others (1958, p. 101) mentioned that limestone in the Hindsville, Hale, and Bloyd Formations has furnished the most suitable limestone for aggregate. The Hindsville is thin to absent in Muskogee County. The Pitkin, Hale, and Bloyd Formations crop out in the area east of the Arkansas River and should have potential for building stone and aggregate. Gregware (1958, p. 74) reported that the Chesterian (Pitkin) and Morrowan (Hale and Bloyd) rocks that crop out west of the Arkansas River, in T. 13 N., R. 20 E., include limestones suitable for building purposes but that they are relatively inaccessible. Bell (1959, p. 78) wrote that the Morrowan limestones crop out in T. 15 N., R. 19 E., west of the Arkansas River, but are reported to be of poor quality, unsuitable for most purposes. The Pennsylvanian limestones—Spaniard, Sam Creek, Inola, Doneley—crop out west of the Arkansas River. In general, they are too thin and impure to be of much use. According to Dott (*in* Wilson and Newell, 1937, p. 120):

> In the vicinity of Porum, north of Keefeton and around Muskogee . . . outcrops of Spaniard and Sam Creek are widespread, and considerable quantities of both beds could be quarried at little expense. The Inola limestone should be readily available in many parts of Tps. 14 and 15 N., R. 17 E. The lower Boggy [Doneley] limestone might be profitably worked in conjunction with the underlying coal [Rowe].

Building Stone

In addition to building stone already mentioned under the preceding section on Limestone, many of the sandstone outcrops in Muskogee County have been used successfully for building stone. Dott (*in* Wilson and Newell, 1937, p. 128) states:

> Many of the older buildings and residences in Muskogee and the smaller towns were built of sandstone cut from conveniently located outcrops in the vicinity. More recently, numerous quarries have been opened for material to be used on projects of various Federal agencies. The material has come into considerable use by the WPA [Work Projects Administration] for building National Guard armories in Muskogee, Haskell and Boynton, and for masonry work on bridges and culverts. Some of it has been crushed to surface farm-to-market roads and quantities have been used by the soil erosion service for the construction of baffles to retard gullying and washing. The Resettlement Administration has employed the stone for home construction, masonry work around wells, out buildings, etc. In addition, native stone is gaining increasing popularity as a veneer for private residences.
>
> Sandstone is the most abundant, the most readily accessible, and most easily-worked of the building stones in the district, and quarries can be opened almost at will in any locality.

Clay Shale

The clay shales of Muskogee County have been used in the past for the manufacture of brick and tile. According to Dott (*in* Wilson and Newell, 1937, p. 122), one plant, owned by the Muskogee Clay products Co., was in operation in the northern part of Muskogee. It had a capacity of 50,000 bricks per day and made common brick, rough red brick, paving brick, and all sizes of building tile. A second plant, owned by the same company, had been shut down for a number of years.

Although, to the writer's knowledge, no clay products are being manufactured at the present time in Muskogee County, suitable material for such use is widespread within the County. Thus conveniently located sites could, no doubt, be found by diligent searching, accompanied by appropriate analyzing and testing.

Sand and Gravel

The following quotation is from Bell (1959, p. 78).

> The channel and bars of the Arkansas River have provided abundant sand for use in construction and other purposes. One large sand company has equipment located at the south end of the bridge across the Arkansas River on Highway 69, and is dredging sand deposited by the Arkansas River.

Dott (*in* Wilson and Newell, 1937, p. 116) stated:

The gravel deposits reported are restricted to recent bars along the west bank of the Arkansas River, composed of material which was probably washed down by floods from the large deposits in the bed of Grand [Neosho] River. Data are available on only four such deposits, of which the one located in secs. 13, 14 and 24, T. 13 N., R. 19 E. . . . is the most important.

Water Resources

Muskogee County depends for its water supplies upon both ground water and surface water. Small supplies can be had from wells in most parts of the County, and some afford fairly large supplies. Upland wells produce from both sandstone and sandy shale. Production from many individual wells in shale is surprisingly large, in view of the low permeability of shales in general. However, the shales of Muskogee County are considerably fractured and are sufficiently indurated that the cracks stand open and probably increase both porosity and permeability. Individual wells of largest production are in the recent alluvium or in terrace deposits made by ancient streams; most maintain their output in dry weather. Surface supplies can be provided almost anywhere by building artificial ponds and lakes. In planning such reservoirs, the considerable surface evaporation must be taken into account; depth is as important as areal expanse. Assistance may be available from the County agricultural agent or from the County engineer. Really large supplies come from the Arkansas and Neosho (Grand) Rivers.

For a broad treatment of the water resources of the Muskogee County region, the reader is referred to an atlas entitled *Reconnaissance of the Water Resources of the Fort Smith Quadrangle, East-Central Oklahoma*, by Melvin V. Marcher of the U.S. Geological Survey. Muskogee County is included within the Oklahoma portion of the 1° by 2° quadrangle set, which was published in 1969 by the Oklahoma Geological Survey, in cooperation with the U.S. Geological Survey, as Hydrologic Atlas 1. The atlas consists of a set of four map sheets with text and tables; most of the maps are at a scale of 1:250,000. Each of the sheets treats, in turn, the geology of the quadrangle, the availability of ground water, the chemical quality of ground water, and the surface-water resources.

REFERENCES CITED

Adams, G. I., 1903, Zinc and lead deposits of northern Arkansas: U.S. Geological Survey Bulletin 213, p. 187-196.

Adams, G. I., Purdue, A. H., Burchard, E. F., and **Ulrich, E. O.,** 1904, Zinc and lead deposits of northern Arkansas: U.S. Geological Survey Professional Paper 24, 118 p.

Adams, G. I., and **Ulrich, E. O.,** 1905, Description of the Fayetteville quadrangle [Arkansas-Missouri]: U.S. Geological Survey Geologic Atlas, Folio 119, 6 p.

Bell, Walton, 1959, Surface geology of the Muskogee area, Muskogee County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 113 p.

Bowlby, D. C., 1968, Lithostratigraphy of the Morrow Formation (Lower Pennsylvanian), Tenkiller Ferry Reservoir area, northeastern Oklahoma: University of Oklahoma unpublished M.S. thesis, 151 p.

Branson, C. C., 1954, Marker beds in the Lower Desmoinesian of northeastern Oklahoma: Oklahoma Academy of Science Proceedings 1952, v. 33, p. 190-194.

_____1956, Pennsylvanian history of northeastern Oklahoma: Tulsa Geological Society Digest, v. 24, p. 83-86.

Branson, C. C., Huffman, G. G., Strong, D. M., and others, 1965, Geology and oil and gas resources of Craig County, Oklahoma: Oklahoma Geological Survey Bulletin 99, 109 p.

Brant, R. A., 1941, Stratigraphy of the Meramec and Chester series of Mayes County, Oklahoma: University of Tulsa unpublished M.S. thesis, 44 p.

Campbell, D. G., 1957, Geology of the Jamesville area, Muskogee and Okmulgee Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 91 p.

Chance, H. M., 1890, Geology of the Choctaw coal field: American Institute of Mining Engineers Transactions, v. 18, p. 653-661.

Chrisman, L. P., 1951, The geology of the Big Cabin Creek area, Craig County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 66 p.

Coleman, W. F., 1958, Surface geology of the Rentiesville area, Muskogee and McIntosh Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 100 p.

Dane, C. H., and **Hendricks, T. A.,** 1936, Correlation of Bluejacket sandstone, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 20, p. 312-314.

Dane, C. H., Rothrock, H. E., and **Williams, J. S.,** 1938, The Quinton-Scipio district, Pittsburg, Haskell, and Latimer Counties, *pt. 3 of* Geology and fuel resources of the southern part of the Oklahoma coal field: U.S. Geological Survey Bulletin 874-C, p. 151-253.

Dott, R. H., 1937, Miscellaneous mineral resources, *in* Wilson, C. W., Jr., and Newell, N. D., Geology of the Muskogee-Porum district, Muskogee and McIntosh Counties, Oklahoma: Oklahoma Geological Survey Bulletin 57, p. 116-153.

Drake, N. F., 1897, A geological reconnaissance of the coal fields of the Indian Territory: American Philosophical Society Proceedings, v. 36, p. 326-419.

Gould, C. N., Ohern, D. W., and **Hutchison, L. L.,** 1910, Proposed groups of Pennsylvanian rocks of eastern Oklahoma: Oklahoma State University Research Bulletin 3, 15 p.

Govett, R. W., 1957, The geology of the Cabaniss-Arpelar area, Pittsburg County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 60 p.

——1959, Geology of Wagoner County, Oklahoma: University of Oklahoma unpublished Ph.D. dissertation, 182 p.

Gregware, William, 1958, Surface geology of the McLain area, Muskogee County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 101 p.

Hare, B. D., 1969, Petrology of the Thurman Sandstone (Desmoinesian), Hughes and Coal Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 133 p.

Haugh, B. N., 1968, The biostratigraphy of the Morrow Formation (Pennsylvanian), Tenkiller Ferry Reservoir area, Oklahoma: University of Oklahoma unpublished M.S. thesis, 236 p.

Hayes, C. W., 1894, Chattanooga atlas sheet: description [Tennessee]: U.S. Geological Survey Geologic Atlas, Folio 6, 3 p.

Hayes, C. W., and **Ulrich, E. O.,** 1903, Description of the Columbia quadrangle [Tennessee]: U.S. Geological Survey Geologic Atlas, Folio 95, 6 p.

Hendricks, T. A., 1937, The McAlester district, Pittsburg, Atoka, and Latimer Counties, *pt. 1 of* Geology and fuel resources of the southern part of the Oklahoma coal field: U.S. Geological Survey Bulletin 874-A, p. 1-90.

——1939, The Howe-Wilburton district, Latimer and Le Flore Counties, *pt. 4 of* Geology and fuel resources of the southern part of the Oklahoma coal field: U.S. Geological Survey Bulletin 874-D, p. 255-300.

Hendricks, T. A., and **Parks, Bryan,** 1950, Geology of the Fort Smith district, Arkansas: U.S. Geological Survey Professional Paper 221-E, p. 67-94.

Henry, T. W., 1970, Conodont biostratigraphy of the Morrow Formation (Lower Pennsylvanian) in portions of Cherokee, Sequoyah, Muskogee, and Adair Counties, northeastern Oklahoma: University of Oklahoma unpublished M.S. thesis, 170 p.

——1973, Brachiopod biostratigraphy and faunas of the Morrow Series (Lower Pennsylvanian) of northwestern Arkansas and northeastern Oklahoma: University of Oklahoma unpublished Ph.D. dissertation, 515 p.

Howe, W. B., 1951, Bluejacket sandstone of Kansas and Oklahoma: American Association of Petroleum Geologists Bulletin, v. 35, p. 2087-2093.

Huffman, G. G., and others, 1958, Geology of the flanks of the Ozark Uplift, northeastern Oklahoma: Oklahoma Geological Survey Bulletin 77, 281 p.

Knechtel, M. M., 1949, Geology and coal and natural gas resources of northern Le Flore County, Oklahoma: Oklahoma Geological Survey Bulletin 68, 76 p.

Knechtel, M. M., and **Rothrock, H. E.,** 1935, Apparent recent crustal movement at western end of Ouachita Mountains, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 19, p. 1219-1225.

Lontos, J. T., 1952, The geology of the Coweta area, Wagoner, Muskogee, and Okmulgee Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 55 p.

Lowman, S. W., 1932, Lower and middle Pennsylvanian stratigraphy of Oklahoma east of the meridian and north of the Arbuckle Mountains [abstract]: Tulsa Geological Society Summaries and Abstracts 1932, Tulsa Daily World, December 19, 1932.

McCoy, A. W., 1921, A short sketch of the paleogeography and historical geology of the Mid-Continent oil district and its importance to petroleum geology: American Association of Petroleum Geologists Bulletin, v. 5, p. 541-584.

Manhoff, C. N., Jr., 1957, Geology of the Hitchita area, Okmulgee and McIntosh Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 50 p.

Marcher, M. V., 1969, Reconnaissance of the water resources of the Fort Smith quadrangle, east-central Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 1, 4 sheets, scale 1:250,000.

Marcou, Jules, 1855, Le terrain carbonifère dans l'Amérique du Nord: Archives des Sciences Physiques et Naturelles, v. 29, p. 95-117.

Meek, R. A., 1957, The geology of the Onapa—Council Hill area, Muskogee and McIntosh Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 67 p.

Miser, H. D., 1954, Geologic map of Oklahoma: Oklahoma Geological Survey and U.S. Geological Survey, scale 1:500,000.

Moore, C. A., 1947, The Morrow series of northeastern Oklahoma: Oklahoma Geological Survey Bulletin 66, 151 p.

Morgan, G. D., 1924, Geology of the Stonewall quadrangle, Oklahoma: Norman, Oklahoma, Bureau of Geology Bulletin 2, 248 p.

Nuttall, Thomas, 1821, A journal of travels into the Arkansas Territory during the year 1819: Philadelphia, T. H. Palmer, 296 p.

Oakes, M. C., 1953, Krebs and Cabaniss groups, of Pennsylvanian age, in Oklahoma: American Association of Petroleum Geologists Bulletin, v. 37, p. 1523-1526.

——1963, Geology of Okmulgee County, *pt. 1 of* Geology and water resources of Okmulgee County, Oklahoma: Oklahoma Geological Survey Bulletin 91, p. 1-80, 129-164.

Oakes, M. C., and **Knechtel, M. M.,** 1948, Geology and mineral resources of Haskell County, Oklahoma: Oklahoma Geological Survey Bulletin 67, 134 p.

Oakes, M. C., and others, 1967, Geology and mineral resources of McIntosh County, *pt. 1 of* Geology and petroleum of McIntosh County, Oklahoma: Oklahoma Geological Survey Bulletin 111, p. 1-40, 68-85.

Oklahoma Geological Survey, 1917, A discussion of the oil and gas fields, and undeveloped areas of the state, by counties, *pt. 2 of* Petroleum and natural gas in Oklahoma: Oklahoma Geological Survey Bulletin 19, 536 p.

Penrose, R. A. F., Jr., 1891, Manganese, its uses, ores, and deposits: Arkansas Geological Survey, Annual Report 1890, v. 1, 642 p.

Pierce, W. G., and **Courtier, W. H.**, 1938, Geology and coal resources of the southeastern Kansas coal field, in Crawford, Cherokee, and Labette Counties, with a report on Pennsylvanian invertebrate faunas of southeastern Kansas, by James Steele Williams: Kansas Geological Survey Bulletin 24, 122 p.

Purdue, A. H., 1907, Description of the Winslow quadrangle [Arkansas—Indian Territory]: U.S. Geological Survey Geologic Atlas, Folio 154, 6 p.

Purdue, A. H., and **Miser, H. D.**, 1916, Description of the Eureka Springs and Harrison quadrangles, Ark.-Mo.: U.S. Geological Survey Geologic Atlas, Folio 202, 22 p.

Reed, E. W., **Schoff, S. L.**, and **Branson, C. C.**, 1955, Ground-water resources of Ottawa County, Oklahoma: Oklahoma Geological Survey Bulletin 72, 203 p.

Rowland, T. L., 1970, Lithostratigraphy and carbonate petrology of the Morrow Formation (Pennsylvanian), Braggs-Cookson area, northeastern Oklahoma: University of Oklahoma unpublished Ph.D. dissertation, 354 p.

Saitta B., Sandro, and **Visher, G. S.**, 1968, Subsurface study of the southern portion of the Bluejacket delta, *in* Visher, G. S. (editor), A guidebook to the geology of the Bluejacket-Bartlesville Sandstone, Oklahoma—AAPG and SEPM Annual Meeting, Oklahoma City, 1968: Oklahoma City Geological Society, p. 52-68.

Searight, M. V., and others, 1953, Classification of Desmoinesian (Pennsylvanian) of northern Mid-Continent: American Association of Petroleum Geologists Bulletin, v. 37, p. 2747-2749.

Sellards, E. H., 1935, The Texas-Oklahoma earthquake of April 11, 1934: University of Texas Bulletin 3501, p. 259-266.

Simonds, F. W., 1891, The geology of Washington Co., Arkansas: Arkansas Geological Survey, Annual Report 1888, v. 4, 148 p.

Snider, L. C., 1914, The geology of east-central Oklahoma with special reference to the occurrence of petroleum and natural gas: Oklahoma Geological Survey Bulletin 17, 25 p.

____1915, The geology of a portion of northeastern Oklahoma: Oklahoma Geological Survey Bulletin 24, p. 7-65.

Soyster, H. B., and **Taylor, T. G.**, 1928, Oil and gas in Oklahoma; oil and gas geology of Muskogee County: Oklahoma Geological Survey Bulletin 40-FF, 28 p.

Stewart, Francis, Jr., 1949, A map of portions of Muskogee and McIntosh Counties, Oklahoma, with special reference to the Inola limestone and Secor coal: University of Oklahoma unpublished M.S. thesis, 81 p.

Stine, J. G., 1958, Geology of southern Muskogee County, Oklahoma: University of Oklahoma unpublished M.S. thesis, 89 p.

Taff, J. A., 1899, Geology of the McAlester-Lehigh coal field, Indian Territory: U.S. Geological Survey 19th Annual Report, pt. 3, p. 423-456.

____1901, Description of the Coalgate quadrangle [Indian Territory]: U.S. Geological Survey Geologic Atlas, Folio 74, 6 p.

____1902, Description of the Atoka quadrangle [Indian Territory]: U.S. Geological Survey Geologic Atlas, Folio 79, 8 p.

____1906, Description of the Muscogee quadrangle [Indian Territory]: U.S. Geological Survey Geologic Atlas, Folio 132, 7 p.

Taff, J. A., and **Adams, G. I.**, 1900, Geology of the eastern Choctaw coal field, Indian Territory: U.S. Geological Survey 21st Annual Report, pt. 2, p. 257-311.

Thom, W. T., Jr., 1935, Coal map of the Stigler-Poteau district, Pittsburg, Haskell, and Le Flore Counties, Oklahoma: U.S. Geological Survey unnumbered map, preliminary edition.

Tillman, J. L., 1952, Geology of the Tiawah area, Rogers and Mayes Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 65 p.

Visher, G. S., 1968, Depositional framework of the Bluejacket-Bartlesville Sandstone, *in* Visher, G. S. (editor), A guidebook to the geology of the Bluejacket-Bartlesville Sandstone, Oklahoma—AAPG and SEPM Annual Meeting, Oklahoma City, 1968: Oklahoma City Geological Society, p. 32-51.

Weaver, O. D., Jr., 1954, Geology and mineral resources of Hughes County, Oklahoma: Oklahoma Geological Survey Bulletin 70, 150 p.

Webb, F. S., 1957, Surface geology of the Eufaula-Texanna area, McIntosh and Pittsburg Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 60 p.

____1960, Surface geology of the Eufaula-Texanna area, McIntosh and Pittsburg Counties, Oklahoma: Shale Shaker, v. 10, no. 8, p. 2-14.

Whipple, A. W., 1855, Report of explorations for a railway route, near the thirty-fifth parallel of latitude, from the Mississippi River to the Pacific Ocean: U.S. 33d Congress, 1st Session, House Executive Document 129, v. 18, pt. 2, p. 1-87.

Wilson, C. W., Jr., 1935, Age and correlation of Pennsylvanian surface formations and of oil and gas sands of Muskogee County, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 19, p. 503-520.

Wilson, C. W., Jr., and **Newell, N. D.**, 1937, Geology of the Muskogee-Porum district, Muskogee and McIntosh Counties, Oklahoma: Oklahoma Geological Survey Bulletin 57, 184 p.

Wilson, L. R., 1976, Palynological evidence for the origin of the Atoka Formation (Pennsylvanian) rocks in the type area [abstract]: Geological Society of America Abstracts with Programs, v. 8, p. 72-73.

APPENDIX

Measured Stratigraphic Sections

Thickness (feet)

1

Sec. 4, T. 10 N., R. 19 E. Measured from south roadside ditch at intersection of south line and electric power line ¼ mile west from SE cor., westward to top of escarpment, by J. G. Stine.

Boggy Formation

Sandstone: tan, fine-grained; lower part massive and channeled at base; upper part thin bedded and eroded at top (Bluejacket) 16.0

Savanna Formation

Shale: gray, fissile 4.8
Limestone: gray; a local stringer 0.1
Shale: gray, fissile 176.0
Sandstone: tan, silty, thin-bedded 9.0
Shale: gray; contains limestone stringers 7.8
Limestone: gray, fossiliferous; abundant *Marginifera* (Doneley) 0.3
Shale: gray; contains limestone stringers 3.0
Coal (Rowe) 0.3
Shale: blue-gray, fissile; base covered 0.5

Total 217.8

2

Sec. 22, T. 10 N., R. 19 E. Measured from 300 feet west of NE cor. westward to N¼ cor., by J. G. Stine.

Savanna Formation

Sandstone, poor exposure; forms a ridge, estimated (Spiro) 1.5
Shale: gray, fissile, silty 15.9
Limestone: gray; weathers reddish brown; dense, hard, medium-crystalline, crinoidal (Sam Creek) 0.3
Shale: gray, fissile, soft 29.0
Limestone: dense, hard, coquina of *Marginifera* (Spaniard) 0.2

McAlester Formation

Shale: gray, fissile, silty; base covered 2.0

Total 48.9

3

Sec. 22, T. 10 N., R. 19 E. Measured in east bank of creek about 200 feet south of access road to Eufaula dam in north-central part of sec., by J. G. Stine.

Thickness (feet)

Savanna Formation

Shale: gray, fissile, soft 2.0
Concretionary zone 0.1
Shale: gray, fissile, soft, organic; lower part calcareous, fossiliferous 0.8
Limestone: gray; weathers brown; fossiliferous; crinoid stems and *Spirifer* predominate (Sam Creek) 0.1
Shale: light-gray; weathers brown; fossiliferous; crinoid stems and *Spirifer* predominate 0.4
Shale: black, organic 2.0
Coal 0.2
Shale: gray, soft, fissile; grades upward into organic shale 3.0

Total 8.6

4

Secs. 26 and 35, T. 10 N., R. 19 E. Composite of sections measured in SW¼ of 26 and NW¼ of 35, by J. G. Stine.

McAlester Formation

Sandstone: tan, medium-grained, thin-bedded; lower part ripple marked and well indurated (Keota) 31.7
Shale: light-gray; weathers tan; fissile, pyritic 121.4
Sandstone: light-gray; weathers tan; fine-grained, thin-bedded, finely cross-bedded, ripple-marked (Tamaha) 1.1
Shale: light-gray, fissile to blocky; upper part silty; contains clay-ironstone concretions; grades downward into organic shale with a molluscan fauna in lower part 28.0
Coal 0.25
Shale: gray, organic, somewhat blocky 4.0
Coal (Stigler) 1.5
Underclay: gray, soft 0.1

Total 188.1

5

Sec. 36, T. 10 N., R. 19 E. Measured from approximately 1,800 feet north from cor. along west section-line road to top of escarpment, by J. G. Stine.

McAlester Formation

Sandstone: tan, medium-grained, well-indurated, thick-bedded at base; grades vertically into thinner beds (Tamaha) 24.3

	Thickness (feet)
Shale: gray, fissile; contains clay-ironstone concretions	65.3
Siltstone: thin-bedded	1.5
Shale: gray, fissile	5.9
Siltstone: reddish-brown, hard, fossiliferous	0.1
Shale: light-gray, fissile to somewhat blocky; interbedded with siltstone and grades vertically into siltstone	11.4
Sandstone: greenish-gray; weathers tan; fine- to medium-grained, thin- to thick-bedded (Cameron-Lequire)	13.5
Shale: gray, fissile; base covered	23.0
Total	145.0

6

Sec. 4, T. 10 N., R. 20 E. Measured from stream bed at bridge near E¼ cor. westward ¾ mile to top of escarpment, by J. G. Stine.

	Thickness (feet)
McAlester Formation	
Sandstone: tan, medium-grained, massive, hard (Warner)	18.0
Shale: gray, fissile; clay-ironstone concretionary zone 4 feet below top (McCurtain)	36.2
Covered: probably shale	76.0
Hartshorne Formation	
Sandstone: tan, medium-grained, thick-bedded	1.5
Shale: gray, tan, silty	18.4
Sandstone: thin-bedded, fine-grained, hard; finely cross-bedded	18.2
Total	168.3

7

Sec. 18, T. 10 N., R. 20 E. Measured from ¼ mile east of SW cor. westward to top of escarpment, by J. G. Stine.

	Thickness (feet)
McAlester Formation	
Sandstone: greenish-gray, medium-grained, thin-bedded; weathers tan (Cameron-Lequire)	5.0

8

Sec. 20, T. 10 N., R. 20 E. Measured from vicinity of W¼ cor. northward to top of escarpment, by J. G. Stine.

	Thickness (feet)
McAlester Formation	
Sandstone: tan, massive, medium-grained, friable; grades downward into shale (Warner)	30.0
Shale: gray, fissile; contains phosphatic nodules and clay-ironstone concretions (McCurtain)	116.0
Shale: silty; clay-ironstone concretionary zone at base	4.9
Shale: gray, fissile; base covered	31.0
Total	181.9

9

Secs. 4 and 9, T. 11 N., R. 19 E. Measured from 400 feet north of SW cor. sec. 4, south to top of escarpment, by J. G. Stine.

	Thickness (feet)
Atoka Formation	
Sandstone: tan, thin-bedded, fine-grained, platy	11.6
Shale: gray to tan, silty to sandy, fissile; grades upward into sandstone	20.5
Clay-ironstone concretions: hard, black; weathers concentrically	0.3
Shale: bluish-gray, ferruginous, soft, fissile	11.6
Total	44.0

10

Sec. 22, T. 11 N., R. 19 E. Measured in quarry ¼ mile east from SW cor., on north side of road, by J. G. Stine.

	Thickness (feet)
McAlester Formation	
Sandstone: medium-grained, slabby to massive, tan, hard (Warner)	10.2
Sandstone: light-gray, medium- to fine-grained, slabby; purple banding	6.0
Shale	3.8
Sandstone: massive; upper part light green from iron silicate; lower part light gray	23.6
Covered: not measured	—
Total	43.6

11

Sec. 27, T. 11 N., R. 19 E. Measured along stream southeastward from its intersection with west line to its confluence with tributary from south in SE¼, by J. G. Stine.

	Thickness (feet)
Savanna Formation	
Shale: bluish-gray, fissile, soft; concretionary bed of clay ironstone 0.2 feet thick at top	2.0
Limestone: gray, dense; coquina of *Marginifera* (Spaniard)	0.25
McAlester Formation	
Coal	0.3
Shale: bluish-gray, silty, blocky	2.1
Sandstone: greenish-gray, fine-grained, thin-bedded, calcareous; weathers tan (Keota)	0.6

	Thickness (feet)
Shale: bluish-gray, fissile; contains silt stringers; grades upward into siltstone	4.6
Shale: greenish-gray, fissile, micaceous	0.5
Limestone: gray to brownish-red; upper part hard and dense; lower part silty and shaly; abundant *Marginifera*; calcium carbonate dissolves, leaving siltstone molds of fossils that show both internal and external structures	0.7
Shale: light-bluish-gray, fissile; contains thin siltstone stringers; estimated	20.0
Sandstone: olive-green, fine-grained, silty, hard, slabby; lower part contains thin layers with shale partings (Tamaha)	7.3
Shale: light-gray, fissile to blocky; partly covered; estimated	20.0
Coal (Stigler)	1.5
Total	59.8

12

Sec. 29, T. 11 N., R. 19 E. Measured from vicinity of SW cor. westward to top of escarpment, by J. G. Stine.

McAlester Formation	
Sandstone: tan, medium-grained; weathers into irregular boulders (Warner)	63.0
Covered: probably shale	42.0
Hartshorne Formation	
Sandstone: greenish-brown, fine-grained, thin-bedded; fine cross-bedding, base and top gradational; estimated	4.0
Atoka Formation	
Covered: probably shale	135.0
Total	244.0

13

Sec. 2, T. 11 N., R. 20 E. Measured from NE cor. south to top of escarpment, by J. G. Stine.

	Thickness (feet)
Hartshorne Formation	
Siltstone and shale: Interbedded, thinly laminated; grades into sandstone below; shale is gray and fissile; siltstone is tan; top eroded	11.8
Sandstone: fine-grained, massive, reddish-brown; composed entirely of fossil casts of plants that contain coaly residues	1.3
Atoka Formation	
Shale: gray, fissile	3.3
Sandstone: fine-grained, greenish-gray, hard, concretionary	0.75
Shale: gray, fissile to blocky	10.4
Total	27.6

14

Sec. 4, T. 11 N., R. 20 E. Measured in bank of tributary to South Fork in SW¼NW¼, by J. G. Stine.

McAlester Formation	
Siltstone and shale: interbedded, thinly laminated; shale is organic and pyritic (Warner)	15.0
Shale: gray, organic, pyritic	1.1
Coal	0.8
Underclay	0.1
Sandstone: only upper part exposed; not measured	—
Total	17.0

15

SW¼ sec. 18, T. 11 N., R. 20 E., Trojan Coal Pit. Adapted from Wilson and Newell (1937, p. 160) by J. G. Stine.

McAlester Formation	
Sandstone: flaggy, rippled (Tamaha)	4.0
Shale: sandy above; carbonaceous and flaky below; molluscan fauna in lower part	45.0
Limestone: carbonaceous; contains pelecypods	0.1
Coal (Stigler)	1.5
Shale: hard, silty; underclay at top; not measured	—
Total	50.6

16

Sec. 18, T. 11 N., R. 21 E. Measured from bridge near W¼ cor. south to top of escarpment, by J. G. Stine.

Hartshorne Formation	
Sandstone: greenish-gray, fine-grained, thinly laminated; weathers tan	58.0
Atoka Formation	
Shale: gray, silty	96.0
Sandstone: tan, medium-grained, thinly laminated	2.5
Shale: gray, silty	51.9
Covered: probably shale	26.5
Total	234.9

Thickness (feet)

17

Sec. 9, T. 12 N., R. 19 E. Measured along road in SE¼SE¼, by William Gregware.

McAlester Formation

Sandstone: light-gray to brown, medium-grained, ferruginous, friable; upper part massive; lower part interbedded with shale and siltstone; caps prominent escarpment (Warner) 25.0

18

Sec. 16, T. 12 N., R. 19 E. Measured along south line, by William Gregware.

McAlester Formation

Warner Sandstone: at type locality, light-brown, massive, friable; weathers brown 24.0

Shale (McCurtain): covered 180.0

Hartshorne Formation

Sandstone: very fine-grained, massive, hard; contains plant fossils; not well exposed, but forms a bench 1.5

Atoka Formation

Covered: probably shale 170.0

16 Sandstone: fine-grained, hard; forms a small bench 2.0

Shale: bluish-gray; mostly covered 120.0

12 Sandstone: brown, very fine-grained, massive in upper part; contains some interbedded shale 24.0

Covered: probably shale 45.0

11 Sandstone: greenish-gray, fine-grained, massive 6.0

Total 572.5

19

Sec. 19, T. 12 N., R. 19 E. Measured in NW¼NW¼, by William Gregware.

Boggy Formation

6 Sandstone (Bluejacket): gray to brown, medium-grained, massive, cross-bedded; contains some plant fossils and caps a prominent escarpment 20

Savanna Formation

Shale: partly covered, greenish-gray, silty; contains scattered iron concretions 113.0

Clay ironstone: calcareous, fossiliferous, concretionary 0.3

Shale: dark-gray, carbonaceous, platy 45.0

Limestone: gray, fossiliferous; contains *Neospirifer* and other forms (Doneley) 0.2

Coal (Rowe): exposed at strip pits 0.7

Total 179.2

Thickness (feet)

20

Sec. 30, T. 12 N., R. 20 E. Measured up scarp in NE¼, by William Gregware.

McAlester Formation

Sandstone (Warner): brown, medium-grained, massive; caps prominent escarpment 18.0

Shale (McCurtain): mostly covered, dark-gray; contains scattered clay-ironstone concretions 177.0

Hartshorne Formation

Coal (Hartshorne) 1.0

Covered: about 4.5

Siltstone: interbedded with shale; contains plant fossils; about 10.0

Total 210.5

21

Sec. 31, T. 12 N., R. 20 E. Measured along north line of NW¼, by William Gregware.

McAlester Formation

Sandstone (Warner): light-brown-gray, medium-grained, well-sorted, friable, not well-bedded; contains some ironstone concretions 12.0

Shale (McCurtain): covered 174.0

Hartshorne Formation

Sandstone: light-gray, very fine-grained, thin-bedded; contains numerous plant fossils 3.0

Atoka Formation

Covered: probably shale 150.0

16 Sandstone: gray, fine-grained; contains some carbonaceous material; weathers rubbly 3.5

Total 342.5

22

Sec. 35, T. 12 N., R. 20 E. Measured at strip pits adjacent to bridge across Dirty Creek, in east-central part, by William Gregware.

McAlester Formation

Shale (McCurtain): blue, silty; contains ironstone concretions; top covered 4.0

Siltstone: ferruginous, concretionary 0.2

Shale: greenish-gray and dark-gray, silty, weathers fissile near top 3.2

Hartshorne Formation

Coal (Upper Hartshorne) 1.0

Underclay: plastic 0.1

Siltstone: blue-gray, shaly, poorly bedded; contains numerous plant fossils 0.6

Shale: blue-gray, silty, with some interbedded siltstone 2.0

	Thickness (feet)
Siltstone: greenish-gray, thin-bedded, shaly, extremely micaceous	1.6
Atoka Formation	
Shale: well-bedded, greenish-gray to dark-gray, silty, numerous concretions; base not exposed	12.0
Total	24.7

23

Sec. 12, T. 13 N., R. 15 E. Measured in bed of stream, vicinity of NE cor., by R. A. Meek.

Senora Formation	
Shale: gray to tan; contains ironstone concretions at top	10.0
Shale: black; lower part blocky and hard, upper part fissile	8.0
Limestone: dark-gray to black, fossiliferous; weathers reddish brown (Tiawah?)	0.3
Shale: black, fissile	1.0
Clay-ironstone bed	0.3
Shale: black, fissile	13.0
Coal (probably Tebo)	0.9
Underclay: gray	3.0
Total	36.5

24

Sec. 3, T. 13 N., R. 16 E. Measured from NE cor. southwestward to top of sandstone ridge, by R. A. Meek.

Boggy Formation	
5 Sandstone: tan, thin-bedded to platy, fine-grained; weathers brown	15.0
Covered: probably shale	68.0
4a Sandstone: not measured	—
Total	83.0

25

Secs. 5 and 8, T. 13 N., R. 17 E. Measured from 660 feet north of SE cor. sec. 8 northward to NE cor. sec. 5, by W. F. Coleman.

	Thickness (feet)
Boggy Formation	
5 Sandstone: brown, medium- to fine-grained, silty and shaly, friable; small brown splotches on broken surfaces; probably contains covered shale beds; poorly exposed	33.0
Shale, silt, and sandstone: alternating thin beds	19.0
Covered: probably shale	94.0
3a Sandstone: brown, fine-grained, thin-bedded, cross-bedded, slabby; micaceous partings; probably contains several zones of soft siltstone; grades into brown siltstone at top	10.0
Siltstone: light-brown, soft, thin-bedded	5.0
Covered: probably shale	54.0
Total	215.0

26

Sec. 13, T. 13 N., R. 17 E. Measured in SE¼ of NW¼, by Francis Stewart, Jr.

Boggy Formation	
Limestone (Inola)	0.8
Covered: shale; estimated	6.0
Sandstone: not measured (Crekola?)	—
Total	6.8

27

Sec. 18, T. 13 N., R. 17 E. A composite of several exposures in small dry wash north of stream in SE¼, near abandoned coal pit, measured by W. F. Coleman.

Boggy Formation	
Shale: black, fissile, soft, very carbonaceous, weathered; limonite stains on partings	0.15
Coal: covered by alluvium, probably not full thickness	1.2
Shale: black, fissile; limonite stains on partings	0.15
Coal	0.05
Shale: dark-gray, fissile to blocky	0.75
Shale: black, fissile; limonite stains on partings	0.1
Coal	0.3
Shale: black, fissile; limonite stains on partings	0.01
Sandstone: gray, silty, ripple-marked, cross-bedded, channeled; grades vertically and laterally into laminated siltstone and sandstone; contains abundant carbonized plant debris; not measured	—
Total	2.7

Note: This is typical of coal exposures in this area.

28

Sec. 8 [7?], T. 13 N., R. 18 E. Measured in stream in NE¼, by W. F. Coleman.

	Thickness (feet)
Boggy Formation	
Shale: dark-gray, fissile; contains small nodules; mostly covered; not measured	—
Limestone: dark-gray, hard, fossiliferous (Inola)	0.6
Shale: carbonaceous; much weathered	0.08
Siltstone and shale: brown and gray	15.0
Sandstone: brown, fine-grained, soft; contains black iron-stained partings and scattered small concretions; grades upward into siltstone and shale	4.0
Siltstone: brown to light-gray, thin-bedded	1.0
Shale: brown; grades into shale upward	1.7
Shale: light-gray and dark-gray	5.0
Sandstone: gray, hard, well-indurated, slabby; most continuous part of this essentially sandstone unit	18.0
Total	45.46

29

Secs. 9 and 10, T. 13 N., R. 18 E. Along road on north side and at Lattimore Ranch. Measured by W. F. Coleman.

	Thickness (feet)
Boggy Formation	
Sandstone: brown, medium- to fine-grained; lower and upper parts thin bedded; contains fossil imprints of plants and limonite concretions; limonite stains on weathered surfaces; top covered (Crekola)	6.0
Shale: gray, blocky to fissile; grades upward into brown shale and siltstone	11.0
Shale: black, carbonaceous	0.25
Coal (probably Secor)	0.75
Shale: yellow-brown	0.25
Shale: black, carbonaceous, limonitic	0.07
Shale: yellow-brown	0.17
Siltstone: light-gray	0.25
Shale: blocky to fissile, nonfossiliferous; splotched with limonite stains; contains irregular concretionary beds	25.0
Sandstone: brown, soft, cross-bedded, irregularly bedded; variable grain size; caps high escarpment (Bluejacket)	41.0
Total	84.7

30

Sec. 13, T. 13 N., R. 18 E. Measured approximately 400 feet west of bridge in SE¼NE¼, along stream, by W. F. Coleman.

	Thickness (feet)
Savanna Formation	
Limestone: gray, fossiliferous; weathers red; a much-weathered remnant (Spaniard)	0.17
McAlester Formation	
Shale: brown; weathered to a putty-like clay	0.45
Coal	0.4
Shale: light-gray, soft, clayey	0.66
Shale: brown; grades into gray siltstone at base	21.0
Sandstone: gray, extremely fine-grained, thin-bedded, ripple-marked, slabby; grades into gray shale at base (Keota)	11.7
Shale: gray; upper part silty	8.5
Total	42.9

31

Sec. 13, T. 13 N., R. 18 E. Measured from 150 feet south of bridge on east line south to top of hill, by W. F. Coleman.

McAlester Formation	
Shale: gray, blocky to fissile; contains thin streaks of brown shale	4.3
Limestone: fossiliferous, concretionary	0.4
Shale: gray, fossiliferous	0.66
Siltstone: reddish-gray; grades upward into limestone	0.56
Siltstone: brown, fissile	0.7
Coal	0.7
Shale: brown	0.15
Coal	0.04
Shale:	0.1
Siltstone: upper 2 feet brown and soft; lower 3 feet brown to gray, hard, resistant (Tamaha?)	5.0
Shale: gray, fissile; contains thin concretionary beds	36.5
Coal (Stigler)	0.75
Sandstone: light-gray to brown, soft, thin-bedded, ripple-marked; contains carbonized plant impressions (Cameron-Lequire)	4.0
Shale: gray, fissile	90.7
Siltstone: light-brown, thin-bedded; contains thin clay-ironstone concretionary beds	41.2
Sandstone: buff to brown, cross-bedded, medium-hard; contains a few small ironstone concretions; not measured (Warner)	—
Total	185.7

32

Sec. 24, T. 13 N., R. 18 E. Measured from Keefeton fault in vicinity of NE cor. to base of Warner Sandstone Member in vicinity of SW cor., by W. F. Coleman.

	Thickness (feet)
Sandstone (Warner): not measured	—
Shale: brown, fissile to blocky, soft	10.0
Concretonary bed: dark-brown, silty, fossiliferous	0.5
Sandstone: buff, silty, soft	0.6
Shale: brown, blocky to fissile; silty in part; contains concretionary beds; mostly covered	60.0
Covered: probably shale	178.0
Total	249.1

33

Sec. 26, T. 13 N., R. 18 E. Measured in stream bank on south line of SW¼SE¼, by W. F. Coleman.

	Thickness (feet)
McAlester Formation	
Sandstone: buff to brown, soft, jointed; some zones silty; grades into siltstone and shale at top (upper part of Warner)	8.0
Shale: brown, silty	3.85
Coal: contains silt partings and is silty at base	0.75
Shale: brown to gray	9.0
Sandstone (lower part of Warner): not measured	—
Total	21.6

34

Sec. 28, T. 13 N., R. 18 E. Measured along bank of stream in NE¼SE¼, by W. F. Coleman.

	Thickness (feet)
McAlester Formation	
Sandstone: brown, medium- to fine-grained, thin-bedded to irregularly bedded; some beds finely cross-bedded; thin shale partings (upper part of Warner); not measured	—
Shale: brown	0.6
Shale: black, thinly laminated	0.16
Coal	0.75
Clay: gray	0.75
Shale: brown, clayey	0.08
Shale: gray, clayey	0.5
Shale: gray to black or brown; contains coal seams, about ¼-inch thick, and carbonized plant debris throughout; also thin, discontinuous pyritic, concretionary beds	7.0
Sandstone (lower part of Warner): not measured	—
Total	9.8

35

Sec. 31, T. 13 N., R. 18 E. Measured up escarpment east of Bluejacket Sandstone outcrop in NE¼SE¼, by W. F. Coleman.

	Thickness (feet)
Boggy Formation	
Sandstone: brown, coarse-grained; contains clay-ironstone concretions; not measured (Bluejacket)	—
Savanna Formation	
Sandstone: thin-bedded; interbedded with shale and siltstone	17.0
Shale: brown	53.0
Shale: black, fissile; weathers brown	15.0
Concretionary bed: sparsely fossiliferous (Doneley)	0.3
Shale: black, fissile	44.0
Coal (Rowe)	0.3
Clay: yellow-brown	0.0
Clay: light-gray	1.1
Siltstone: brown to gray; interbedded with shale	0.55
Covered: probably shale	18.0
Siltstone: concretionary, fossiliferous	0.3
Siltstone: gray, blocky	1.0
Limestone: red, shaly, soft; much weathered (Spaniard)	0.9
McAlester Formation	
Clay: gray	0.25
Shale: brown-gray; mostly covered; estimated	25.0
Shale: gray, extremely fossiliferous	4.0
Total	180.7

36

Sec. 7, T. 13 N., R. 19 E. Measured along stream in NW¼, by William Gregware.

	Thickness (feet)
Savanna Formation	
Limestone (Spaniard: gray, shaly, very fossiliferous; weathers light brownish gray with smooth surfaces	1.4
McAlester Formation	
Shale: greenish-gray; fossiliferous especially near top	2.2
Coal: shaly, smutty	0.1
Underclay: blue-gray, plastic; slightly stained by limonite in some places	1.0
Covered: probably shale	1.5
Sandstone: light-brown, fine-grained; contains, at some places, numerous molds of *Lepidodendron* and other plant fossils (Keota)	4.0
Total	10.2

37

Sec. 9, T. 13 N., R. 19 E. Measured along west line from NW cor. south to top of hill, by William Gregware.

	Thickness (feet)
McAlester Formation	
Sandstone: light-brown, fine-grained, micaceous, flaggy (Keota)	3.5

	Thickness (feet)
Shale: greenish-gray, silty; contains some plastic clay and some carbonaceous zones	28.0
Limonite: probably deeply weathered limestone, red-brown, fossiliferous	0.5
Covered: probably shale	11.0
8 Siltstone: olive-green, flaggy, ripple-marked; makes a prominent bench	8.0
Shale: blue-green, silty	9.0
Shale: black, carbonaceous; probably represents a coal horizon	0.1
Shale: green-gray; plastic when wet	5.8
7 Siltstone: greenish-gray, thin-bedded; interbedded with shale; lower 3 feet makes a bench	11.0
Shale: greenish-gray, slightly silty; grades upward into blue-gray shale with thinly interbedded siltstone	17.0
Covered: probably shale	34.0
Siltstone (Tamaha): olive-green, ferruginous, thin-bedded; makes a small bench	3.0
Covered: probably shale; estimated	29.0
Coal (Stigler)	0.2
Total	160.1

38

Sec. 18, T. 13 N., R. 19 E. Measured along bank of stream in NW¼, by William Gregware.

Savanna Formation	
Shale: contains some thin-bedded siltstone zones; covered above	2.0
Shale:greenish-gray; weathers fissile	5.0
Limestone (Sam Creek): dark-gray, finely crystalline, ferruginous; weathers brown; fossiliferous; *Neospirifer dunbari, Marginifera muricatina, Composita subtilita, Mesolobus mesolobus, Punctospirifer* sp., *Linoproductus* sp., *Lophophyllidium* sp., and crinoid stems. Specimens of *Marginifera* are very abundant; the crinoids are very robust	0.3
Shale: dark-gray, calcareous, coquinal; same fossils as above	0.4
Limestone: dark-gray, ferruginous, hard; weathers brown; same fossils as above	0.2
Shale: dark-gray to greenish-gray, fossiliferous, especially near top; same fossils as above; scattered ironstone concretions	7.0
Total	14.9

39

Sec. 18, T. 13 N., R. 19 E. Measured northward along west line from base of Warner Sandstone to Spaniard Creek, by William Gregware.

	Thickness (feet)
Savanna Formation	
Limestone (Spaniard): dark-gray, shaly, fossiliferous	0.4
McAlester Formation	
Covered: probably shale; estimated	25.0
Siltstone: interbedded with shale; siltstone is flaggy, well ripple marked, and contains some limy zones (Keota)	20.0
Shale: greenish-gray, silty	11.0
Siltstone: thinly interbedded with shale; makes a low bench	4.1
Shale: greenish- and bluish-gray; weathers fissile; in part is thinly interbedded with thin-bedded siltstone; partly covered	41.5
Siltstone (Tamaha); interbedded with greenish-gray shale; contains scattered ironstone concretions; makes a low bench; about	5.0
Shale: green and blue-gray; contains scattered ironstone concretions; partly covered	31.0
Coal (Stigler)	0.8
Underclay: plastic	1.0
Siltstone (Cameron): brown, platy; makes a small bench	5.0
Shale: silty; mostly covered	130.0
Sandstone (Warner): light-brown, medium-grained, massive, poorly exposed; estimated	30.0
Covered: probably shale; not measured	—
Total	304.8

40

Greenleaf Dam Section

Sec. 2, T. 13 N., R. 20 E. Measured by C. A. Moore (1947, p. 71-72).

Atoka Formation	
Covered, sandy soil	64.0
Sandstone: light gray to yellow brown, medium grained; thin-bedded	8.0
Bloyd Formation	
Covered	12.0
Shale: blue gray, fissile, limonite concretions	10.0
Limestone: brown gray, fine even crystalline; weathers smooth and light blue splotched, brittle	3.5
Limestone: at base gray to brown, medium; thin-bedded	16.8
Shale, poorly exposed: blue gray, fissile, limonite concretions	15.2
Limestone: blue gray, coarse, iron stained red; uneven and thin-bedded, cross-bedded	13.2
Shale: blue gray, fissile, limonite concretions	1.0
Limestone, conglomeratic: brown gray, fine medium matrix; weathers sandy; fossiliferous, *Pleurodictyum (Michelinia)*, cephalopods; carries limonite pebbles with trace phosphate	1.0

	Thickness (feet)
Shale: poorly exposed	3.5
Limestone: blue gray, very coarse; uneven bedded; weathers granular and thin-bedded; crinoidal	5.6
Shale: blue gray, fissile, limonite concretions; few covered intervals	33.4
Hale Formation	
Limestone: blue gray in lower part and gray in upper half; thin-bedded in lower half	12.0
Shale: calcareous, buff	0.5
Limestone, very sandy: gray, earthy to fine crystalline; weathers sandy and iron stained	0.5
Shale: blue gray, fissile, limonite concretions	1.5
Limestone: blue gray, fine medium; weathers thin-bedded, spalls off and is uneven bedded; crinoid stems replaced by orange calcite	3.5
Limestone: blue gray, very coarse crystalline; granular and cross-bedded; fossiliferous, crinoidal	5.0
Sandstone, calcareous: medium grained; weathers pitted and cavernous. Seems to grade into limestone above	3.0
Total	213.2

41

Bluffs Section

Sec. 26, T. 13 N., R. 20 E. Measured by C. A. Moore (1947, p. 72-73).

	Thickness (feet)
Atoka Formation	
Covered to top of hill	26.0
Sandstone: thin-bedded, forms cliff	6.0
Covered	14.0
Sandstone: massive bedded	3.0
Covered	19.0
Sandstone: yellow brown, coarse grained; cross-bedded, thin- to massive-bedded	6.0
Sandstone, calcareous: buff to gray, medium to fine, even grained; thin-bedded; weathers buff brown, calcareous	4.0
Bloyd Formation	
Limestone: gray, very coarse; uneven bedded and cross-bedded; weathers granular. Upper 1-foot fine crystalline and weathers rubbly	6.0
Shale: poorly exposed	20.0
Limestone: poorly exposed	2.0
Shale	7.0
Limestone: poorly exposed	1.0
Shale	6.0
Limestone, poorly exposed: rubbly limestone pebbles on slope, blue gray with greenish lenses; fossiliferous	2.0
Shale: poorly exposed	9.0
Limestone: gray with greenish streaks, sublithographic; weathers smooth and in big pittings	3.0
Shale: poorly exposed	2.0
Limestone, few shale breaks; brown to brown gray with greenish lenses, very coarse; uneven-bedded; weathers fluted; coarsely crinoidal	14.0
Limestone: gray with greenish argillaceous streaks, sandy; weathers rubbly	2.0
Shale: poorly exposed	12.0
Limestone: very rubbly	4.0
Shale: poorly exposed	2.0
Limestone: brown gray, fine even crystalline; uneven bedded; weathers rubbly	10.0
Shale: poorly exposed, includes a 1-foot limestone bed	5.0
Hale Formation	
Limestone: blue gray with brown gray lenses; uneven bedded, rubbly	3.0
Shale: blue gray, fissile, limonite concretions; includes two thin argillaceous limestone beds 0.5 foot thick	8.0
Limestone, sandy: blue gray with brown lenses, fine; uneven bedded	4.0
Shale: blue gray, fissile, sandy	4.0
Limestone, sandy: buff gray to brown gray; grades into shale above	2.0
Shale: blue gray, fissile; somewhat calcareous near top and fossiliferous	4.0
Covered: may include two thin argillaceous beds	9.0
Shale: blue gray, fissile	8.0
Limestone, sandy: blue gray, fine, argillaceous; weathers very sandy	5.0
Limestone: brown gray, coarse medium; weathers brown, smooth, and spalls off. Grades into limestone above	4.0
Covered: not measured	—
Total	236.0

42

Section at Bluff Siding

Sec. 27, T. 13 N., R. 20 E. From Huffman and others (1958, p. 116).

Hale Formation	
Sandstone, medium-grained, calcareous, cross-bedded (not measured)	—
Limestone, blue-gray, medium crystalline, sandy, fossiliferous	50.6
Pitkin Formation	
Limestone, gray, crystalline, limonite-stained, uneven-bedded, fossiliferous, with crinoid fragments and *Archimedes*	4.2
Covered	1.0

	Thickness (feet)
Limestone, gray, medium-crystalline, in thin beds with shale partings, crinoid stems prominent on weathered surface	2.0
Limestone, blue-gray, crystalline, oolitic, massive-bedded, *Archimedes*	6.0
Limestone, dove-gray, dense with crystalline white calcite streaks, thin and weathers smooth and rubbly	7.5
Limestone, blue-gray, crystalline, extremely fossiliferous, with *Archimedes, Linoproductus*, and *Polypora*	0.5
Limestone, gray, dense, brittle, weathers smooth	1.2
Shale	0.2
Limestone, gray, medium crystalline, oolitic, medium-bedded, fossiliferous	2.6
Covered	17.0
Limestone, gray, coarsely crystalline, oolitic, limonite-stained, weathers rough	8.3
Total	101.1

43

McClain Section

Sec. 28, T. 13 N., R. 20 E. Measured by C. A. Moore (1947, p. 73-74).

	Thickness (feet)
Atoka Formation	
Sandstone	3.0
Bloyd Formation	
Shale: blue gray, fissile; limonite concretions	8.0
Limestone: dark gray to blue gray, fine medium with few coarse crystals; uneven-bedded; weathers smooth, pitted and well jointed	3.0
Shale	3.0
Limestone: weathers thin-bedded	6.0
Limestone: light gray, very fine to sublithographic; weathers rubbly and uneven bedded	3.0
Shale	15.0
Limestone: neutral gray, coarse, well jointed; weathers uneven bedded and smooth; fossiliferous, *Hustedia*	2.0
Shale	4.0
Limestone: yellow gray, coarse with large calcite masses; weathers uneven bedded and granular	6.0
Shale	4.0
Limestone: buff to gray, very coarse, large calcite masses; weathers granular; crinoidal, large brachiopods	3.0
Shale	3.0
Limestone: gray, fine medium to fine; uneven bedded, well jointed, weathers smooth; fossiliferous	3.0
Shale	4.0
Hale Formation	
Limestone: blue gray to brown gray, coarse medium with very coarse crystals, large calcite masses; weathers very sandy on surface	2.0
Shale	4.0
Limestone: blue gray with brown gray lenses, medium with large calcite masses; weathers in light blue splotches and rubbly; fossiliferous	2.0
Shale: sandy	3.0
Limestone: blue gray; weathers granular and thin bedded; crinoidal, fossiliferous	3.0
Shale	4.0
Limestone: blue gray, fine crystalline to sublithographic; weathers buff	4.0
Shale	8.0
Shale: poorly exposed, may include some limestone	18.0
Shale: blue gray, fissile, limy concretions and limy lenses	8.0
Sandstone, calcareous: dark gray, fine-grained, argillaceous; weathers limonite stained	1.0
Pitkin Formation	
Limestone: gray, fine medium; weathers fluted; fossiliferous	2.0
Limestone, granular: very coarse crystalline with some sublithographic beds, few shale breaks	10.0
Covered	16.0
Fayetteville Formation	
Covered	14.0
Limestone: blue gray to gray, very coarse, large calcite masses; uneven bedded; weathers locally thin bedded; fossiliferous, *Archimedes*	8.0
Shale: dark gray to black	8.0
Covered	32.0
Limestone: blue, sublithographic; jointed, brittle	1.0
Total	218.0

44

Secs. 29, 30, T. 13 N., R. 20 E., and secs. 25, 26, T. 13 N., R. 19 E. Measured from road intersection in SW¼ sec. 29 along south line to top of hill in SE¼ sec. 26, by William Gregware.

	Thickness (feet)
Atoka Formation	
12 Sandstone: brown, fine-grained, thin-bedded; upper part massive; caps prominent escarpment	7.5
Coal: a smut streak	0.1
Underclay: green, plastic, silty	1.5
Covered: probably shale	185.0
10 Sandstone: brown, very fine-grained; interbedded with siltstone; not well exposed; about	3.0

	Thickness (feet)
Shale: greenish-gray, silty; contains some interbedded siltstone; partly covered	190.0
6 Sandstone: light-brown, fine-grained; lower part massive; upper part thin bedded; about	10.0
Shale: dark-gray; contains scattered ironstone concretions; partly covered; estimated	75.0
5 Sandstone: brown, very fine-grained, massive; contains marine fossils	4.0
Shale: dark-gray, silty, platy	31.2
Covered: probably shale	40.0
4 Sandstone: tan, very fine-grained, hard, massive; makes a low bench	4.0
Total	551.3

45

Partial Section of the Moorefield

Sec. 36, T. 13 N., R. 20 E. From Huffman and others (1958, p. 116-117).

Fayetteville Formation	
Shale, black, fissile, interbedded with thin blue-black limestone stringers	41.5
Moorefield Formation	
Siltstone, yellow-brown, platy, shaly	5.5
Limestone, black, dense, argillaceous, weathers gray and shaly	4.0
Shale, poorly exposed	8.0
Limestone, blue-black, silty, fossiliferous, with *Leiorhynchus carboniferum*	3.0
Covered	6.0
Limestone, gray, dense, argillaceous, fossiliferous	4.0
Shale, gray, platy, calcareous	2.0
Limestone, gray, argillaceous, massive-bedded, weathers shaly, contains many large productid brachiopods	3.0
Shale, and limestone, poorly exposed	10.0
Limestone, blue-gray, silty, massive-bedded, fossiliferous	3.0
Shale (in creek bed north of hill), black, hard, jointed into rectangular blocks	1.0
Total	91.0

46

Secs. 1 and 8, T. 14 N., R. 15 E. Computed from barometric data, by D. G. Campbell.

	Thickness (feet)
Senora Formation	
8 Sandstone: eroded and covered by its own rubble	16.0
Shale: mostly covered, gray to buff, silty to sandy, micaceous	240.0
4 Sandstone: gray to brown, fine-grained, thin-bedded, shaly	12.0
Total	268.0

47

Sec. 14, T. 14 N., R. 15 E. Measured along east boundary south of Cane Creek, by D. G. Campbell.

Senora Formation	
Limestone: dark-gray, dense, fossiliferous; weathers reddish brown (Tiawah)	0.5
Shale: black, fissile; contains iron carbonate concretions	16.5
Coal (probably Tebo)	0.6
Shale: gray, argillaceous	9.5
Total	27.1

48

Secs. 21 to 24, T. 14 N., R. 15 E. Composite section computed from barometric data, by D. G. Campbell.

Senora Formation	
Covered: a few exposures indicate gray to buff, silty to sandy, micaceous shale, about	290.0
4 Sandstone: gray to brown, fine-grained, massive to thin-bedded; contains coal stringers and plant fossils in upper part, about	8.0
Total	298.0

49

Secs. 2, 3, and 5, T. 14 N., R. 16 E. Composite of sections measured by D. G. Campbell.

Senora Formation	
Sandstone: yellow-brown, fine-grained; weathers brown; contains fossil molds and casts; not measured	—
Boggy Formation	
5c Sandstone: gray to buff, fine-grained, regularly bedded	3.0
Shale: gray to buff, locally ferruginous, micaceous; upper part silty	12.0
Shale: blue-gray to buff, silty	16.5
5b Sandstone: coffee-brown to ochre, fine-grained, thin-bedded, fossiliferous; estimated	3.5
Covered: probably silty shale	10.5

	Thickness (feet)
5a Sandstone: light-gray to buff, fine-grained, cross-bedded, shaly, silty, micaceous: upper part platy	6.5
Shale: gray; lower part argillaceous; upper part silty	25.0
Covered: probably shale; estimated	70.0
4 Sandstone: mostly covered; top eroded	4.5
Covered: probably shale	30.0
Shale: light-gray, argillaceous	1.0
Shale: black, fissile; contains ironstone concretions	6.5
Coal	0.3
Underclay: steel-gray, carbonaceous	2.1
Covered: probably shale; estimated	30.0
Total	221.4

50

Sec. 14, T. 14 N., R. 16 E. Measured up north face of escarpment in SW¼, by D. G. Campbell.

Boggy Formation	
4 Sandstone: covered by debris; probably shaly	5.5
4 Sandstone: gray-brown, fine-grained, cross-bedded, micaceous; weathers light brown with orange and black iron stains	2.1
Shale: light-gray to red, argillaceous; upper part silty	6.5
4 Sandstone: light-brown, fine-grained, cross-bedded; weathers gray	2.0
Shale: buff, silty, micaceous	2.5
Covered to base of escarpment	16.0
Total	34.6

51

Secs. 20, 21, and 30, T. 14 N., R. 16 E. Computed from barometric data along south line of 20 and 21 and in NE¼ 30, by D. G. Campbell.

Boggy Formation	
Covered: probably shale	66.0
5 Sandstone: buff, fine-grained, thin-bedded; weathers gray brown; top eroded	3.0
Covered: a few exposures of gray, micaceous shale	58.0
Total	127.0

52

Sec. 21, T. 14 N., R. 16 E. Measured up east face of escarpment in SE¼, by D. G. Campbell.

	Thickness (feet)
Boggy Formation	
4 Sandstone: gray to buff with limonite stains on weathered surface, fine-grained, lenticular, cross-bedded, micaceous, shaly; top eroded	14.0
Shale: gray, argillaceous to silty, micaceous; contains clay-ironstone concretions	15.5
Covered: probably shale	31.0
4 Sandstone: gray-brown, fine-grained, shaly; base not exposed, not measured	—
Total	60.5

53

Sec. 27, T. 14 N., R. 16 E. Measured on outlying hill in NE¼, by D. G. Campbell.

Boggy Formation	
7c Sandstone: gray to buff, fine-grained, massive to platy, ripple-marked; top eroded	8.0
Shale: gray, argillaceous; contains clay-ironstone concretions; about	34.0
Covered: probably shale to base of hill	37.0
Total	79.0

54

Sec. 30, T. 14 N., R. 16 E. Measured from bottom of shale quarry upward and westward to top of escarpment, near center, by D. G. Campbell.

Senora Formation	
2 Sandstone: gray to brown, fine-grained, micaceous, irregularly bedded; top eroded	4.0
Covered: probably shale; exposures are gray and argillaceous to silty	35.0
6? Sandstone: gray to brown, extremely fine-grained, massive to thin-bedded, shaly, micaceous; contains plant impressions; channeled at base	9.0
Shale: lower part dark gray; upper part buff to gray; calcareous; micaceous; contains large oblate, calcareous concretions; upper part silty	35.0
Covered: probably shale; not measured	—
Total	83.0

55

Sec. 32, T. 14 N., R. 16 E. Measured eastward from stream bed at SW cor., by D. G. Campbell.

Boggy Formation	
5 Sandstone: banded red and gray, much weathered; not measured	—

	Thickness (feet)
Shale: brick-red, clayey to silty	1.5
Sandstone: gray to brown, extremely fine-grained, regularly bedded, micaceous	1.5
Shale: medium- to light-gray; weathers buff with limonite stains; upper part silty	10.2
Sandstone: gray to buff, ripple-marked, cross-bedded, shaly; weathers gray brown; locally carbonaceous	18.5
Total	31.7

56

Secs. 3 and 10, T. 14 N., R. 17 E. Measured from vicinity of W¼ cor. of 3 southward to top of outlying hill on west line of 10, by Walton Bell.

	Thickness (feet)
Boggy Formation	
3 Sandstone: fine- to medium-grained, soft, friable, massive; contains limonite balls and stringers	20.0
Covered: probably shale	30.0
2 Sandstone: silty, micaceous; weathers light brown; not mapped	4.0
Covered: probably dark-gray to black shale containing clay-ironstone concretions	104.0
1 Sandstone: reddish-brown, coarse-grained, not well-cemented	4.0
Shale: gray to black, fissile; contains clay-ironstone concretions	15.0
Limestone (Inola): dark-gray, hard, dense, blocky, fossiliferous; exposed above alluvium	1.0
Total	178.0

57

Sec. 5, T. 14 N., R. 17 E. Measured in vicinity of NE cor., by Walton Bell.

	Thickness (feet)
Boggy Formation	
3 Sandstone: some beds are massive, coarse grained, friable, contain clay between the grains, and weather brick red or yellowish-brown; others are fine grained, more blocky, better cemented, and weather light brown	45.0
Covered: probably shale	62.0
2 Sandstone: thin-bedded to massive, micaceous; weathers light brown	5.0
Covered: probably shale	200.0
Total	312.0

58

Sec. 17, T. 14 N., R. 17 E. Measured in vicinity of SE cor., by Walton Bell.

	Thickness (feet)
Boggy Formation	
Sandstone: silty, micaceous, thin-bedded; weathers light rust brown (Crekola)	4.0
Covered: probably shale	36.0
Total	40.0

59

Sec. 24, T. 14 N., R. 17 E. Measured in SW¼ west end of Chimney Mountain, by Francis Stewart, Jr.

	Thickness (feet)
Boggy Formation	
Sandstone: coarse, angular grains	3.5
Shale: silty	6.5
Conglomerate: pebble	4.0
Shale: gray and buff, silty	10.0
Sandstone: buff, fine	1.0
Shale: silty	12.0
Sandstone: fine	0.8
Shale: silty	5.5
Sandstone: fine	0.5
Shale: silty	11.0
Sandstone: fine	3.0
Shale: silty	3.0
Sandstone: fine	3.0
Shale: silty	3.0
Sandstone: fine	3.0
Shale: silty	2.5
2x Sandstone: fine to medium	18.5
Shale: silty	13.5
Sandstone: fine	2.2
Shale: silty	3.0
Sandstone: fine	2.5
Shale: silty	3.0
Sandstone: fine	0.7
Shale: silty, with sandstone lenses	35.0
1x Sandstone: fine, blocky	1.0
Shale: fissile, black, with layer of ironstone concretions at center	30.0
Covered: shale	85.0
Total	266.7

60

Sec. 24, T. 14 N., R. 17 E. Measured near center of Chimney Hill Mountain, in SW¼, by Francis Stewart, Jr.

	Thickness (feet)
Boggy Formation	
3x Sandstone: coarse angular grains; hematite cement	10.5
Shale: buff, silty	8.0
Sandstone: brown, fine	2.0
Shale: buff to gray, silty	13.0
Sandstone: fine to coarse; channel	11.0
Shale: silty	7.5
Sandstone: brown, fine	6.5
Total	58.5

61

Sec. 2, T. 14 N., R. 18 E. Measured on stream 90 feet east from railroad bridge in NW¼, from north to south, by Walton Bell.

	Thickness (feet)
Savanna Formation	
Limestone: medium-gray, hard, dense, jointed; contains corals, crinoids, and brachiopods (Sam Creek)	0.5
Shale: grayish-brown, silty, jointed; contains clay-ironstone concretions	25.0
Limestone: medium-gray, hard, dense, jointed; contains corals, crinoids, and brachiopods (Spaniard)	2.0
McAlester Formation	
Shale: medium-gray, argillaceous, calcareous, fossiliferous	2.0
Sandstone: calcareous, micaceous, fairly thin-bedded; contains marine fossils (Keota)	3.0
Shale: gray to brown, silty; contains clay-ironstone concretions	3.0
Limestone: dark-gray, hard, extremely ferruginous, fossiliferous	0.5
Shale: gray, argillaceous, fossiliferous	1.0
Coal	0.4
Underclay: medium-gray	1.5
Shale: grayish-brown; contains clay-ironstone concretions; base covered; exposed	3.0
Total	41.9

62

Sec. 7, T. 14 N., R. 18 E. Measured westward along north line from NE cor. to top of hill, by Walton Bell.

	Thickness (feet)
Boggy Formation	
Sandstone: massive, friable, porous, not well-cemented; weathers rust brown; mostly covered; estimated (Crekola)	20.0
Covered: probably shale	30.0
Sandstone: massive, friable, not well-cemented; weathers light rust brown (Bluejacket)	15.0
Savanna Formation	
Covered: probably mostly shale	120.0
Total	185.0

63

Sec. 13, T. 14 N., R. 18 E. Measured along east line, by Walton Bell.

	Thickness (feet)
McAlester Formation	
Sandstone: thin-bedded to massive, ripple-marked, silty, micaceous, weathers light brown (Warner)	10.0
Shale and coal	0.9
Underclay	1.0
Sandstone: very silty and shaly; weathers light brown (Warner)	10.0
Covered: probably shale	20.0
Total	41.9

64

Sec. 23, T. 14 N., R. 18 E. Measured southward along east line from stream at NE cor. to vicinity of E¼ cor., by Walton Bell.

	Thickness (feet)
McAlester Formation	
Sandstone: thin-bedded to massive, micaceous, silty; shaly in part; weathers tan (Tamaha)	10.0
Shale: grayish-brown, silty; contains tabular sandstone beds	10.0
Covered: probably shale	7.5
Coal	0.4
Underclay: light-gray	1.0
Covered: probably shale	24.0
Sandstone: mostly covered; but at most places it is light brown, silty, and micaceous (Warner)	2.0
Shale: light-gray, fissile; contains clay-ironstone concretions	5.4
Coal: just a smut streak	0.1
Underclay: light-gray	1.0
Shale: not measured	—
Total	61.4

65

Sec. 25, T. 14 N., R. 18 E. Measured from bed of stream just east of NE cor. westward to NE cor., by Walton Bell.

	Thickness (feet)
McAlester Formation	
Sandstone: massive, fine- to medium-grained; weathers brownish gray; some beds contain balls and stringers of clay ironstone (Warner)	25.0
Covered: probably shale	40.0
Total	65.0

66

Sec. 31, T. 14 N., R. 18 E. Measured in SW¼, by Francis Stewart, Jr.

	Thickness (feet)
Boggy Formation	
Sandstone: white, fine, clean; weathers brown to buff; flat cross-bedding (Bluejacket)	20.0
Covered: shale slope	48.0
Sandstone: brown, silty, platy, fine-grained	7.6

Thickness (feet)

Shale: black, fissile; contains ironstone concretions 20.0

Total 95.6

67

Sec. 36, T. 14 N., R. 18 E. Measured along east line from stream ⅓ mile south of NE cor. north to top of sandstone in vicinity of that cor., by Walton Bell.

McAlester Formation

Sandstone: brownish-gray, fine- to medium-grained, massive to thin-bedded, ripple-marked; thicker beds contain balls and stringers of clay ironstone (Warner) 25.0
Covered: shale 20.0

Total 45.0

68

Sec. 36, T. 14 N., R. 18 E. Measured along south line from top of sandstone ridge in SW¼ to top of sandstone, by Walton Bell.

McAlester Formation

Sandstone: grayish-brown, silty, well-cemented (Keota) 3.0
Shale: gray to brown, micaceous, silty; contains thin, tabular sandstone beds 55.0

Total 58.0

69

Sec. 1, T. 14 N., R. 19 E. Measured along stream and up slope from Quaternary terrace deposit in SE¼ to middle of west line, by William Gregware.

Atoka Formation

7 Sandstone: light-brown, massive, cross-bedded; caps prominent escarpment; estimated 12.0
Covered: probably shale 24.5
5 Sandstone: brown, fine-grained, massive; lower 3 feet silty and shaly 10.0
Covered: probably shale 23.0
Sandstone: brown, very fine-grained; not well exposed 3.0
Covered: probably shale 28.0
4 Sandstone: light-brown, very fine-grained, massive; makes a low bench; estimated 5.0
Covered: probably shale 34.0
3 Sandstone: red to brown, fine-grained, massive; makes a low bench 2.0
Covered: probably shale 23.0
2 Sandstone: tan, fine-grained, massive; makes a low bench 2.0

Thickness (feet)

Covered: probably shale 28.0
1 Sandstone: gray to brown, medium-grained, cross-bedded, massive; contains scattered coarse-grained zones 30.0

Bloyd Formation

Covered: probably shale 3.0
Sandstone: gray to brown, calcareous, extremely fossiliferous; weathers thin bedded locally 12.0
Limestone: light-gray, fine- to medium-crystalline, hard, massive, extremely fossiliferous 2.0
Covered: probably shale 17.0
Sandstone: light-brown, medium-grained, massive, ferruginous 10.0
Limestone: gray, massive, medium-crystalline, fossiliferous 2.0

Total 270.5

70

Secs. 1 and 2, T. 14 N., R. 19 E. Measured from escarpment in SW¼ sec. 1 westward across west line to top of small hill, by William Gregware.

Atoka Formation

8 Sandstone: light-gray-brown, very fine-grained, massive, hard, fossiliferous; weathers tan 4.2
Covered: probably shale 11.5
7 Sandstone: light-brown, very fine-grained, massive, hard; contains fossil worm borings and casts of brachiopods, especially *Dictyoclostus* 5.0

Total 20.7

71

Sec. 3, T. 14 N., R. 19 E. Measured from bed of stream south of NE cor. south along east line to top of hill, by William Gregware.

Atoka Formation

7 Sandstone: brown, fine-grained, hard, massive 5.0
Covered: probably shale 14.0
6 Sandstone: light-brown, fine- to medium-grained, massive; makes a bench 4.5
Shale: gray and brown; mostly covered 25.0
5 Siltstone: olive-green, thin-bedded; makes a bench 3.5
Covered: probably shale 62.0
4 Sandstone: light-reddish-brown, fine-grained, massive, ferruginous; makes a prominent bench 3.5
Covered: probably shale 40.0
3 Sandstone: reddish-brown, fine-grained, massive; poorly exposed along a low bench; about 3.0

	Thickness (feet)
Covered: probably shale	11.5
2 Siltstone: light-gray to light-brown, massive; upper 2 feet calcareous	6.7
Total	178.7

72

Sec. 14, T. 14 N., R. 19 E. A composite of several sections measured by William Gregware.

	Thickness (feet)
Hartshorne Formation	
Sandstone: light-greenish-brown, very fine-grained, thin-bedded to massive; weathers dark brown (Hartshorne)	17.0
Shale: gray to light-brown, silty, platy	3.5
Coal	0.6
Atoka Formation	
Shale: contains some thin beds of siltstone and sandstone; mostly covered	130.0
16 Sandstone: light-brown, very fine-grained; contains abundant plant fossils; caps an escarpment	3.0
Covered: probably shale	39.0
15 Sandstone: poorly exposed along low bench	2.0
Shale: gray and brown; mostly covered	17.0
14 Limestone: dark-gray, medium-crystalline, thin-bedded to massive, shaly, fossiliferous	4.0
Shale: dark-gray, mostly covered	15.0
Limestone: dark-gray, massive to thin-bedded, extremely fossiliferous	5.0
Shale: dark-gray	2.0
Total	238.1

73

Sec. 22, T. 14 N., R. 19 E. Measured at exposures in stream near middle of sec., by William Gregware.

	Thickness (feet)
Atoka Formation	
14 Limestone: gray, ferruginous, medium-crystalline, hard, extremely fossiliferous; *Marginifera, Mesolobus, Juresania, Neospirifer*, nuculinids, and others; weathers red	0.5
Shale: dark-gray, calcareous, fossiliferous; same fossils as above	0.5
Coquinite: interbedded with dark-gray shale	0.4
Shale: dark-gray, calcareous, fossiliferous	0.3
Coquinite: gray	0.1
Shale: dark-gray, calcareous, fossiliferous	1.0
Coquinite: gray; abundant small gastropods and specimens of *Marginifera*	0.2
Shale: dark-gray, calcareous; contains limy concretions	4.0
Limestone: medium-gray, hard, extremely fossiliferous; *Marginifera*, crinoids, ammonites, gastropods, and others abundant; weathers reddish brown	0.9
Total	7.9

74

Secs. 4, 5, 7, 18, T. 14 N., R. 20 E. Measured southwestward from SW¼ sec. 4 to NE¼ sec. 18, by William Gregware.

	Thickness (feet)
Hartshorne Formation	
Sandstone: light-brown, hard, massive, fine-grained; coated with ferruginous material (Hartshorne)	1.5
Atoka Formation	
Covered: probably shale	125.0
16 Sandstone: light-brown, thin-bedded to massive; shaly in places; weathers brown; makes a bench	7.0
Covered: probably shale	60.0
15 Sandstone: brown, fine-grained; makes a bench	5.0
Covered: probably shale	40.0
12 Sandstone: light-gray to light-brown, very fine-grained; shaly in places	3.0
Covered: probably shale	30.0
11 Sandstone: light-brown, thin-bedded, shaly; makes a bench	5.0
Total	276.5

75

Sec. 4, T. 15 N., R. 15 E. Measured in stream bed in center of south half, by D. G. Campbell.

	Thickness (feet)
Senora Formation	
Shale: dark-gray, carbonaceous	0.4
Limestone: dark-gray, dense, ferruginous, fossiliferous; much weathered (Tiawah)	0.2
Shale: maroon to light-gray, argillaceous; contains clay-ironstone concretions	2.3
Shale: black, fissile; contains phosphatic nodules	2.2
Coal (Tebo?)	0.5
Underclay: gray to blue, carbonaceous, micaceous; limonite zone at top	2.3
Shale: light-gray, argillaceous	2.5
Fault	
3 Sandstone: gray to tan, fine- to very fine-grained, thin-bedded to lenticular, cross-bedded, ripple-marked, jointed; base not exposed	8.0
Total	18.4

76

	Thickness (feet)
Sec. 4, T. 15 N., R. 15 E. Measured northward up escarpment along west line, by D. G. Campbell.	
Senora Formation	
Sandstone: light-gray to buff, massive to thin-bedded, cross-bedded, ripple-marked, shaly; locally ferruginous; top eroded (Chelsea)	21.0
Shale: gray to tan, silty	8.0
Total	29.0

77

	Thickness (feet)
Secs. 20 and 29, T. 15 N., R. 15 E. Measured along west line southward from intersection with stream in SW¼ of 20 to top of hill in NW¼ of 29, south of Midway, by D. G. Campbell.	
Senora Formation	
Sandstone: ochre, fine-grained, lenticular, micaceous, limonitic, fossiliferous: weathers buff to brown: top eroded (Chelsea)	3.0
Shale: gray to buff, micaceous; upper part silty; lower part grades into sandstone below	38.0
8 Sandstone: buff, fine-grained, thin-bedded; upper part shaly; top sharply defined	28.0
Shale: gray, micaceous	12.0
Limestone: gray, dense, fossiliferous (Tiawah)	0.6
Shale: black, fissile	6.0
Coal: exposed in bank of stream north of Midway (Tebo)	0.5
Total	88.1

78

	Thickness (feet)
Secs. 22 and 29, T. 15 N., R. 15 E. Computed from barometric data from NW¼ of 22 and NE¼ of 29, by D. G. Campbell.	
Senora Formation	
Covered: a few exposures of silty to sandy shale	110.0
3 Sandstone: gray to buff, fine-grained, thin-bedded, shaly, micaceous; top eroded	12.0
Shale: gray, argillaceous to silty	13.5
Shale: black, fissile, jointed; contains iron carbonate concretions; grades upward into gray shale	9.0
Limestone: gray, dense, fossiliferous, jointed; weathers light gray	0.8
Shale: dark-gray, calcareous	0.2
Limestone: dark-gray, fossiliferous; weathers red brown	0.9
Total	146.4

79

	Thickness (feet)
Sec. 24, T. 15 N., R. 15 E. Measured up stream from its intersection with east line to concrete bridge on south line, and thence west to SW cor., by D. G. Campbell.	
Senora Formation	
3 Sandstone: brown, thin-bedded, poorly exposed; not measured	—
Covered: probably shale; about	40.0
2 Sandstone: gray to brown, fine-grained, micaceous, lenticular, about	3.5
Shale: gray, silty	6.5
Shale: black, fissile; contains clay-ironstone concretions	3.5
Coal	0.4
Underclay: light-gray	3.0
1 Sandstone: buff to light-brown, fine-grained, thin-bedded, jointed; exposed as inliers in stream bed; base not exposed; at least	2.0
Total	58.9

80

	Thickness (feet)
Sec. 13, T. 15 N., R. 16 E. Measured in center of S½, by D. G. Campbell.	
Boggy Formation	
Shale: black, fissile; contains iron carbonate concretions in upper part	21.5
Limestone: red to gray, dense, fossiliferous, jointed; weathers brown (Inola)	0.4
Shale: green to maroon to light-gray, argillaceous to silty	4.0
Sandstone: gray, fine-grained, massive to thin-bedded, weathers buff to yellow brown (Bluejacket)	6.0
Total	31.9

81

	Thickness (feet)
Secs. 13 and 25, T. 15 N., R. 16 E. Composite of sections measured in SE¼ of 13 and along west line of 25, by D. G. Campbell.	
Boggy Formation	
3 Sandstone: light-gray to buff, medium- to fine-grained, micaceous, lenticular, cross-bedded; weathers gray to brown; contains some interbedded shale; top eroded	27.0
Shale: light-gray to buff, argillaceous, micaceous; upper part silty	22.0
Covered: probably shale	16.0
2 Sandstone: gray-brown, fine-grained, platy, micaceous; weathers brown; about	2.0

	Thickness (feet)
Shale: light-gray, silty, micaceous; weathers buff; locally carbonaceous	20.0
Covered: probably shale	80.0
Total	167.0

82

Sec. 23, T. 15 N., R. 16 E. Measured southward from Arkansas River flood plain in NE¼, by D. G. Campbell.

	Thickness (feet)
Boggy Formation	
3 Sandstone: variegated, gray to green to red, fine-grained, cross-bedded, shaly	7.5
Covered: a few exposures of gray, argillaceous to silty shale; about	40.0
2 Sandstone: buff, fine-grained, massive, micaceous; weathers gray; thin bedded at top; locally limonitic	20.0
Shale: gray, argillaceous to silty, micaceous; locally carbonaceous	4.0
Covered: probably shale	23.0
Total	94.5

83

Sec. 23, T. 15 N., R. 16 E. Measured along east bank of stream in NW¼NE¼SW¼, by D. G. Campbell.

	Thickness (feet)
Boggy Formation	
Shale: black, blocky to fissile, jointed; contains siliceous concretions; grades upward into gray shale	13.5
Coal	0.4
Underclay: gray, carbonaceous, silty	1.7
Siltstone: gray, micaceous, ferruginous	0.6
Shale: greenish-gray, argillaceous; weathers light gray	1.5
Shale: gray, silty, slightly calcareous; contains limy concretions at top	1.0
3 Sandstone: gray, fine-grained, thin-bedded, cross-bedded; has red calcareous ridges along bedding planes; base not exposed	5.0
Total	23.7

84

Sec. 25, T. 15 N., R. 16 E. Measured from vicinity of entrance to Taft Hospital south along east line to crest of hill, by D. G. Campbell.

	Thickness (feet)
Boggy Formation	
3 Sandstone: gray to brown, lenticular, massive to thin-bedded, medium-grained; weathers brown with ferruginous stains; top eroded	37.0
Shale: light-gray to buff, silty, micaceous; upper part carbonaceous and contains ironstone concretions	7.5
Covered: probably shale	55.5
2 Sandstone: gray to buff, shaly; not well defined; about	4.5
Covered: probably shale	15.0
Total	119.5

85

Sec. 26, T. 15 N., R. 16 E. Measured along stream in north part to north line and thence west to NW cor., by D. G. Campbell. Note: This section is probably faulted above the black fissile shale.

	Thickness (feet)
Boggy Formation	
Covered: a few exposures of gray silty shale; about	140.0
Shale: black, fissile; contains abundant iron carbonate concretions	15.5
Clay: gray, carbonaceous	1.0
Coal: contains pyrite concretions	0.4
Underclay: carbonaceous	2.0
3 Sandstone: gray, thin-bedded, cross-bedded, fine-grained, silty; contains fossil plants, including *Stigmaria;* not measured	—
Total	158.9

86

Sec. 27, T. 15 N., R. 16 E. Measured along south line up west side of outlying hill, by D. G. Campbell.

	Thickness (feet)
Boggy Formation	
5b Sandstone: gray to brown, lenticular, fine-grained, cross-bedded, micaceous, friable; top eroded	12.5
Shale: gray to buff, silty, micaceous	8.0
Covered: probably silty shale	12.5
5a Sandstone: gray brown, fine-grained, lenticular, locally ferruginous; weathers buff; upper part platy	2.5
Shale: gray to buff, micaceous, locally limonitic; upper part silty; lower part argillaceous	25.0
Covered: probably silty shale	18.0
Shale: brown-gray, argillaceous to silty, micaceous; weathers buff with limonite stains	6.5
Total	85.0

87

Sec. 29, T. 15 N., R. 16 E. Measured westward from intersection of stream with east line to vicinity of NW cor., by D. G. Campbell.

	Thickness (feet)
Boggy Formation	
2 Sandstone: gray-brown to brown, fine-grained, thin-bedded, micaceous; base not well defined; top eroded	4.0
Covered: a few exposures of gray, slightly silty shale; about	21.0
1 Sandstone: gray, buff to brown, platy, cross-bedded, micaceous, limonitic	2.5
Shale: dark- to light-gray, micaceous	5.5
Limestone: dark-gray to black, dense, ferruginous, jointed	0.2
Shale: black, carbonaceous, fissile; contains iron carbonate concretions	7.0
Coal	0.3
Shale: light-gray, argillaceous to silty, micaceous; contains limonite streaks and fossil plants	4.5
Total	45.0

88

Sec. 9, T. 15 N., R. 17 E. Measured in vicinity of SE cor., by Walton Bell.

Boggy Formation	
Sandstone: light-brown, thin-bedded, silty, micaceous, much-weathered (Crekola)	3.0
Shale: grayish-brown, much-weathered	4.0
Coal (Secor)	0.8
Underclay: light-gray	1.0
Shale: gray, much-weathered	4.0
Sandstone (Bluejacket): not measured	—
Total	12.8

89

Sec. 13, T. 15 N., R. 17 E. Measured from stream west of NE cor. to top of outlying hill in NE¼, by Walton Bell.

Boggy Formation	
Sandstone: massive to blocky, silty, micaceous, friable; weathers tan or light reddish brown (Bluejacket)	18.0
Savanna Formation	
Shale: partly covered, light-gray, fissile	85.0
Sandstone: silty, micaceous, weathered	2.0
Shale: medium-gray, fissile, jointed, concretionary	30.0
Total	135.0

90

Sec. 16, T. 15 N., R. 17 E. Measured in bed of stream in extreme northwest part, by Walton Bell.

	Thickness (feet)
Boggy Formation	
Shale: black, fissile; contains clay-ironstone concretions and, in lower part, black nodules about ½ inch in diameter	20.0
Limestone: dark-gray, fossiliferous, shaly; grades downward into shale (Inola)	0.5
Shale: much-weathered; estimated	2.0
Limestone: medium-gray, hard, dense, sandy (Inola)	0.7
Shale: gray, sandy	5.0
Total	28.2

91

Sec. 19, T. 15 N., R. 17 E. Measured in vicinity of SE cor., by Walton Bell.

Boggy Formation	
3 Sandstone: reddish-brown to light-brown, massive, coarse-grained; contains some angular quartz grains 2 mm in diameter; limonite balls and stringers; plant impressions	25.0
Covered: probably shale	80.0
2 Sandstone: silty to fine-grained, thin-bedded to blocky	6.0
Covered: probably shale	48.0
Total	159.0

92

Sec. 20, T. 15 N., R. 17 E. Measured on east side of stream, in vicinity of NW cor., by Walton Bell.

Boggy Formation	
Sandstone: silty, micaceous, thin-bedded to blocky, friable to well-cemented, jointed; weathers light brown; contains a few thin shale beds (Crekola)	10.0
Shale: light-gray, micaceous, silty	10.6
Coal (Secor)	1.0
Shale: medium-gray, silty, micaceous, fissile; contains clay-ironstone concretions	17.6
Total	39.2

93

Sec. 7, T. 15 N., R. 18 E. Measured in middle of south side about 150 feet west of creek and 60 feet north of south line, by Walton Bell.

Savanna Formation	
Shale: medium-gray, concretionary; not measured	—

	Thickness (feet)
Coal	0.1
Concretion bed: calcareous	1.0
Limestone: medium-gray, hard, dense, massive, fossiliferous; contains abundant *Caninia torquia* and numerous brachiopods (Spaniard)	3.0
McAlester Formation	
Covered: probably shale; estimated	2.0
Sandstone: silty, micaceous, thin-bedded (Keota)	3.0
Total	9.1

94

Sec. 7, T. 15 N., R. 18 E. Measured on outlier in NE¼, by Walton Bell.

Boggy Formation	
Sandstone: silty, micaceous, massive (Crekola)	8.0
Shale: tan, silty	3.0
Coal (Secor)	0.3
Underclay: light-gray	1.0
Shale: tan	8.0
Sandstone: massive, silty, micaceous; weathers rust brown (Bluejacket)	45.0
Covered: probably shale; not measured	—
Total	65.3

95

Sec. 10, T. 15 N., R. 18 E. Measured in vicinity of east line, by Walton Bell.

McAlester Formation	
Covered: probably shale; not measured	—
Coal	0.3
Underclay: light-gray	0.5
Shale: light-brown, silty	1.0
Sandstone: light-gray, hard, calcareous, well-cemented (Warner)	4.0
Siltstone: light-gray, calcareous	0.5
Siltstone: light-gray, calcareous, hard, very thin-bedded	9.5
Total	15.8

96

Sec. 16, T. 15 N., R. 18 E. Measured 150 feet west of NE cor., by Walton Bell.

	Thickness (feet)
McAlester Formation	
Siltstone: brownish-gray, silty, micaceous (Tamaha)	5.0
Shale: gray, silty, micaceous; contains clay-ironstone concretions	5.8
Coal: poorly developed; contains a few small brachiopods	0.3
Limestone: black, carbonaceous, fossiliferous	0.5
Coal	0.3
Shale: tan to gray, silty, micaceous, poorly bedded; contains clay-ironstone concretions as long as 1 foot; contains fossiliferous concretions in upper part; base not exposed; more than	6.0
Total	17.9

97

Sec. 17, T. 15 N., R. 18 E. Measured in vicinity of 60 feet west of east line, above small pond on northward-flowing stream, by Walton Bell.

McAlester Formation	
Sandstone: light-gray, thin-bedded, silty, micaceous, calcareous (Keota)	7.0
Shale: grayish-brown; contains marine fossils	3.5
Limestone: much-weathered, fossiliferous; only a clay-iron residue left	0.5
Coal	0.3
Shale	5.0
Limestone: deeply weathered, fossiliferous; contains abundant brachiopods	0.5
Shale: grayish-brown, silty, micaceous; mostly covered	20.0
Sandstone: tan, blocky, compact, micaceous, silty, upper 2 feet shaly; base not exposed	8.0
Total	44.8

98

Sec. 18, T. 15 N., R. 18 E. Measured in creek bed, 150 yards south of middle of north line, by Walton Bell.

Savanna Formation	
Limestone: medium-gray, hard, dense, massive, cryptocrystalline, very fossiliferous; contains a large coral, *Caninia torquia*, that constitutes about one-third of the rock in this exposure (Spaniard)	2.5
McAlester Formation	
Shale: gray, deeply weathered (Keota)	3.5
Coal	0.3
Total	6.3

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Sec. 18, T. 15 N., R. 18 E. Measured in bed of stream about 600 feet south of north line and 300 feet east of west line, by Walton Bell.

	Thickness (feet)
Savanna Formation	
Shale: not measured	—
Sandstone: porous, friable, silty; weathers light brown	2.5
Clay: much-weathered	0.5
Coal	0.2
Underclay: light-gray	1.0
Shale: black, fissile; estimated	12.0
Limestone: grayish-blue to black, carbonaceous, fossiliferous, thin-bedded, shaly to nodular; contains abundant crinoid stems, small brachiopods, and some *Spirifer* spp. (Doneley)	1.3
Coal (Rowe)	1.0
Total	18.5

100

Sec. 34, T. 15 N., R. 18 E. Measured northward along midline from top of sandstone outlier to stream, by Walton Bell.

McAlester Formation	
Sandstone: fine-grained, massive; contains red-clay casts as much as 1 foot in length (Keota)	5.0
Covered: probably shale	38.0
Limestone: dark-gray, hard, dense, very ferruginous, fossiliferous; contains *Marginifera*	0.6
Limestone: medium-gray	2.5
Shale: tan, micaceous, calcareous, very thin-bedded	7.0
Sandstone: rust-brown, fine-grained, massive (Tamaha)	2.0
Covered: probably shale	20.0
Total	57.1

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Sec. 25, T. 15 N., R. 19 E. Measured in south part ¼ mile east from bend in trail in vicinity of SW cor., by Walton Bell.

	Thickness (feet)
Atoka Formation	
1 Sandstone: light-gray, compact, fine-grained, micaceous, slightly fossiliferous	15.0
Morrow Group [Bloyd and Hale Formations]	
Covered: probably shale	24.4
Sandstone: greenish-brown to gray, calcareous, fine-grained, well-cemented	8.0
Covered: probably shale	10.7
Limestone: rust-brown, sandy, fossiliferous, deeply weathered	5.3
Covered: probably shale	15.0
Limestone: reddish, crinoidal, thin-bedded to massive	10.7
Limestone: greenish, hard, dense, brittle, crinoidal	10.7
Covered: probably shale	10.7
Limestone: bluish-gray, hard, dense, thin-bedded to massive; brachiopods abundant	3.0
Covered: probably shale	18.5
Shale: bluish-gray, fissile	4.0
Limestone: light-gray, thin-bedded to massive, crinoidal; contains abundant brachiopods and a blastoid, "*Pentremites*"	10.0
Shale: grayish-black, fissile	6.0
Limestone: medium-gray, thin-bedded to massive, crinoidal; contains a few brachiopods	20.0
Covered: probably shale	4.0
Limestone: light-gray, crinoidal, sandy	20.0
Covered: probably shale	23.0
Limestone: crinoidal, hard, dense, massive	4.0
Total	223.0

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Goose Neck Bend Section

Sec. 26, T. 15 N., R. 19 E. Measured by C. A. Moore (1947, p. 94).

Atoka Formation	
Sandstone: massive bedded	6.0
Sandstone, calcareous: iron stained buff; cross-bedded and thin uneven bedded	8.0
Bloyd Formation	
Covered	8.0
Shale: blue gray, fissile, limonite concretions; poorly exposed	6.0
Limestone: blue gray, medium, heavily iron stained; thin and uneven bedded; weathers platy and spalls off	4.0
Covered	16.0
Shale: blue gray, fissile, limonite concretions	4.0
Limestone: gray, fine medium crystalline, coarse in lower part; fossiliferous, crinoidal; few thin shale beds	16.0
Shale: poorly exposed	14.0
Limestone: blue gray, heavily iron stained, very coarse to coarse; thin-bedded; weathers into small platy boulders; crinoidal, fossiliferous	2.0
Shale: poorly exposed, includes a limestone bed that is light blue on weathering	10.0
Limestone: blue gray to brown gray, medium crystalline with coarse crystals and calcite masses; massive- to thin-bedded; weathers brown buff; *Pentremites*	4.0

	Thickness (feet)
Shale: poorly exposed	10.0
Limestone: gray, heavily iron spotted, coarse with very coarse crystals; massive and thin, uneven bedded; crinoidal, fossiliferous, bryozoans	2.0
Shale: poorly exposed	11.0
Limestone: gray, coarse medium; crinoidal	3.0
Shale: poorly exposed	10.0
Hale Formation	
Limestone: conglomeratic	0.5
Limestone	30.0
Limestone: blue gray, heavily iron stained, very coarse with large calcite crystals; weathers granular; crinoidal	4.0
Total	168.5

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Sec. 36, T. 15 N., R. 19 E. Measured along south line from vicinity of S¼ cor. eastward to SE cor., by Walton Bell.

	Thickness (feet)
Atoka Formation	
7 Sandstone: micaceous, thin-bedded to blocky, fine-grained, well-cemented; nodules or concretions 2 inches in diameter weather out of some beds	8.0
Shale: light-gray, argillaceous, calcareous, fossiliferous; contains maroon, fossiliferous, clay-iron concretionary beds	5.5
Shale: grayish-black, unfossiliferous, argillaceous; lower part contains unfossiliferous clay-iron concretionary beds	12.0
Shale: light-gray, argillaceous, fossiliferous; contains clay-iron concretionary bed about 1 foot from base	3.0
6 Sandstone: grayish-brown, fine-grained, calcareous, well-cemented, hard; contains fossil molds	4.5
Shale: gray, calcareous; contains marine fossils and woody material; grades downward into sandy, calcareous shale, followed by gray argillaceous shale with clay-iron concretions	4.0
5 Sandstone: medium-gray, fine-grained, micaceous, well-cemented, hard; contains fossil impressions and small limonite balls	3.0
Shale: mostly covered; upper 5 feet is gray, calcareous, and contains marine fossils	25.0
4 Sandstone: light-brown, calcareous, micaceous, well-cemented, fine-grained, thin-bedded to blocky; contains molds of marine fossils	8.0
Covered: probably shale; estimated	30.0
3 Sandstone: light-brown, fine-grained, well-cemented	8.0
Covered: probably shale; estimated	10.0
2 Sandstone: extremely fine-grained or silty, whitish-gray, jointed, fairly thin-bedded, hard, compact, faintly ripple-marked; 18 feet from top, contains thin, gray, argillaceous shale and much weathered sandy limestone	34.0
1 Shale: gray, calcareous, argillaceous; contains thin, fossiliferous, sandy limestone beds and one thin sandstone bed	17.5
Total	172.5

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Sec. 12, T. 15 N., R. 20 E. Stream cut, near bridge. From Huffman and others (1958, p. 167).

Fayetteville Formation (base in water—top covered)	
Shale, black, fissile, weathers iron-stained, 5 feet above stream there is a 0.5 foot limestone, black sublithographic, lens-like bed	20.0
Hindsville Formation	
Limestone, blue-gray, coarsely crystalline, unevenly bedded, weathers to rubble; contains numerous brachiopods including *Diaphragmus*, and *Linoproductus ovatus* in zones	3.6
Limestone, black, lithographic to sublithographic, fossiliferous, weathers light blue-gray, smooth, subcuboidal, in beds 0.5 feet thick separated by thin shale breaks	5.0
Total	28.6

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Sec. 12, T. 15 N., R. 20 E. Measured by C. A. Moore (1947, p. 94).

Atoka Formation	14.0
Bloyd Formation	114.0
Hale Formation	46.0
Pitkin Formation	66.0
Total	240.0

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Along Stream Cut

Sec. 15, T. 15 N., R. 20 E. From Huffman and others (1958, p. 167-168).

Pitkin Formation	
Limestones, partially covered	50.0
Fayetteville Formation	
Shale, black, fissile, mostly covered	53.0

	Thickness (feet)
Limestone, black, lithographic, in beds 0.7 [feet] thick, thin conglomerate at top	6.5
Shale, black fissile, covered	3.0
Hindsville Formation	
Limestone, blue-gray to black, fine crystalline, massive *Linoproductus ovatus* zone	2.0
Limestones, black, lithographic, subcuboidal, 0.2-0.6 feet thick separated by black, calcareous, platy shale	10.0
Moorefield Formation	
Covered, probably shale	5.0
Shale, and black argillaceous limestone grading into each other, *Leiorhynchus*	16.0
Total	145.5

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East Braggs Mountain Section

Secs. 21 and 28, T. 15 N., R. 20 E., along road cut on Highway 10 between Muskogee and Braggs. Measured by C. A. Moore (1947, p. 95-96).

	Thickness (feet)
Atoka Formation	
Sandstone: stained tan and buff, fine grained at base; locally cross bedded. There is a trace of coal smut at base	8.0
Bloyd Formation	
Sandstone and sandy shale: fine, stained brown to tan	3.0
Shale: blue gray, fissile, seems to grade into sandy beds above	5.0
Limestone: blue gray, medium crystalline; weathers brown gray; crinoidal, fossiliferous. Seems to occur as a lens in the shale	5.5
Shale: blue gray, fissile	8.5
Limestone, poorly exposed: rubbly on weathering, weathers into pseudo cross beds; extremely crinoidal	3.0
Shale, poorly exposed	9.0
Limestone: blue gray, very fine crystalline, few shale breaks; crinoidal on weathering	6.0
Shale: fine silty, gray and buff with greenish cast	4.0
Covered, probably shale	3.0
Limestone: blue gray; weathers buff; *Pentremites*	3.5
Shale: blue gray, poorly exposed, fissile	5.0
Hale Formation	
Limestone: poorly exposed, blue gray, medium to fine crystalline; thin bedded, platy, may include some shale	8.0
Shale: calcareous, marly buff; fossiliferous nodules at top, *Composita*, crinoid stems	2.0
Limestone as below, few thin shale beds	3.0
Limestone: brown gray, coarse to medium crystalline, crinoidal; massive bedded in lower part, locally platy in upper part	11.0
Shale: blue gray, fissile, weathers buff	10.0
Limestone: brown gray, fine sandy; weathers into pseudo cross beds; upper part is platy; crinoidal	8.0
Shale: blue gray, fissile; weathers iron stained buff; *Pleurodictyum (Michelinia)*	1.5
Limestone: blue gray, very fine to sublithographic; fossiliferous, brachiopods, fenestellids	2.2
Limestone: light blue gray, locally very sandy, fine granular, fine crystalline; weathers into honeycombed sandy beds. Conglomerate beds 3 to 6 inches at base, red, very limy	11.0
Pitkin Formation	
Limestone: light blue gray, fine crystalline; weathers porous and in pseudo cross beds; coquina-like beds of fossil fragments, crinoidal. Basal 2 to 3 feet is dense concretionary limestone. Upper 3 feet oolitic, few glauconite specks; weathers porous and in pseudo cross beds; *Archimedes*	11.0
Limestone, with thin dark shale breaks: rubbly, beds average 1-inch thick; concretionary, crinoidal	2.0
Limestone: blue gray, very fine to dense crystalline; brown gray on weathering; fossiliferous streaks, fenestellids, *Diaphragmus*, crinoidal	6.0
Shale: dark gray, with thin concretionary limestone beds that average 2½ inches thick; *Archimedes*; a 3-inch limestone bed at top	6.0
Limestone: brown blue gray, fine crystalline; fossiliferous, *Diaphragmus*	6.0
Shale	0.3
Limestone: blue gray, medium crystalline; appears cross bedded, limonite staining accentuates the cross bedding; crinoidal	4.5
Shale: dark gray, soft	0.3
Limestone: light blue gray, dense, tiny calcite inclusions; breaks with conchoidal fracture; weathers light gray, buff	17.0
Limestone: gray, blue gray, lithographic, appears rubbly locally, concretionary; upper part is more massive bedded; medium crystalline; crinoidal, extremely fossiliferous, *Diaphragmus*, *Archimedes*	6.5
Fayetteville Formation	
Shale and limestone: gray, concretionary; limestone beds average 4 inches thick, upper 6 inches is limestone; fossiliferous, gastropods, productids	7.5

	Thickness (feet)
Limestone: gray brown; very fine crystalline; fossiliferous, *Composita*, productids	1.2
Limestone: light blue gray, coarse to medium crystalline; brown gray on weathering; carries a wedging shale bed in top 2 feet; very crinoidal, *Archimedes*	10.0
Limestone: blue gray, concretionary, dense, many thin shale beds	7.0
Shale, with beds of concretionary limestone averaging 4 inches thick: blue gray, dense; weathers buff tan	18.0
Shale: gray to dark gray, fissile	11.0
Limestone as below	0.3
Shale: gray, fissile, silty	0.3
Limestone: gray brown to brown, shaly, silty, concretionary; iron stained on weathering	0.3
Shale: gray to black, fissile; hard concretions with finely disseminated pyrite in few beds; buff in basal part on weathering	45.0
Limestone: gray; beds average 1 foot thick; weathers buff yellow; very fossiliferous, *Composita* abundant, *Punctospirifer*, *Diaphragmus*	5.0
Shale: gray to black, fissile-jointed; weathers iron stained	17.0
Shale: tan, buff, soft, well jointed	12.0
Meramec Series?	
Limestone: light gray to brownish, very fine (Mayes type), shaly; fossiliferous	4.0
Covered	—
Total	318.4

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Highway 10 Section, Braggs Mountain

Secs. 21 and 29, T. 15 N., R. 20 E. From Huffman and others (1958, p. 168-169).

	Thickness (feet)
Atoka Formation	
Sandstone: tan to buff, fine-grained at base, locally cross-bedded, trace of coal smut at base	8.0
Bloyd Formation	
Sandy shale, brown to tan stain, fine	3.0
Shale, fissile, grades into sandy beds above	5.0
Limestone, blue-gray, medium crystalline, weathers brown-gray, crinoidal, fossiliferous	5.5
Shale, blue-gray, fissile, jointed	8.9
Limestone, poorly exposed, rubbly, weathers pseudo-cross-bedded; extremely crinoidal, reddish and porous	3.0
Shale, poorly exposed, brown, fissile, fossiliferous	9.0
Limestone, blue-gray, very fine crystalline, crinoidal	6.0
Shale, fine, silty, gray and buff, greenish cast	4.0
Shale (covered)	3.0
Limestone, blue-gray, weathers buff, abundant *Pentremites*	3.5
Shale, poorly exposed, gray-black, fissile	5.0
Hale Formation	
Limestone, poorly exposed, blue-gray, medium to fine crystalline, thin-bedded, platy, may include some shale	8.0
Shale, calcareous, marly, buff, fossiliferous nodules at top, *Composita* and crinoid stems	2.0
Limestone, brown-gray, few thin shale beds	3.0
Limestone, brown-gray, coarse to medium crystalline crinoidal, massive in lower portion, locally platy in upper portion	11.0
Shale, black-gray, fissile, weathers buff, poorly exposed	10.0
Limestone, brown-gray, fine sandy, weathers to pseudo-crossbeds, upper [part] is platy and crinoidal	8.0
Shale, black-gray fissile, weathers buff, *Pleurodictyum*	1.5
Limestone, black-gray, very fine to sublithographic fossils, brachiopods, fenestellids	2.2
Limestone, light blue-gray, locally very sandy, fine granular crystals, weathers into honeycomb sandy beds	11.5
Conglomerate at base, 3-6″ small flat, rounded pebbles, red and very limy	0.5
Pitkin Formation	
Limestone, light blue-gray, fine-crystalline, porous and pseudo-crossbedded, coquina, crinoidal, basal [part] is dense, 2-3′ concretionary, upper 3′ oolitic, few glauconite specks, *Archimedes*, porous weathering	11.0
Limestone, thin, dark shale, rubbly and crinoidal	2.0
Limestone, blue-gray, dense to crystalline, *Fenestella*, *Diaphragmus*, fossiliferous streaks, fossiliferous pseudo-crossbedded	6.0
Shale, dark gray, thin concretionary bed at top, nodular, weathers to gray clay	6.0
Limestone, brown, blue-gray, *Diaphragmus*, fossiliferous	6.0
Shale (covered)	0.3
Limestone, blue-gray, medium-crystalline, cross-bedded, limonite-stained	4.5
Shale, dark gray, soft	0.3
Limestone, light blue-gray to gray, dense, calcite inclusions, conchoidal fracture, fossiliferous oolitic in part, *Pentremites*	17.0
Limestone, gray, blue-gray, black, lithographic, rubbly, nodular, concave, upper [part] is massive and coarsely crystalline, fossiliferous, *Archimedes*	6.5

	Thickness (feet)
Fayetteville Formation	
Shale and limestone, blue-gray to black, crystalline to lithographic, fossiliferous, 4" thick beds; shale, black to gray, fissile, in thin beds	7.5
Limestone, gray-brown, very fine, (*Composita*)	1.2
Limestone, and shale; limestone is blue-gray to brown, fine to coarsely crystalline, crinoidal, oolitic in part, fossiliferous, thick-bedded, shale gray, calcareous, rubbly, contains small limestone lenses	13.7
Shale, black fissile, six to eight thin limestone lenses, black, lithographic to medium coarse crystalline, fossiliferous	36.1
Shale, gray to dark gray, concretionary	11.1
Covered	2.0
Shale, black, fissile, large septarian concretions 2-3 feet across	45.0
Hindsville Formation	
Limestone, black, medium crystalline with *Diaphragmus*, *Composita*, *Agassizocrinus*	5.0
Moorefield Formation	
Ordnance Plant Member	
Shale, brown, silty, gray, and black, jointed fissile, concretion-like	17.0
Shale, buff, soft, jointed, calcareous	12.0
Bayou Manard Member	
Limestone, black, argillaceous, scales off, weathers gray on surface, grades into black, platy, calcareous shales, *Leiorhynchus*, *Spirifer arkansanus*, *Moorefieldella*	24.5
Limestone, black, dense, lithographic, petroliferous odor	1.5
Total	357.8

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West Braggs Mountain Section

Sec. 29, T. 15 N., R. 20 E., along old route of Highway 10. Measured by C. A. Moore (1947, p. 96-98).

	Thickness (feet)
Atoka Formation	
Sandstone: cross-bedded, several thin-bedded layers, few fossils	45.0
Bloyd Formation	
Shale: blue gray, fissile, concretions; few covered intervals	36.0
Limestone: blue, with black calcite crystals, coarse medium to fine medium; weathers iron stained buff	3.0
Shale and covered	6.0
Shale: buff with greenish cast, sandy; thin-bedded	2.0
Shale: plastic, iron streaked	3.0
Limestone: blue and buff mottled, fine medium; weathers buff; moderately fossiliferous	2.0
Shale: blue gray	2.0
Limestone: blue gray, fine medium to fine; weathers rather purplish, in thin uneven beds and rather rubbly	2.5
Shale: blue gray, fissile, poorly exposed	9.6
Limestone: blue, fine with medium crystalline bands and lenses; even bedded; weathers uneven and rather rubbly; moderately fossiliferous	1.0
Hale Formation	
Limestone: blue gray, fine medium matrix with coarse crystals, has argillaceous streaks, crinoidal; weathers rather fluted; upper few inches shaly and extremely fossiliferous, Bryozoa, *Pleurodictyum*, *(Michelinia)*, *Pentremites*, crinoid remains, *Punctospirifer*	20.2
Shale: blue gray	0.4
Limestone, sandy: light gray, very coarse to coarse; weathers in uneven and fluted beds; crinoidal, fossiliferous	4.5
Limestone: blue to blue gray, fine crystalline; thin-bedded, moderately fossiliferous	2.5
Covered	3.0
Sandstone: slightly calcareous, medium- to fine-grained, heavily iron stained; thin-bedded	6.0
Limestone: blue to blue-gray with greenish hue, heavily iron stained, very coarse, very crinoidal, trace phosphatic; thin-bedded; grades into limestone below	0.3
Limestone: dark blue, coarse; weathers smooth and spalls off; very fossiliferous, coarsely crinoidal	3.0
Limestone: blue to blue gray, very coarse; moderately iron stained, small lenses appear very sandy; upper part rather uneven bedded and thinner bedded; weathers smooth, extremely crinoidal; very fossiliferous	10.0
Limestone: very sandy, medium grained, ferruginous	5.0
Limestone: lower half is good conglomerate, upper half conglomeratic sandy limestone, contains limonite pebbles, iron spotted and stained	1.0
Pitkin Formation	
Limestone: light blue gray, fine medium to fine; weathers smooth	2.0
Limestone: blue to blue gray, coarse; weathers with large crinoid stems on surface and fluted; coarsely crinoidal, *Ethelocrinus (Eupachycrinus)* base	16.2

Thickness (feet)

Limestone: rubbly with thin shale partings 1.0
Limestone: blue to blue gray, coarse; weathers rubbly and knobby; *Archimedes* common 5.5
Limestone: neutral gray, variably crystalline, fine medium lenses in very coarse crystalline masses; very uneven bedded; weathers in cross bedded flutings and crinoidal; moderately iron spotted, extremely crinoidal, somewhat oolitic 10.0
Shale: black, fissile 0.5
Limestone: dark blue gray with black crystals, fine; weathers iron stained; somewhat oolitic 1.0
Shale: blue gray, fissile, sandy, calcareous 1.5
Limestone: blue to brown, very argillaceous; thin-bedded; fossiliferous; seems to grade into shale above 0.5
Limestone: very coarse with large black calcite masses, somewhat oolitic, carries lenses of crinoidal material, 10 to 22 mm thick 2.5
Limestone: brown gray, fine, brittle 0.5
Limestone: gray to brown gray, coarse; even bedded; fossiliferous, brown crinoid remains 2.5
Limestone: blue gray and brown gray, very coarse; coarsely crinoidal, very fossiliferous; trace phosphatic 0.2
Shale: slightly calcareous 0.3
Limestone: rubbly and knobby 4.0
Limestone: dark neutral gray, brittle, rubbly and knobby; thin uneven bedded, thin calcite veins; light blue buff on weathering, *Diaphragmus* 4.0
Shale: black, fissile 4.0
Limestone: extremely crinoidal, extremely oolitic in lower few inches, black calcite crystals; uneven bedded; weathers rough and crinoidal; *Archimedes* 5.0
Limestone: and shale interbedded 1.0
Shale: black, contains black calcite veins; buff on weathering 5.0

Fayetteville Formation

Shale and covered: black shale, poorly exposed 20.4
Limestone: gray, sublithographic 0.5
Shale: black, fissile 5.6
Shale: poorly exposed 11.2
Shale: black, fissile, well jointed, trace phosphatic 9.2
Shale: blue black, calcareous 2.0
Shale: black, fissile, well jointed 5.6
Shale: poorly exposed, many covered intervals 11.2
Limestone: poorly exposed 2.0
Covered 14.0
Limestone: dark blue gray, very fine; weathers jointed, knobby, and buff 2.0

Total 318.9

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River Bluff Section

Thickness (feet)

W½ sec. 32, T. 15 N., R. 20 E. Measured by C. A. Moore (1947, p. 98-99).

Atoka Formation

Covered to top of hill, bed of sandstone 13.0
Sandstone, poorly exposed 6.0

Bloyd Formation

Limestone: blue gray; uneven bedded; rubbly on weathering 3.0
Covered 24.0
Limestone: blue gray to brown gray, fine medium, with very coarse crystals; thin-bedded; appears sandy on weathering; fossiliferous, crinoidal 2.0
Covered 45.0
Limestone: gray, very fine to sublithographic; weathers uneven bedded and rather rubbly 5.0
Covered 28.0

Hale Formation

Limestone 6.0
Limestone: blue gray, medium, sandy lenses and stringers; weathers red and purplish; fossiliferous 4.0
Sandstone: upper 3 feet well exposed, calcareous, fossiliferous, phosphatic, fine-grained; sandy limestone lenses that are crinoidal 20.0
Shale: blue gray, fissile 3.0
Limestone, very shaly: blue gray to brown gray, coarse medium; extremely fossiliferous, bryozoans, *Pleurodictyum (Michelinia)*, crinoid stems; carries peculiar white and black chert-like pebbles average 5 mm diameter, very iron stained 0.5

Pitkin Formation

Limestone: blue gray to brown gray, fine; many thin-bedded layers, grades laterally into oolitic, light buff gray limestone, fine, with some coarse crystalline crinoidal; weathers uneven and in cross-bedded flutings and spalls off 39.0
Shale 2.0
Limestone 2.0
Limestone: gray to blue gray, sublithographic crystalline; weathers smooth; crinoidal, fossiliferous, bryozoans, brachiopods 7.0
Shale: carries *Archimedes* 0.3
Limestone: rubbly; weathers light blue 4.0
Limestone: lower part, brown gray, fine to very fine; weathers buff and uneven; forms cliff 24.0

Fayetteville Formation

Covered 90.0
Shale 20.0
Limestone; poorly exposed 2.0

Total 349.8

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