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GEOLOGY AND PETROLEUM OF McINTOSH COUNTY, OKLAHOMA

PART I. GEOLOGY AND MINERAL RESOURCES OF McINTOSH COUNTY

by

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with a chapter on paleontology by

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PART II. PETROLEUM GEOLOGY OF McINTOSH COUNTY

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ABSTRACT

Part I. Geology and Mineral Resources

McIntosh County is an area of about 700 square miles in eastern Oklahoma, with a total topographic relief of about 400 feet. The consolidated rocks that crop out in the county are of Pennsylvanian age and are mostly sandstones and shales; shales predominate in amount. The shales are mostly silty to sandy and dark gray to black, but weather to various shades of brown and yellow. The sandstones are conspicuous because their outcrops occupy extensive areas on dip slopes and cap long escarpments, and their residual debris litters much of the area otherwise underlain by shale. Most of the sediments that form these rocks seem to have come from the south but a minor amount, in the northern part of the county, seems to have come from the north. The consolidated rocks contain only one important unconformity, that between the Krebs and Cabaniss Groups of the Des Moines Series.

The surface structure in Boggy and older rocks that crop out in eastern McIntosh County and in adjacent parts of Pittsburg and Haskell Counties is dominated by several westward-trending folds and faults. Major folds are the Brooken Creek syncline, an unnamed anticline, the Porum syncline, the Warner uplift, and the Rattlesnake Mountain syncline. The two major faults are called descriptively the north and south faults of the Warner uplift. This complex structure probably extends beneath western McIntosh County but is concealed there by rocks of the Cabaniss Group, younger than the Boggy Formation.

The post-Boggy rocks that crop out in western McIntosh County dip 1 degree or less toward a little north of west. Local variations in this generally simple structure probably indicate rejuvenation of more pronounced structural features in Boggy and older rocks.

The Quaternary System is represented by unconsolidated rocks, the terrace deposits associated with major streams and the Recent alluvium.

Numerous occurrences of coal have been reported from time to time, but only the Secor vein, in the northern part of the county, has been mined commercially and there has been but little production from that. None of the limestone is of economic importance. Sandstone useful for building is relatively abundant. Shale suitable for common brick and tile could probably be found at many places.

Part II. Petroleum Geology

Since 1912, the year of the completion of the first gas well in the county, 442 tests for oil and gas were drilled through December 31, 1966. Of this total, 19 were completed as oil wells and 167 were completed as gas wells; the remainder were dry holes. On December 31, 1965, the county had 13 producing oil wells and 28 producing gas wells. Production is primarily from Pennsylvanian sandstones.

Hydrocarbon accumulation is generally structurally controlled, but in many instances stratigraphic factors limit production. A combination of structural and stratigraphic control is found in most fields.

A normal sequence of rocks from Pennsylvanian (Des Moines) to Ordovician (Arbuckle) is penetrated by wells drilled in the county. Basement rock has not been reached by drilling, the deepest penetration into the Arbuckle Group being 469 feet. Two nearby wells in adjacent counties have found 1,082 feet and 1,434 feet of Arbuckle rocks overlying the basement.

PART I. GEOLOGY AND MINERAL RESOURCES OF McINTOSH COUNTY

Malcolm C. Oakes

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INTRODUCTION

Purpose. — The primary purpose of this investigation was to study the character, distribution, thickness, and paleontology of the rocks exposed in McIntosh County, in order to apply to them the classification commonly used for stratigraphically equivalent rocks in that part of Oklahoma. Other purposes were to describe deposits of mineral materials of economic value and to make more precise correlations of the exposed rocks with rocks encountered in the subsurface in areas farther west.

Location. — McIntosh County is in the eastern part of Oklahoma (fig. 1). Eufaula, the county seat, is in the south-central part of the county and is about midway between McAlester, the county seat of Pittsburg County to the south, and Muskogee, the county seat of Muskogee County to the north. The county is about 700 square miles in area.

Accessibility. — Eufaula is on U. S. Highway 69, which crosses the eastern part of the county and passes through Checotah and Eufaula. State Highway 9 enters the county from the west, passes across the southern part, and joins U. S. Highway 69 at Eufaula; it follows the route of U. S. Highway 69 a short distance, bears southeast across the Canadian River, and continues eastward across northeastern Pittsburg County and northwestern Haskell County. The northern part of McIntosh County is crossed by U. S. Highway 266, which crosses U. S. Highway 69 at Checotah. Interstate Highway 40 parallels U. S. Highway 266, approximately, a short distance to the south. State Highway 74 enters the county from the north and joins U. S. Highway 266. All these roads are paved. State Highway 52 is paved from Hanna to its junction with State Highway 9; it fol-

Figure 1. Index map of Oklahoma showing location of McIntosh County and adjoining areas in Pittsburg and Haskell Counties.

lows that highway eastward for a short distance and thence extends northward across the western part of the county as a graveled road. The Indian Nation Turnpike crosses the extreme western part of the county from north to south. It crosses State Highway 9 and passes between Vernon and Hanna. Good dirt and graveled roads extend along most section lines except in the most rugged areas and on some of the bottom lands of major streams.

Previous investigations. — Nuttall (1821), Marcou (1855), and Whipple (1855) visited parts of eastern Oklahoma, and one or all may have visited parts of the area now included in McIntosh County. Chance (1890) and Drake (1897) studied the coal fields of Indian Territory (eastern Oklahoma) but did no noteworthy geological work in McIntosh County. Taff (1899, 1901, 1902) and Taff and Adams (1900) studied the rocks that crop out in the coal fields of Indian Territory, south of McIntosh County, and divided them into formations which they named, defined, and described. Of these formations, the Atoka, McAlester, Savanna, Boggy, Stuart, Senora, and Calvin extend northward into McIntosh County.

Gould, Ohern, and Hutchison (1910) proposed that the rocks that crop out in eastern Oklahoma be divided into several named groups, but that proposal was not generally adopted by geologists who worked later in the area. Snider (1914) wrote on the geology of east-central Oklahoma, including the eastern part of McIntosh County.

Clark (1928) and Clark and Bauer (1921) wrote about surface and subsurface rocks of McIntosh County in their relation to the production of petroleum. Dane and Hendricks (1936) traced the Bluejacket Sandstone of northeastern Oklahoma across eastern McIntosh County and correlated it with the lowest sandstone unit of the Boggy Formation, as mapped by Dane, Rothrock, and Williams (1938) immediately south of the county.

Wilson (1937) mapped Tps. 11, 12 N., R. 18 E., in McIntosh County; and Dunham and Trumbull (1955) included secs. 7, 18, 19, T. 11 N., R. 14 E., in their map of the Okmulgee mining district, Okmulgee County.

Present investigation. — The investigations reported here are part of a continuing cooperative project of the Oklahoma Geological Survey and the School of Geology of The University of Oklahoma for geologic mapping in Oklahoma. The imminent flooding of a part of the area by the Eufaula reservoir hastened the field work in McIntosh County.

William D. Pitt mapped Tps. 8, 9, 10 N., R. 13 E. Ralf E. Andrews, Jr., Virgil S. Whitesides, Jr., Charles N. Manhoff, Jr., Frank S. Webb, Robert A. Meek, Joseph G. Stine, and Walter F. Coleman 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. Likewise, Francis Stewart (1949) mapped T. 12 N., R. 18 E., under 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. It was thought best to restudy the area in the light of new knowledge, and the area was reassigned to Coleman.

Field work was done as time was available during the period 1956-1957; by Andrews, July and August 1956; by Whitesides, June through August 1956; by Manhoff, March and July 1956; by Webb, June through July 1956; by Meek, June through July 1956; by Stine, February through July 1957; by Coleman, February to September 1957.

The Oklahoma Geological Survey uses aerial photographs in most of its geologic mapping. The photographs used for the work in McIntosh County constitute a full stereoscopic coverage of prints from negatives made in 1949 for the Agricultural Adjustment Administration of the U. S. Department of Agriculture. Their scale is about 1:20,000, or about 3 inches per mile. The photographs have so little tip or tilt and topographic relief in McIntosh County is so small that the geologic map (pl. I), has more accuracy in detail than is attainable by any method of mapping that involves sketching from a limited number of accurately determined points, such as plane-table mapping, even if done with a telescopic alidade.

All indications of mappable geologic features that appeared on the stereoscopic image were marked on the photographs in the office and investigated later in the field; the photographs served as a stereoscopic base for the field work. All verifiable geologic features and other useful features, such as streams and roads, were transferred to township plats of approximately the same scale as the photo-

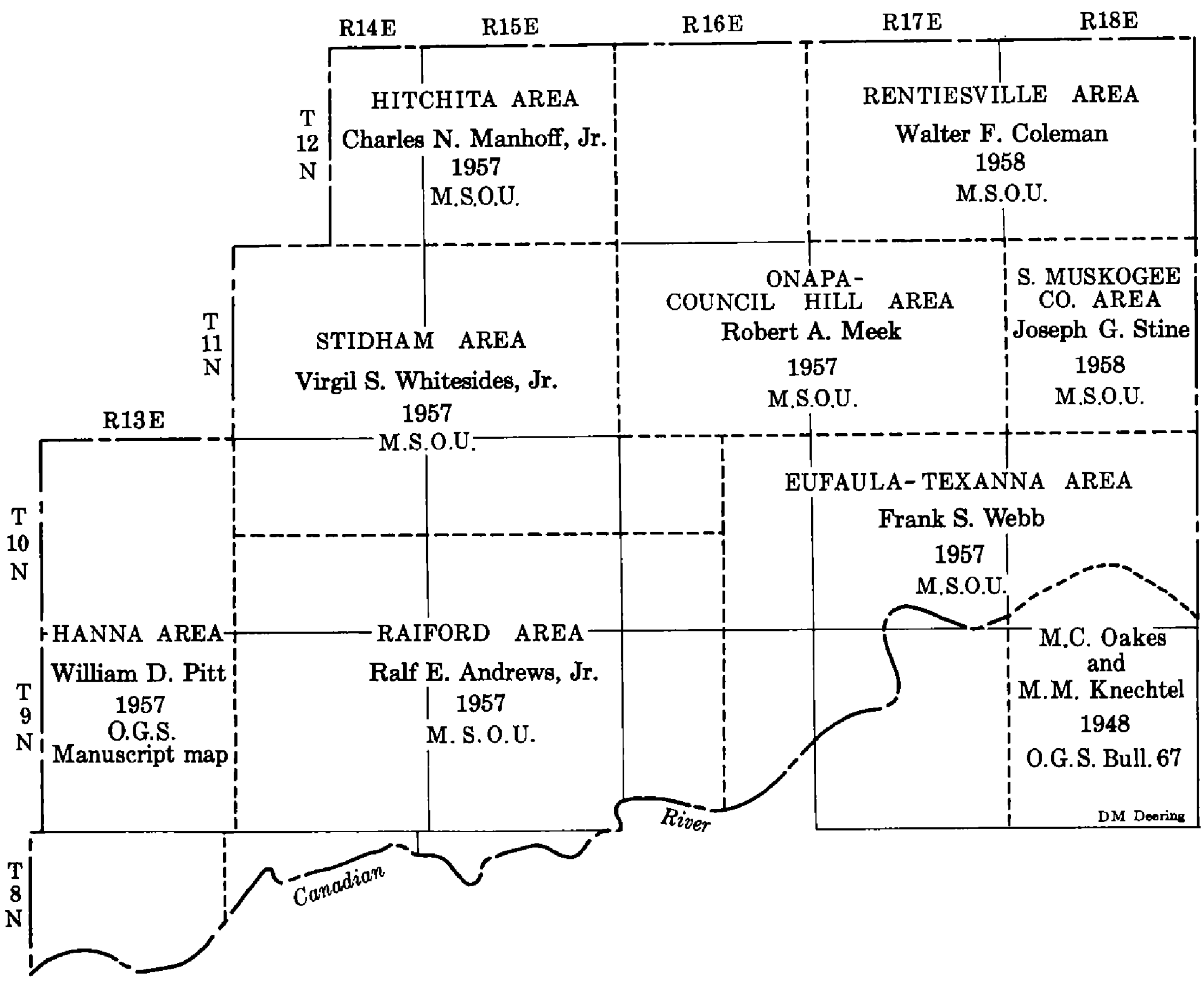

Figure 2. A diagram showing the principal sources of information used in the preparation of this report. The area in Haskell County (from Oakes and Knechtel, 1948) was mapped by the author in the summer of 1944. He also supervised the field work in all other areas.

graphs, principally by tracing. The plats were used in compiling the map of Pitt's area and the maps which accompanied the several theses.

The geologic map of McIntosh County (pl. I), was compiled from the maps described in the preceding paragraph, and includes an area of about 31 square miles in adjoining Pittsburg County, which had not been mapped in detail before. Another area of about 45 square miles in northwestern Haskell County, mapped by the author in 1943-1944 (Oakes and Knechtel, 1948) was added to complete the geologic setting of the Eufaula dam and to include more of the reservoir. The symbols used on plate I are not the same as the symbols that appear on any of the maps from which it was compiled, nor is the grouping of the outcrops into map units exactly the same at all places.

Stratigraphic sections were measured by hand level where feasible. Thicknesses of many of the large shale units were computed. Differences in elevations used in such computations were determined by use of the telescopic alidade or from barometric data, using a single Paulin altimeter. Distances could be measured with sufficient accuracy on the photographs. Barometric readings were corrected for changes in atmospheric pressure and for instrumental drift by prompt return to a previously occupied station; corrections were distributed in proportion to elapsed time. Dips were determined by suitable barometry in the vicinity; local dips, such as can be measured by a clinometer, are generally unreliable for this purpose in this region.

Acknowledgments. — Carl C. Branson, director of the Oklahoma Geological Survey, provided opportunity for participation in the field work leading to this report, gave constructive criticism of the manuscript, and, with L. R. Wilson, wrote the chapter on paleontology. William E. Ham, associate director of the Survey, supervised the drafting and printing of the map (pl. I).

Roy D. Davis, chief geological draftsman of the Survey, and his assistant, David M. Deering, have been helpful with suggestions during the work of drafting the map (pl. I), figures, and representative outcrop sections (pl. II).

Alfred Christy, county agricultural agent of McIntosh County, supplied the data on precipitation and temperature (tables I, II). The citizens of McIntosh County were outstandingly courteous and cooperative during the field investigations. They supplied much information and, without exception, gave ready permission to enter upon and cross their lands.

The author takes this opportunity to express his appreciation to his assistants, William D. Pitt, Ralf E. Andrews, Jr., Virgil S. Whitesides, Jr., Charles N. Manhoff, Jr., Frank S. Webb, Robert A. Meek, Joseph G. Stine, Walter F. Coleman, and Francis M. Stewart, Jr. for their excellent work and for their cheerful companionship in the field.

GEOGRAPHY

Topographic features. — Parts of McIntosh County appear on each of the following 30-minute topographic sheets of the U. S. Geological Survey: Okmulgee (1896), Sans Bois (1897), and the 15-minute Keefeton sheet (1948). Together, these sheets cover the county. The contour interval on the Okmulgee and Sans Bois sheets is 50 feet, and on the Keefeton sheet it is 20 feet. The total relief is about 400 feet, from the Canadian River at the east boundary of the county to the highest hills along the west side of Tps. 10, 11 N., R. 14 E., in the northwestern part of the county.

The Canadian River is the south boundary of McIntosh County; its course trends somewhat north of east and it drops from about 650 feet above sea level to about 500 feet. The North Canadian River flows eastward in a broad arc, concave to the south, through the west-central part of the county, drops from about 620 feet above sea level to about 520 feet, and joins the Canadian River about 3 miles east of Eufaula.

Local relief varies greatly. The maximum by square townships ranges from about 100 feet to about 300 feet.

Present topography is the result of erosion on rocks of unequal resistance. Rocks at the surface are mostly shale, but at varying intervals are more resistant rocks, generally sandstones 5 to 25 feet thick, or even thicker. Originally all strata were deposited essentially horizontally. Subsequently they were tilted and now dip westward, northwestward, and southwestward, commonly at rates of 40 to 60 feet per mile, but beds are steeper locally. Erosion has resulted in the ridge-and-plain type of topography common on rocks of this type and structure.

The hills are generally capped by resistant sandstone that has protected the underlying shale from erosion. Some of the hills are round or oval, and shale is at the surface on all sides, below the sandstone cap. Most hills, however, are elongate, either straight or curved, and, in general, are parallel to the strike of the rock. Most of these elongate hills are asymmetrical. The more gentle slope is in the direction of the dip of the rocks but is less steep. Commonly these more gentle slopes are on sandstone, at least in their upper parts. The sandstone caps the ridges and litters the steeper slopes with debris that ranges in size from large blocks to sand and silt.

Drainage. — A minor part of McIntosh County, the extreme northeastern part, drains into the Arkansas River, outside the county, through Dirty Creek. The remaining and greater part is drained by streams originally tributary to Canadian River but which now flow directly into Eufaula reservoir. One arm of the reservoir drowns Canadian River along the south side of the county; another drowns Deep Fork in the northwestern part; and still another drowns the greater part of North Canadian River in the west-central part. The southwestern part of the county drains into the reservoir through Mill Creek, and the eastern part through Mud Creek and its tributary, Duchess Creek. The parts of Pittsburg and Haskell Counties shown on the geologic

TABLE I. — MONTHLY PRECIPITATION
MCINTOSH COUNTY, 1953-1962

MONTH	MEAN PRECIPITATION (INCHES)
January	1.56
February	1.96
March	4.13
April	4.61
May	6.47
June	3.49
July	5.43
August	5.52
September	4.31
October	3.05
November	2.68
December	2.83

TABLE II. — MONTHLY TEMPERATURE
MCINTOSH COUNTY, 1953-1962

MONTH	MEAN TEMPERATURE (DEGREES F)
January	39.5
February	46.1
March	51.5
April	62.4
May	70.9
June	77.4
July	85.3
August	82.2
September	75.6
October	65.2
November	51.1
December	43.1

map (pl. I) drain into the reservoir through Long Town and Brooken Creeks.

Climate. — The climate of McIntosh County is mild; snow rarely stays on the ground more than a few days. Summers are long and occasionally the temperature rises as high as 95 or 100 degrees F, but rarely higher. The growing season averages 261 days. The mean date of the last killing frost in the spring is March 28. The mean date of the first killing frost in the fall is October 30. Tables I and II are based upon records of the Weather Bureau of the U. S. Department of Commerce for the period 1953 to 1962, inclusive.

Economic development. — A little farming had been done in McIntosh County, as in other parts of Indian Territory, since the middle of the nineteenth century, but prior to the beginning of the twentieth century ranching had been the principal livelihood. At that time farmers began to arrive in force, and within a few years much of the land on the Recent alluvium and high terraces along the streams was under cultivation. Eventually much upland, even some that was totally unfit for tillage, was ploughed. For a few years yields were fairly good. Cotton, corn, and hay were the principal crops. However, little effort was made to check erosion or to maintain the humus in the soil; mineral fertilizers were practically unheard of. Soon the upland fields were gullied and sheet-washed. Much of the bottom land was covered by a blanket of barren sand that grew thicker with every spring overflow. By 1930 the retreat from the land was well underway. Cotton, corn, grain sorghums, and forage crops are still raised, but most of the old fields have been returned to grass and are used for hay and pasture. Stock raising is again a prominent occupation.

McIntosh County did not participate to any great extent in the profitable oil boom that swept sister counties to the north and west, but a modest amount of oil and gas has been produced since the middle of the second decade of this century.

McIntosh County is now at the beginning of a major change. The Eufaula dam, on the Canadian River at the southeast corner of the county, has been completed. It impounds water in the valleys of the Canadian River and of several tributaries that enter the Canadian just above the dam, from both south and north. More water is impounded along the tributaries than along the Canadian itself. The lake extends from the vicinity of Hartshorne and McAlester in Pittsburg County, across McIntosh County, to the vicinity of Henryetta in Okmulgee County, with many miles of shoreline. Considerable hydroelectric power will be generated. McIntosh County will be an important recreation center, and should have some light manufacturing.

SURFACE STRATIGRAPHY

Historical setting. — It will be easier to understand the stratigraphy, character, and interrelations of the rocks that crop out in McIntosh County if we first review, even though briefly, the history of deposition and structural changes in a much wider region that includes eastern Oklahoma, southeastern Kansas, southern Missouri, and northwestern Arkansas. The following discussion first appeared in Oklahoma Geological Survey Bulletin 91 (Oakes, 1963, p. 17-20) and is equally applicable here.

This wider region consists of two areas: the northern and western area, usually called the shelf or platform area, and the southern area, usually called the Ouachita geosynclinal area. The shelf area is commonly subdivided into two areas based upon the present attitude of the rocks. One subdivision 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 present on the shelf and in the geosynclinal area range in age from Cambrian to Pennsylvanian, inclusive. 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.

In contrast, the rocks of the geosynclinal area are mostly clastic. Nearly all units thicken remarkably southeastward. The evidence indicates that the source of the clastic sediments in the geosynclinal area and of much of the clastic sediments on the shelf was an ancient landmass somewhere to the southeast, now buried beneath Cretaceous and younger rocks. However, some of the clastics on the shelf seem to have come from the east, others from the north, and some even from the west. Many of the sandstones in the geosynclinal area thin out and disappear northward before they reach the shelf area, but some clastic units extend from the geosynclinal area northward over the shelf area with great thinning, convergence of beds, and gradual change of facies. They thus indicate that the shelf area was changing but little with respect to the level of the sea during the time when the geosynclinal area was sinking and being filled continuously or intermittently. It is probable that the geosyncline was so well filled with clastic sediments much of the time that the water was shallower over the geosynclinal area than over the shelf area. Futhermore, coal beds of Pennsylvanian age that extended over part of the shelf area and are still preserved from erosion in the north end of the geosynclinal area indicate that at times swamps extended over parts of both areas.

At the present time, Mississippian rocks crop out around the Ozark dome except where they are covered by Quaternary sediments, and outliers of Mississippian rocks are so distributed over much of the Ozark dome as to indicate that much of the area of the dome was below sea level in at least part of Mississippian time. Also, outliers of probable Desmoinesian (Pennsylvanian) age are distributed over a considerable part of the Ozark dome, many being preserved in sinkholes into which they have fallen. They indicate that probably as late as Desmoinesian time, and possibly later, the area of the Ozark dome was truly a part of the shelf area.

Rocks of the greater part of the Ouachita geosynclinal area have been much folded, and in Oklahoma they have been much faulted. These folded and faulted rocks now form the Ouachita Mountains, the northern limit of which in Oklahoma is the Choctaw fault. The forces that formed the Ouachita Mountains were compressive, from the south and southeast, and most of the large faults are reverse faults, upthrown on the south side. The rocks in that part of the geosynclinal area north of the Choctaw fault have been squeezed between rocks of the Ouachita Mountains and rocks of the stable shelf area, and now lie in an east-west syncline, formerly called the McAlester coal basin or the Arkansas-Oklahoma coal basin, but now called the Arkoma basin (Branson, 1956, p. 83).

It has been generally observed in drilling for oil and gas in Oklahoma that most structures persist to great depths. In general, they are most intensely folded and faulted in the oldest rocks penetrated by drilling, as if they were initiated at an early time and have been repeatedly rejuvenated. They may even extend into the basement rocks. By analogy we may surmise, or perhaps even assume, that the present structure of the Ouachita Mountains had its beginning as more or less gentle folds and perhaps even small faults long before the youngest of the rocks of the Ouachita Mountains were deposited.

Rocks younger than the Atoka Formation have been eroded from the Ouachita Mountains 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, thins northward out of the basin; many of the sandstone units pinch out in that direction, others converge, and at least two merge. It appears that the McAlester sediments 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, and 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 are of Atokan age, but earlier uplift of considerable magnitude is indicated by chert pebbles near the base of 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-Atokan 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 were over before the Thurman Sandstone was deposited.

Rocks in the Arkoma basin and on the shelf west of the Ozark dome as young as the Boggy Formation are only less complexly folded and faulted than are the rocks in the Ouachita Mountains. The character, distribution, and orientation of these folds and faults indicate that some are related to the compressive forces that made the Ouachita Mountains, and others to the more vertical forces that raised the eastern part of the shelf area to make the present Ozark dome. Some of these structures are discernible in the Thurman Sandstone and younger rocks, but in these younger rocks the amplitude is much smaller. One exception is the Ahloso fault, south of Ada, Pontotoc County. It cuts the Thurman Sandstone 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 Mountains area.

Chert pebbles in the Thurman Sandstone and younger formations seem to have come from the southeast and their presence indicates recurrent uplift in the Ouachita Mountains, but lack of evidence of pronounced movement in the Thurman and younger rocks indicates that these later stresses in the Ouachita Mountains 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, and occasional weak tremors indicate that some faults in the Ouachita Mountains and in the Arkoma basin are still slightly active.

General character. — The consolidated rocks that crop out in McIntosh County are mostly shales, but sandstones are conspicuous because their outcrops occupy extensive areas on dip slopes, they cap long escarpments, and their residual debris, ranging in size from large blocks to sand and silt, litters much of the area otherwise underlain by shale. Two thin limestone beds crop out inconspicuously in the northern part of the county, in the Boggy Formation. One, the Inola Limestone, is from 215 to 350 feet above the base of the Boggy; the other, unnamed but designated IPb-l on plate I, is about 450 feet above the base.

Origins. — The sediments that comprise most of the sandstones and shales of southern McIntosh County apparently came from the south, and probably from the Ouachita Mountains area. All units are much thicker in that direction; the sandstones are coarser grained and some are even conglomeratic. Some of these sandstones of apparent southern origin, notably the Bluejacket Sandstone Member of the Boggy Formation and the sandstones of the Senora Formation, are continuous northward beyond the county. However, some sandstones in the middle part of the Boggy extend into the county from the north and probably do not have counterparts in southern McIntosh County or farther south. They seem to have their origins northward and eastward, and some may contain constituents from the northwest. The Inola Limestone extends far to the north but is not present in the southern part of the county.

Nomenclature. — The names Atoka, Hartshorne, McAlester, Savanna, Boggy, Thurman, Stuart, and Senora used in this report belong to the nomenclature established in the area north of the Arbuckle Mountains. The name Bluejacket, applied to the basal sandstone of the Boggy Formation, belongs to the nomenclature of northern Oklahoma, as does the name Inola, applied to a limestone member of the Boggy Formation. Two other names that belong to the nomenclature of northern Oklahoma, Crekola and Taft, are not used in this report. The name Crekola has been applied to several different tongues of the Bluejacket Sandstone by several different workers, including Wilson (1935, 1937). Similarly, the name Taft has been applied to several different sandstones in the upper part of the Boggy Formation.

PENNSYLVANIAN SYSTEM

Pennsylvanian rocks of northern Oklahoma are included in three main divisions. They are the Des Moines Series, the Missouri Series, and the Virgil Series, in ascending order. South of the latitude of central Mayes County are Pennsylvanian rocks older than Desmoinesian. Most of the rocks that crop out in McIntosh County are included in the Des Moines Series, but rocks of late Atokan age crop out in a small area in the northeastern part of the county.

Pre-Desmoinesian Rocks

Five lenses of fine-grained, silty sandstone and siltstone crop out in the northeastern part of T. 11 N., R. 18 E., and in the extreme southeastern part of T. 12 N., R. 18 E., on the Warner uplift. Together with the associated shales they are here referred to the Atoka Formation because they are older than rocks identifiable as McAlester, because the sandstones are finer grained and more lenticular than is common among McAlester rocks, and because none seemed representative of the Hartshorne Sandstone. Both the Hartshorne Sandstone and the associated Hartshorne coal are probably absent from this area on the Warner uplift.

Des Moines Series

In Iowa, Missouri, and Kansas the base of the Des Moines Series is generally placed at the unconformity between the Pennsylvanian and pre-Pennsylvanian rocks, Mississippian and older. This placement is satisfactory for northern Oklahoma, but south of central Mayes County are still older Pennsylvanian rocks. They are thousands of feet thick in the Arkoma basin, in contrast to the mere hundreds of feet of Desmoinesian rocks along the Kansas-Oklahoma line. Some writers have placed these older, much thicker Pennsylvanian rocks in the Des Moines Series, in accordance with the practice of placing the lower boundary of the Des Moines at the pre-Pennsylvanian unconformity. To others, such a drastic expansion of the Des Moines Series has seemed out of place, out of proportion, and incongruous with usual practice. However, attempts to reach other generally acceptable solutions foundered in a sea of perplexity.

By the time preparation of the *Geologic Map of Oklahoma* (Miser, 1954) was nearing completion, it seemed fairly certain that future usage would arrange these older Pennsylvanian rocks in several series, and that the youngest would include the rocks of the Atoka Formation. Accordingly, Oakes (1953) placed the base of the Des Moines Series in Oklahoma at the top of the Atoka Formation, or the top of pre-Pennsylvanian rocks wherever the Atoka Formation is absent. The top of the series is at the obscure but important and extensive pre-Missourian unconformity, at the base of the Seminole Formation.

In Kansas and northern Oklahoma, as far south as the Arkansas River, the Marmaton

Group of the Des Moines Series extends from the base of the Fort Scott Limestone, below, to the top of the series. Farther south in Oklahoma, the upper limit is the same, but the Fort Scott Limestone is not identifiable much farther south than the Arkansas River. In the course of field work incident to the preparation of the *Geologic Map of Oklahoma* (Miser, 1954), Oakes (1953) found that the base of the Fort Scott Limestone occupies substantially the same stratigraphic position as does the base of the Calvin Sandstone south of the Arkansas River and placed the base of the Marmaton Group at the base of the Calvin in that area. He found further that at the top of the Boggy Formation is an unconformity which is of considerable extent; he therefore subdivided the Desmoinesian rocks older than the Marmaton into two groups: the Krebs Group, below the unconformity, and the Cabaniss Group, above.

At many places along the unconformity, shale below is succeeded by similar shale above, and the unconformable contact cannot be mapped exactly. The criteria for drawing the unconformity are: (1) the abrupt change in the character of the sediments in the Arkoma basin, south of McIntosh County, where chert pebbles mixed with coarse quartz sand in the base of the Thurman Sandstone abruptly succeed shale and fine-grained sandstone of the Boggy Formation; (2) a distinct paleontological break, especially noticeable north of the Arkansas River; and (3) marked structural discordance.

KREBS GROUP

The Krebs Group was named for the town of Krebs in T. 5 N., R. 15 E., central Pittsburg County, Oklahoma (Oakes, 1953) and includes, in ascending order, the Hartshorne Sandstone, the McAlester Formation, the Savanna Formation, and the Boggy Formation.

TABLE III. — SUBDIVISIONS OF THE KREBS GROUP IN OKLAHOMA

Des Moines Series
unconformity
Krebs Group
Boggy Formation
Savanna Formation
McAlester Formation
Hartshorne Sandstone
Pre-Desmoinesian rocks*

* Of the pre-Desmoinesian rocks, only the upper part of the Atoka Formation crops out in McIntosh County.

The rocks of the Krebs Group include minor amounts of limestone and some important coal seams, but they are dominantly dark to gray clay shale and some silty shale, alternating with sandstone in widely spaced units. They crop out from the northeast flank of the Arbuckle Mountains northeastward to the Kansas-Oklahoma line and eastward in the Arkoma basin to the Arkansas-Oklahoma line. They are thickest along the axis of the Arkoma basin, about 6,000 feet thick west of McAlester and more than 8,000 feet thick in T. 7 N., R. 25 E., near Poteau, about 9 miles east of the Arkansas-Oklahoma line, where much of the Boggy Formation has been eroded. They are much thinner both southwestward and northeastward, out of the Arkoma basin, and the thinning is apparent in all formations and in even their smallest mappable units (Oakes, 1953).

The Krebs Group is conformable on the Atoka Formation, below, wherever the Atoka is present, but is unconformable on older rocks both in the Arbuckle Mountains and in northeastern Oklahoma. It is unconformable beneath the Cabaniss Group, above.

Hartshorne Sandstone

Outcrops of the Hartshorne Sandstone were not found in McIntosh County. One would expect to find such outcrops in the eastern part of T. 11 N., R. 18 E., but the Warner uplift was probably too high in Hartshorne time to receive sand deposits.

McAlester Formation

Nomenclator. — J. A. Taff (1901).

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

Original description. — Of the formation in the McAlester district, Taff (1899, p. 437) wrote:

> This formation, for convenience of discussion, may be divided into a series of three parts. The lowest one is composed almost entirely of shale, with thin sandstone and coal, in all 800 feet thick. Locally sandstone occurs with thin coal beds near the center of this shale. The Hartshorne or Grady coal occurs at the base of this shale. The middle division of the McAlester shale is composed of three to four beds of sandstone separated by shale 100 to

200 feet thick. Together these beds of sandstone and shale are about 500 feet thick. The lowest of these sandstone beds caps the mesa of Belle Star Mountain and the ridge northwest of Hartshorne. Here it is nearly 200 feet thick. Over most of its surface area, however, the sandstone is not well exposed. The upper division is almost entirely of shale nearly 700 feet thick and the McAlester coal is about 50 feet above its base. Several thin seams of coal occur in this shale also, but none have been found thick enough to be workable. The shale is blue, gray or black, with the gray color predominating.

History of usage. — Common usage in Oklahoma has attempted to apply the term "McAlester Shale" or "McAlester Formation" to the strata between the top of the Hartshorne Sandstone, below, and the base of the Savanna Formation, above. Oakes and Knechtel (1948, p. 23) restricted the McAlester to strata above the Hartshorne coal in Haskell County and that restriction should be extended to McIntosh County, but in as much as the Hartshorne Sandstone cannot be identified and the Hartshorne coal, commonly associated with it, has not been found, the base is indeterminate in McIntosh County. Oakes and Knechtel (1948, p. 51) presented evidence that the base of the Spaniard Limestone of Wilson (1935, 1937) is, for all practical purposes, the top of the McAlester Formation in Muskogee County. Accordingly, the base of the Spaniard is here taken as the top of the McAlester Formation in McIntosh County.

Distribution. — Outcrops of the McAlester Formation extend from the north flank 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. The formation crops out across the Warner uplift, along the east side of McIntosh County.

Character. — The McAlester Formation in the Arkoma basin, south of McIntosh County, consists predominantly of clay shale and silty shale, but at widely spaced intervals are prominent sandstone beds which give rise to conspicuous escarpments. The McAlester contains also a few thin discontinuous limestone beds and several coal seams. The only seams which have been much worked are the Lower McAlester, the Upper McAlester, and the Stigler seams. The Stigler is worked in Muskogee and Haskell Counties, east and southeast of McIntosh County. Some geologists have equated the Stigler coal with the Upper McAlester coal, but others have considered it a somewhat higher seam.

In 1927 Thom made a preliminary investi-

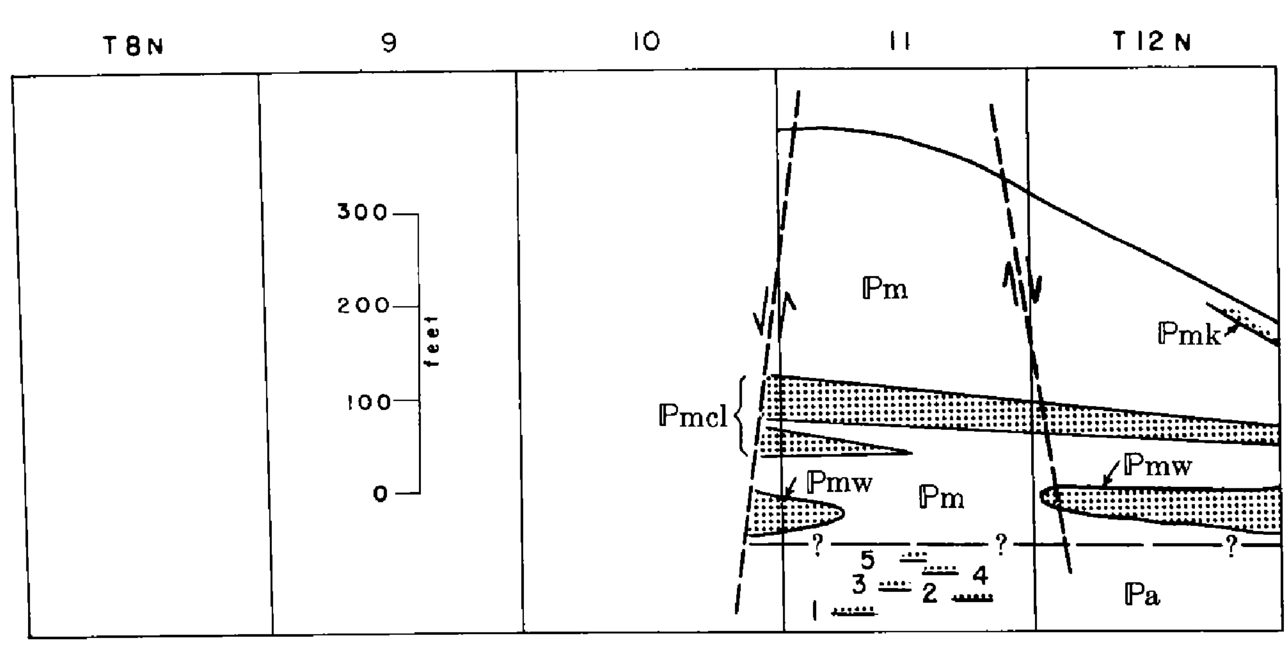

Figure 3. Diagram of the McAlester Formation and the upper part of the Atoka Formation in Tps. 10, 11, 12 N., R. 18 E., approximately to scale. Faults of the present Warner uplift are indicated by dashed lines. The Warner Sandstone (IPmw) is present in the Rattlesnake Mountain syncline but is absent over most of the uplift, which was probably too high in Warner time to retain sediments. At least the upper part of the Cameron-Lequire Sandstone (IPmcl) was probably deposited across the uplift. The Keota Sandstone (IPmk) is commonly erratic in both character and distribution; a representative is thought to be present in the Rattlesnake Mountain syncline.

The upper part of the Atoka Formation (IPa) is represented by five sandstone lenses. Neither the Hartshorne Sandstone nor the Hartshorne coal is present, and consequently the boundary between the Atoka and the McAlester cannot be drawn.

gation of most of Haskell County and of northern Le Flore County, in the course of which he applied names to most of the sandstone units of the McAlester Formation and to the lower shale unit (Thom, 1935). Charles W. Wilson, Jr., under Thom's direction, carried these names northward into Muskogee County and made first published application of them (Wilson, 1935). From the base upward the units so named are the McCurtain Shale, the Warner Sandstone, the Lequire Sandstone, the Cameron Sandstone, the Tamaha Sandstone, and the Keota Sandstone. At places, even in Haskell County, the shale intervals between some of the named sandstone units are so filled with sandstone that hyphenated names were applied, such as Cameron-Lequire and Lequire-Warner (Oakes and Knechtel, 1948).

McCurtain Shale

The McCurtain Shale is the oldest member of the McAlester Formation. Representatives probably are present on the Warner uplift in the eastern part of T. 11 N., R. 18 E., but are not differentiated as such on plates I and II because the Hartshorne coal, which normally lies immediately below the McCurtain at this latitude, is absent, as is the Hartshorne Sandstone, which is commonly found a short distance below the coal; and further, because the Warner Sandstone, which commonly overlies the McCurtain, is absent over much of the area. The McCurtain Shale was therefore mapped with shale in the upper part of the Atoka Formation and with shale younger than Warner, which extends unbroken up to the Cameron-Lequire Sandstone over most of the Warner uplift.

Warner Sandstone (IPm-w)

The Warner Sandstone was mapped into McIntosh County from Muskogee County by Stine (1958) and by Coleman (1958). In weathered exposures the Warner is buff to brown, medium grained, cross-bedded, and soft. The exposure in the southeastern part of T. 11 N., R. 18 E., is about 40 feet thick at the east line but pinches out in sec. 26, on the Warner uplift. The exposure in the northeastern part of T. 12 N., R. 18 E., is also about 40 feet thick and contains a shale a few feet thick in the upper part, in which is a thin coal seam. Such shale and coal combinations are common in Muskogee and Haskell Counties. The Warner Sandstone was probably not deposited on the highest parts of the Warner uplift.

The shale that overlies the Warner Sandstone is brown and silty, and contains thin, discontinuous, silty sandstone lenses. It is estimated to be about 60 feet thick in the southeastern part of T. 11 N., R. 18 E., and is about 25 feet thick in the northeastern part of T. 12 N., R. 18 E. Equivalent shale is mapped with shale in the upper part of the Atoka Formation where the Warner is absent.

Cameron-Lequire Sandstone (IPm-cl)

Two sandstones separated by 13 feet of shale are present north of the south fault of the Warner uplift in secs. 1, 2, 3, T. 10 N., R. 18 E., and in secs. 34, 35, 36, T. 11 N., R. 18 E.; the lower sandstone is 30 to 40 feet thick, and 45 feet of the upper sandstone is exposed. The sandstones and the shale between them thin northward so that in sec. 23, T. 11 N., R. 18 E., only one sandstone is present. This sandstone continues northward across the Warner uplift to the north fault. Throughout, the top is concealed by Quaternary cover. Because of the stratigraphic position of the sandstone, above the Warner sandstone, and because of its thickness, it is here mapped as a representative of the Cameron-Lequire Sandstone of Haskell County.

A coal seam 8 to 10 inches thick has been mined locally in the northeastern part of T. 12 N., R. 18 E. It is here called the Stigler coal because the Stigler is the one seam persistently present in the McAlester Formation of Muskogee County, immediately east of McIntosh County. A soft, brown, thin-bedded, cross-bedded, fine- to medium-grained, ripple-marked sandstone, 4 to 6 feet thick, crops out only a few feet at most below the coal and is here mapped as a representative of the Cameron-Lequire Sandstone because of similarly close association of the Cameron-Lequire with the Stigler coal elsewhere.

Rocks of McAlester age younger than the Cameron-Lequire Sandstone in T. 11 N., R. 18 E., are concealed by terrace deposits of Quaternary age. The shale that overlies the Cameron-Lequire in the northeastern part of T. 12 N., R. 18 E., is brown and silty, contains thin silty sandstone lenses, and is about 30 feet thick.

Tamaha Sandstone (IPm-t)

The Tamaha Sandstone is thought to be

represented by soft, brown, medium- to fine-grained sandstone, estimated to be less than 2 feet thick, which crops out locally in secs. 3, 10, T. 11 N., R. 18 E. The shale that overlies the Tamaha in sec. 10 is brown and silty and about 120 feet thick. It contains two lenticular limestones, each less than 1 foot thick, and one thin coal seam, all unmapped. The lower of the two limestones is about 30 feet above the Tamaha representative. It was seen at only one place, where it grades from fossiliferous limestone to a clay ironstone concretionary bed within 75 feet. The higher of the two limestones is about 100 feet above the representative of the Tamaha. It is less than 1 foot thick. The coal seam is about 1 inch thick and lies less than 1 foot below the upper limestone.

Keota Sandstone (IPm-k)

A brown silty sandstone about 6 feet thick crops out in the upper part of the McAlester Formation in the northeastern part of T. 12 N., R. 18 E. Because of its character and stratigraphic position, it is here considered to be a much attenuated representative of the Keota Sandstone Member of the McAlester Formation in Haskell County, where the Keota is a sequence of lenticular sandstones and arenaceous shales, containing locally one or more coal seams of no economic value. At some places in Haskell County, the Keota sequence is more than 200 feet thick. The shale that overlies this representative of the Keota in the northeastern part of T. 12 N., R. 18 E., only about 20 feet thick at most, is brown to gray and silty, and at some places fossiliferous. It contains a coal seam about 1 inch thick and 0.5 to 1.5 feet below the overlying Spaniard Limestone, the basal member of the Savanna Formation in Muskogee and McIntosh Counties.

Savanna Formation

Nomenclator. — J. A. Taff (1899).

Type locality. — Taff did not mention a specific type locality, but he probably had in mind the vicinity of Savanna, Pittsburg County, Oklahoma.

Original description. — Taff (1899, p. 437) wrote:

> Next above the McAlester shale there is a series of sandstones and shales about 1,150 feet thick. The shaly beds combined are probably thicker than the sandstones, but since the sandstones are better exposed and their presence is so strongly impressed upon the observer in the prominent ridges which they make, sandstone seems the more appropriate term. There are five principal sandstone beds, which have different thicknesses, from nearly 50 feet to 200 feet, the one at the top and the one at the base being generally thicker than the intermediate ones. These sandstones may be distinguished only by their position in the section or their thickness of bedding. They are brown or grayish brown, fine grained and compact. Except in the uppermost beds, upon which the town of South McAlester is built, the beds are generally thin and in part shaly. The uppermost sandstone occurs in two members, 75 to 100 feet thick, separated by variable blue clay shales. The uppermost beds of sandstone are found in many places to be massive, and those in contact with the shale are often beautifully ripple marked. No coal of any value has been found associated with these beds of sandstone in the McAlester district, though a thin bed has been reported to occur in the upper part of the series.

History of usage. — For many years usage of the term "Savanna Sandstone" or "Savanna Formation" attempted to follow the original sense of Taff. However, because of the variable nature of individual beds, difficulties of precise correlation, and lack of detailed mapping, writers in various areas may have included, both above and below, somewhat more or less than equivalents of the original Savanna 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) in an attempt to correlate them with Savanna rocks in the vicinity of Savanna, Pittsburg County, at a time when detailed geologic mapping of the intervening territory was incomplete. When the *Geologic Map of Oklahoma* was compiled by Miser (1954) the top of the Savanna Formation was raised to the base of the Bluejacket Sandstone Member of the Boggy Formation because that proved to be the longest continuously mappable boundary available, and it seemed suitable and acceptable. Thereby a unit, as much as 800 feet thick and consisting dominantly of shale but containing a variable amount of sandstone, was transferred from the Boggy Formation to the Savanna Formation. The rocks so transferred contain the Doneley Limestone and its closely subjacent Rowe coal seam, the "lower Boggy" coal of Wilson (1937, p. 53).

Distribution. — Like the underlying Mc-

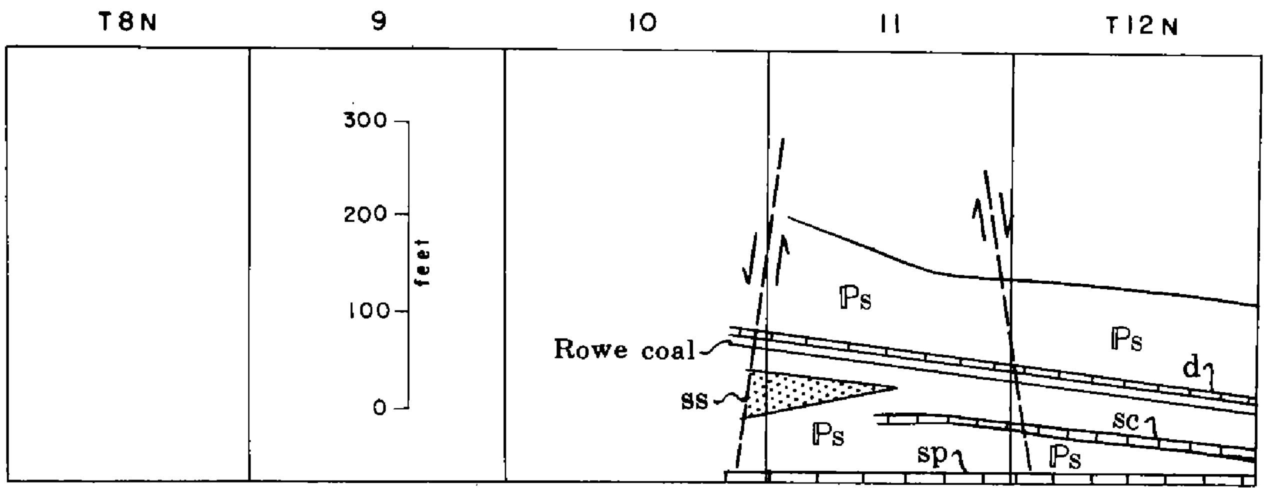

Figure 4. Diagram of the Savanna Formation, approximately to scale. Faults of the present Warner uplift are indicated by dashed lines. The Spaniard (sp) and Doneley (d) Limestones and the Rowe coal are present in both the Porum and Rattlesnake Mountain synclines but have not been found on the uplift, but may be present. The Spiro Sandstone (ss) is present in the Porum syncline but seems to pinch out on the uplift where it may well be covered by terrace deposits. The Sam Creek Limestone (sc) is present in the Rattlesnake Mountain syncline and on the uplift but is absent in the Porum syncline and farther south.

Alester Formation, the Savanna Formation crops out from the north flank 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. It crops out in eastern McIntosh County, in Tps. 10, 11, 12, N., R. 18 E.

Thickness and character. — The author concludes from data by Hendricks (1939, p. 272) and by Knechtel (1949, p. 30) that the Savanna Formation of present usage is about 2,500 feet thick along the axis of the Arkoma basin, in the vicinity of Cavanal Mountain, in eastern Oklahoma.

Hendricks (1939, p. 273, fig. 16) indicated that the Savanna Formation of older usage is about 1,500 feet thick along the axis of the Arkoma basin about 25 miles south of eastern McIntosh County. The author estimates that the thickness of the shale and minor amount of sandstone between the originally defined top of the Savanna and the base of the Bluejacket Sandstone is about 500 feet in that vicinity, and therefore concludes that the Savanna Formation of present usage is about 2,000 feet thick there.

The Savanna Formation in the Arkoma basin consists mostly of sandstone and shale. The sandstones are highly variable in both thickness and character from place to place in a single bed and from bed to bed. It contains also a few disconnected, thin limestone beds and numerous coal seams too thin to be worked. Like other formations, the Savanna thins markedly northward out of the basin. It thins northward across eastern McIntosh County, from 300 feet thick in T. 10 N., R. 18 E., to 200 feet thick in T. 12 N.; it contains one named and mapped sandstone unit, three named and mapped limestone units, and one coal seam, the Rowe coal, formerly called lower Boggy coal (Wilson, 1937, p. 53).

Spaniard Limestone (IPs-sp)

The Spaniard Limestone, at the base of the Savanna, was named by S. W. Lowman from Spaniard Creek, SW¼ NE¼ sec. 11, T. 13 N., R. 18 E., Muskogee County, in an unpublished manuscript, from which Wilson (1935, p. 510) quoted the following measured section:

	FEET	INCHES
Dark-gray, fine-grained limestone; weathers brown	1	2
Dark to black, fossiliferous shale; weathers buff	0	6
Blue-gray, fossiliferous, calacreous shale	1	6
	3	2

Oakes and Knechtel (1948) suggested that the base of the Spaniard Limestone is a suitable marker for the base of the Savanna Formation in Muskogee County and farther north in Oklahoma. They did not presume to say that the Spaniard is continuous with the sandstone at the base of the Savanna in Haskell County, but did say that it seems to occupy substantially the same stratigraphic position.

Coleman (1958) found that the Spaniard Limestone varies greatly in appearance in T.

12 N., R. 18 E., McIntosh County, and in T. 13 N., R. 18 E., Muskogee County. The variation depends in part on the environment of weathering. In streams, it appears dark and is normally smooth and dense, but in well-drained places the weathered surface is normally light gray and at some places has the texture of a coquina. It is generally less than 1 foot thick. The Spaniard is probably concealed by Quaternary cover in T. 11 N., R. 17 E. Webb (1957, 1960) saw it at only one place in T. 10 N., R. 18 E., on the north flank of a small anticline about ⅓ mile south of NE cor. sec. 1, where it is about 0.5 foot thick, is dark gray to black, weathers buff, contains numerous brachiopod fragments and crinoid stems, and is quite impure. A 50-gram sample, boiled with hydrochloric acid, yielded 31.4 percent of insoluble residue, which consisted mostly of clay minerals with a few fine quartz grains. The Spaniard at this place is overlain by, and should probably include, 1.5 feet of clay shale which contains large crinoid columnals and many fragments of species of the brachiopod *Desmoinesia.*

Sam Creek Limestone (IPs-sc)

The Sam Creek Limestone was named by S. W. Lowman in the unpublished manuscript mentioned above. The name is from Sam Creek and the type locality is in sec. 12, T. 14 N., R. 18 E., Muskogee County. Wilson (1935, p. 510) quoted the following measured section from the manuscript:

	FEET	INCHES
Gray limestone; weathers brown; contains so many *Marginifera muricata* that it is almost a coquina	0	6
Gray fossiliferous shale	3	6
Alternations of gray limestone, and gray fossiliferous shale; the former essentially a reef composed of *Campofilium torquium*	0	11
Gray limestone with layers of gray shale	3	8
	8	7

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

Coleman (1958) found that a shale zone about 80 feet thick extends from the top of the Spaniard Limestone to the base of the Doneley Limestone in the northeastern part of T. 12 N., R. 18 E. It is mostly gray to brown silty shale and should contain the Sam Creek Limestone and the Spiro Sandstone. The Spiro was not found and probably was not deposited there, but Coleman did find a zone filled with fossiliferous shale and thin limestones and thought that at least part of the zone represents the Sam Creek Limestone. Surficial cover and slumping in the area preclude mapping any of the limestone beds continuously for any appreciable distance, and it was only with difficulty that sections could be measured. However, from a study of the sections measured by Coleman, the author concludes that the zone is about 20 feet thick; probably contains three limestone beds, each less than 1 foot thick, the oldest being about 25 feet above the Spaniard Limestone and the youngest about 35 feet below the Doneley Limestone; and that the zone represents the Sam Creek Limestone of Lowman.

The Sam Creek Limestone mapped by Meek (1957) in T. 11 N., R. 17 E., is about 4 inches thick. It is dark gray but weathers to light gray; it is dense to platy and fossiliferous. Gray shale, approximately 48 feet thick, is exposed below the Sam Creek of this locality. The lower part of the shale, and probably the Spaniard Limestone as well, is concealed by Quaternary cover.

Webb (1957, 1960) said that in T. 10 N., R. 18 E., the strata above the Spaniard Limestone and its overlying 1.5 feet of fossiliferous clay shale consist of alternating dark-gray to gray shale and thin siltstones and sandstones. The unit is progressively more silty and sandy toward the top and grades into the overlying Spiro Sandstone. It is 75 feet thick and includes the horizon of the Sam Creek Limestone, but the Sam Creek was not found and, in as much as it belongs to the shelf facies, it probably was not deposited that far south. The best exposures of this shale are in sec. 10, along Black Haw Creek and its tributaries, which flow toward the axis of the anticline.

Spiro Sandstone (IPs-s)

The Spiro Sandstone of McIntosh County is of the basin facies and is probably continuous with the lower tongue of the upper sandstone unit of the Savanna Formation in

T. 10 N., R. 19 E., Haskell County (Oakes and Knechtel, 1948, p. 51), which is 400 feet below the top of the Savanna Formation of present usage in that area. The sandstone mapped by Webb (1957, 1960) as Spiro in T. 10 N., Rs. 17, 18 E., is about 180 feet below the top of the Savanna and about 75 feet above the base. It consists of tan, fine-grained, thin- to massive-bedded sandstone which weathers brown to gray, is 30 to 40 feet thick, and grades into shale both above and below.

In T. 11 N., R. 17 E., gray to tan, silty shale, 22 feet thick, overlies the Sam Creek Limestone and grades upward into the Spiro Sandstone, which is 4 to 5 feet thick and consists of grayish-tan, fine-grained, micaceous, cross-bedded, thin-bedded sandstone that weathers reddish brown. As in T. 10 N., R. 18 E., it is the first sandstone below the top of the Savanna Formation. It has not been found farther north in McIntosh County.

Doneley Limestone (IPs-d)

A description of the Doneley Limestone was first published by Branson (1952, p. 192), as follows:

> 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 to and 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, which is shown on the United States Geological Survey Topographic Map of Vinita Quadrangle in the NW¼ sec. 27, T. 26 N., R. 20 E. This school has been replaced by the Pheasant 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 Doneley in the northeastern part of T. 12 N., R. 18 E., is a gray fossiliferous limestone. Its thickness is variable but it averages 0.5 foot. Commonly the outcrop is indicated by weathered brown fossiliferous rubble. It contains *Neospirifer,* Bryozoa, and crinoid debris. At one locality a pebbly maroon limestone was found at the horizon of the Doneley. The Doneley is overlain by 40 to 60 feet of black to dark-gray fissile shale containing concretionary clay ironstone beds and at some places a thin fossiliferous limestone bed, not mapped. Above the black shale is about 50 feet of brown silty shale which grades upward into the Bluejacket Sandstone at the base of the Boggy Formation, about 100 feet above the Doneley Limestone.

In T. 11 N., R. 17 E., poorly exposed shale about 150 feet thick extends from the Spiro Sandstone, below, to the base of the Bluejacket Sandstone, above. Neither the Doneley Limestone nor its closely underlying coal was found, but both could well be concealed by the colluvium. The lower part of this shale is gray to black, and the upper part is gray and silty to sandy.

In T. 10 N., R. 18 E., the shale between the Spiro Sandstone, below, and the Bluejacket Sandstone, above, is about 180 feet thick; it is so poorly exposed as to preclude detailed description. However, it ranges from gray to black, from silty to clayey, and from fissile to blocky. The upper part contains bands of clay ironstone concretions. The Doneley Limestone and the Rowe coal are exposed about 30 feet above the Spiro Sandstone in NW¼ SW¼ NE¼ sec. 11, T. 10 N., R. 18 E. The Rowe coal is about 6 inches thick and the superjacent Doneley Limestone is less than 1 foot thick. In consequence of its high organic content, the Doneley is gray to black; its insoluble residue is 9.7 percent. The Rowe coal was found also in NE¼ NW¼ SE¼ sec. 7, T. 10 N., R. 18 E., where it is 6 inches thick and is overlain by 53 feet of black to gray fissile shale.

Boggy Formation

Nomenclator. — J. A. Taff (1899).

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

Original description. — Taff (1899, p. 438-439) wrote of the Boggy in the McAlester district:

> There is a mass of shale and sandstone above the Savanna sandstone nearly 3,000 feet thick. Throughout a part of this field it is possible, and would be desirable, to separate these beds and map them as two or more series of beds from both stratigraphical and structural points of view. In other parts of the field, however, it is not possible to trace or map beds of sandstone or shale in separate collections of strata, since they are concealed by superficial deposits or are worn down to a smooth surface so that all rocks alike are concealed beneath the soil. No coal of workable extent or other beds of economic importance have been found in these rocks to warrant greater effort in detailed mapping. In the Boggy shale there are probably not less than sixteen beds of sandstone ranging in thickness from 20 to 150 feet, separated by shale from 100 to 600 feet thick. One coal bed, about 2 feet 6 inches thick, has been located and worked to a small extent, though now abandoned. The coal bed is about 400 feet above the base of the Boggy shale and has been prospected and worked, to a small extent, on the Missouri, Kansas, and Texas Railway, at points 1 and 3 miles south of McAlester. In other parts of the field, upon further investigation, it may prove to be workable.
>
> The shales of this series are exposed to a very slight extent. In the few hill slopes and stream cuttings where observed the shales are bluish fissile clay containing ironstone concretions, thin wavy sandstone plates, and shaly sandstone strata. The sandstones fall in one general class and vary but little in minor detail of structure. They are generally brownish or gray and some beds are quite ferruginous. In some of these the iron ore cuts the face of the ledge or particular bed into a network of angular blocks as if filling a plexus of mud cracks. All the sandstones are fine grained and were without doubt deposited under very similar conditions.

History of usage. — Subsequent usage of the terms "Boggy Shale" or "Boggy Formation" followed the intent of Taff until Wilson (1935) inadvertently included the Bluejacket Sandstone Member 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. As here used, then, 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 River. Outcrops of the Boggy Formation are also present as synclinal outliers in the Arkoma basin in Pittsburg, Haskell, and Le Flore Counties. Boggy rocks constitute most of the bedrock outcrops of eastern McIntosh County.

Thickness and character. — 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 unexpectably thick in local basins, such as the Porum and Rattlesnake Mountain synclines, and surprisingly thin over structurally high areas, such 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., in Pittsburg County, about 35 miles southwest of Eufaula, McIntosh County. A summation of measured surface sections in T. 8 N., Rs. 13-18 E., Pittsburg and Haskell Counties, indicates that the Boggy Formation of present usage is about 1,500 feet thick there (Dane, Rothrock, and Williams, 1938, pl. 16). Similar summations from plate II of this report indicate that 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. The following quotation from Hendricks (1937, p. 23-24) indicates the character of the formation in the deeper parts of the Arkoma basin, in general 18 to 25 miles south of McIntosh County.

In the McAlester district the Boggy shale consists of thin sandstone beds alternating with thick shale beds. As many as 18 sandstone beds are present in the formation, but over the greater part of the district their aggregate thickness is only about 7.5 percent of that of the entire formation. Some of the sandstone beds are too thin to be mapped, and some were grouped for convenience in mapping. In the northeastern part of the district the lower sandstone beds thicken and probably constitute 15 percent or more of the total thickness of the formation. The sandstone beds of the Boggy shale are locally variable, platy, and ripple-marked to coarse-grained and massive. Some of the sandstones show extreme false bedding locally. Worm trails, fucoid markings, and fragments of *Sigillaria, Lepidodendron,* and *Calamites* are common in the sandstone beds . . .

The shale beds of the formation are generally dark, platy to blocky, and carbonaceous and at most places contain invertebrate remains. Locally, especially in the north half of the district, plant remains were found near the base and near the top of the formation. At some places in the western part of the district beds as much as 40 feet thick of conglomeratic, blocky, red clay similar to those found in the Savanna sandstone are present in the shale. These clay beds are made up of spheroidal pellets of clay one-tenth of an inch or less in diameter in a matrix of similar material. Larger fragments of coal, shale, and sandstone and calcareous nodules containing small black pellets are present in the clay.

A coal bed about 20 feet above the base of the formation has been mined in the NW¼ sec. 3, T. 4 N., R. 14 E. This bed is believed by me to be at or near the horizon of the Lower Witteville coal, which is found near Poteau, Oklahoma, about 70 miles to the east. About 50 feet above the lowest sandstone of the Boggy shale is the Secor coal bed, which has been mined in several parts of the district. It is probably the equivalent of the Upper Witteville coal of the Poteau district. Several other thin coal beds are present in the formation, but none of them, so far as known, is thick enough to be mined.

The Quinton-Scipio district lies between the McAlester district, mapped by Hendricks, and the south side of McIntosh County. The following quotation is from Dane, Rothrock, and Williams (1938, p. 160-161) and describes the Boggy in that area.

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. The zones of sandstone are as much as 100 feet thick. Where the dips are relatively steep, as in the south 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 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 on the areal map 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 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

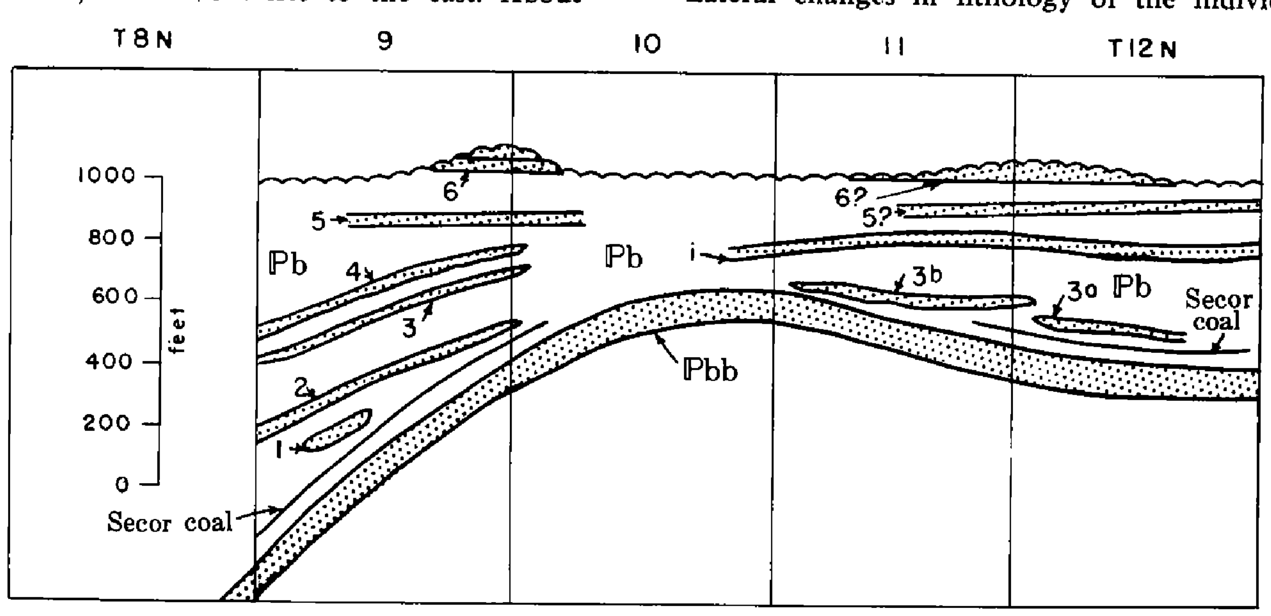

Figure 5. Diagram of the Boggy Formation, roughly to scale. The Warner uplift lies in the northern part of T. 10 N. and the southern part of T. 11 N. The Bluejacket Sandstone (IPbb) is the only unit that could be traced across the uplift. Unit 5 is correlated with unit 5? and unit 6 with unit 6?. Other units are probably not continuous across the uplift. Sandstone lenses between the Inola Limestone (i) and unit 5? are not shown. They are designated IPb-4a on the map (pl. I). The upper limit of the Boggy is thought to mark a widespread unconformity.

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.

Dane, Rothrock, and Williams (1938) found a total of eight such sandstone units in the Boggy Formation and numbered them in ascending order as follows: 1, 2, 3, 3A, 4, 5, 6, and 7. Of these, 1, 2, 3, 3A, 4, and 5 extend into the area shown on the geologic map of this report (pl. I). Unit 6 of Dane, Rothrock, and Williams seems to grade into shale beneath alluvium associated with the Canadian River. The outcrop of unit 7 is interrupted by the alluvium but a probable correlative was mapped immediately north of the alluvium as IPb-5 of this report. An additional sandstone unit, IPb-6 of this report, which was mapped at the top of the Boggy Formation in McIntosh County, seems to be younger than any Boggy unit mapped by Dane, Rothrock, and Williams. Most of the intervals in the Boggy are thinner in the area of this report than in the adjoining area to the south.

Bluejacket Sandstone (IPb-b)

The Bluejacket Sandstone Member was named by D. W. Ohern, in an unpublished manuscript (1914), from the hills west of the town of Bluejacket, Craig County, Oklahoma. 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.

Howe (1951, p. 2089) limited application of the term "Bluejacket sandstone" to certain of the sandstone beds in the type locality; but the name is still applied, as by Ohern, to the conspicuously outcropping unit composed of alternating lenticular sandstone and intervening sandy shale beds. Its outcrop extends from Kansas-Oklahoma line to southwestern Pittsburg County.

Owing to miscorrelation across faults, McCoy (1921) applied the name by inference to the Warner Sandstone Member of the McAlester Formation in the vicinity of Warner, Muskogee County. Wilson (1937) mapped the Bluejacket Sandstone by tracing and by correlation across faults as far south as T. 10 N., R. 18 E., and found it to be the massive sandstone on Rattlesnake Mountain, which Taff (1906, p. 4) described as the lowest sandstone unit of the Boggy Formation. Dane and Hendricks (1936, p. 312-314) 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 by Dane, Rothrock, and Williams (1938).

In the area of this report, as shown on the geologic map (pl. I), the Bluejacket Sandstone crops out in Tps. 9, 10 N., R. 18 E., in Haskell County, where Oakes and Knechtel (1948, p. 61) found it to be 50 to 75 feet thick. The lower part is massive and weathers into large exfoliated blocks which are prominent in the talus material; the upper part crops out on dip slopes, seems to be thinner bedded, and grades into the overlying shale.

The Bluejacket crops out north of the Arkansas River in T. 10 N., R. 18 E., McIntosh County, in the Porum syncline. It is tan to gray, fine to medium grained, and cross-bedded. The lower part is massive and yields large, exfoliated blocks in weathering. The upper part is thin bedded at many places and has been quarried for veneer stone. The full thickness is not exposed in this area, but is probably considerably more than 100 feet. Its subsurface representative, the Salt sand of oil field parlance, is 150 feet thick in the Carter Oil Company 1 Graham well in NW¼ SE¼ NE¼ sec. 3, T. 9 N., R. 16 E., 1 mile west of Eufaula, McIntosh County, and 1 mile north of the axis of the Porum syncline.

The Bluejacket crops out across the Warner uplift in Tps. 10, 11 N., R. 17 E., in an area 2 to 4 miles wide. Approximately the lower half is similar to the Bluejacket in the outcrops in Tps. 9, 10 N., R. 18 E., discussed above. This lower part is succeeded by sandstone which is more lenticular and more cross-bedded, contains more intermixed clay, and is less resistant. In general, this upper part is covered by a deeper soil. It is similar to sandstones of the shelf facies younger than Bluejacket and may not be represented farther south. It is mapped with the Bluejacket because no mappable line of demarcation is between them. The total thickness of the Bluejacket, so mapped, could not be determined from surface data on account of the width of outcrop and the inconstancy of all observed dips. It is 200 feet thick in the Brown 1 Whittaker well in NE¼ SW¼ SE¼ sec. 12, T. 10 N., R. 16 E. At the time Webb was in the field, summer of 1956, the Corps of Engineers, U. S. Army, drilled several core holes in the vicinity of the northeast corner of sec. 12, and penetrated 90 feet of the upper part of the Bluejacket. The cores were almost entirely sandstone, with a few widely spaced intercalations of sandy shale. Some cores contained black carbonaceous residue with a distinct petroleum odor.

The Bluejacket outcrop is less than 1 mile wide north of the north fault of the Warner uplift in T. 11 N., Rs. 17, 18 E., and the sandstone dips steeply northwestward into the Rattlesnake Mountain syncline. It has the same characteristics as on the Warner uplift. The thickness could not be determined from surface data, but is 170 feet in the A. C. Long et al. 1 Brumley well in SE¼ SE¼ NW¼ sec. 1, T. 11 N., R. 17 E., near the axis of the Rattlesnake Mountain syncline.

A broad outcrop of Bluejacket Sandstone extends from southeast to northwest across T. 12 N., Rs. 17, 18 E., mostly on the north flank of the Rattlesnake Mountain syncline. It was mapped by Coleman (1958), who conducted the author on a tour of the area; I am indebted to him for most of the following observations.

The Bluejacket Sandstone is in irregular contact with the underlying siltstones and shales of the Savanna Formation. Channeling is evident at some places; at others the contact is gradational. The lower beds are as much as 15 feet thick and are generally massive, cross-bedded, brown to gray sandstone. Between the thick beds is brown to gray, thin-bedded, silty sandstone and silty shale. Scattered plant fossils and local coal seams of knife-blade thickness were seen in the lower part of the Bluejacket. In the area of its maximum thickness, the northeastern part of T. 12 N., R. 17 E., the lower part of the Bluejacket is separated from the upper part by an interval of soft, variable-grained, cross-bedded sandstone. The upper part forms several ridges which radiate from the area where it is thickest, sec. 1, T. 12 N., R. 17 E. The rocks that compose these ridges exhibit profound cross-bedding and at many places the apparent dip coincides with the slope of the ridge. No evidence shows these ridges to be the result of tectonic deformation; it seems more likely that they are the result of sedimentation on a small delta. The present surface probably resembles the surface of the delta just before the overlying shale was deposited.

The uppermost part of the Bluejacket in the vicinity of Rentiesville contains several shale lenses. In one such lens is a coal seam with a maximum measured thickness of 4 inches, it crops out in the bank on the south side of the road near N¼ cor. sec. 15, T. 12 N., R. 17 E., in the town of Rentiesville. Some of the shale lenses seem to indicate small southwestward-plunging anticlines, as if there has been some slight local post-Bluejacket deformation, but the writer regards the evidence as inconclusive.

The Bluejacket Sandstone Member seems to have been deposited during a time of relative tectonic stability in eastern McIntosh County, for its thickness has little reference to the Porum and Rattlesnake Mountain synclines or to the Warner uplift between them. Boggy beds younger than Bluejacket, on the other hand, seem to have been deposited during growth of these features. They are markedly thicker in and south of the Porum syncline than on the Warner uplift, and available data seem to indicate that they are, in turn, somewhat thicker in the Rattlesnake Mountain syncline than on the uplift.

Post-Bluejacket rocks in and south of the Porum syncline

The shale that overlies the Bluejacket Sandstone in T. 9 N., R. 18 E., is about 200 feet thick and is composed for the greater part of dark clay shale. It contains, near the middle, the Secor coal seam, about 24 inches thick. About 5 feet from the top is a fossiliferous limestone, about 1 inch thick, underlain by shale and a coal seam, each about 1 inch thick.

Unit IPb-1, (unit 2 of Dane, Rothrock, and Williams, 1938) is about 40 feet thick in sec. 36, T. 9 N., R. 17 E., Pittsburg County, and about 20 feet thick in the southern part of T. 9 N., R. 18 E., Haskell County. It was not confidently traced as far north as the Canadian River. It is overlain by dark shale about 170 feet thick, mostly covered.

IPb-2 (unit 3A of Dane, Rothrock, and Williams, 1938) is about 40 feet thick in sec. 36, T. 9 N., R. 17 E., Pittsburg County, and about 20 feet thick in the southern part of T. 9 N., R. 18 E., Haskell County. It was not confidently traced as far north as the Canadian River. It is overlain by about 80 feet of shale which is gray to black, blocky to fissile, and at many places silty or sandy; it contains a few thin zones filled with siltstone. The best exposure of this shale is along a much eroded trail in sec. 35, T. 9 N., R. 17 E.

Unit IPb-3 (unit 4 of Dane, Rothrock, and Williams, 1938) crops out in T. 9 N., Rs. 17, 18 E., Pittsburg and Haskell Counties, and extends north to the Canadian River. The lower part is composed of medium- to fine-grained, gray to brown, massive sandstone lenses as much as 10 feet thick, but no one of them has any great lateral extent. In Haskell County these lenses form the capping rimrock of an escarpment about 300 feet high, known as Brooken Mountain. The upper part is composed of thinner, finer-grained lenticular sandstone beds. Webb (1957, 1960) found the total thickness to be about 40 feet. The thickness of 100 feet reported by Oakes and Knechtel (1948) includes younger sandstone and sandy shale beds on the dip slope of Brooken Mountain, mapped by Webb in younger units. This unit, IPb-3, is of the basin facies and probably was not deposited northward beyond the Porum syncline. The overlying shale is about 50 feet thick but is poorly exposed.

Unit IPb-4 (unit 5 of Dane, Rothrock, and Williams, 1938) is composed of about 35 feet of tan, lenticular, fine-grained, thin to thick and massive beds of sandstone separated by thin beds of silty to sandy shale. It crops out in secs. 17, 18, 19, 20, T. 9 N., R. 17 E., an area densely covered by scrub oak, and dips northward into the Porum syncline, where it is covered by alluvial deposits associated with the Canadian River. Like unit IPb-3, it is of the basin facies and probably grades into shale in the Porum syncline, beneath alluvial cover.

The overlying shale is about 300 feet thick. It is gray to black, fissile to blocky, and silty to sandy. Webb found 230 feet of this shale exposed between the Canadian River and the base of the sandstone IPb-5, which is here considered equivalent to unit 7 of Dane, Rothrock, and Williams, at Standing Rock in sec. 13, T. 9 N., R. 16 E., near the axis of the Porum syncline. According to Dane, Rothrock, and Williams (1938, pl. 16), the same interval is 300 feet in T. 8 N., R. 16 E., and their shaly sandstone unit 6 occupies the middle 100 feet. It is therefore thought that their unit 6 grades into shale beneath the alluvium associated with the Canadian River.

Unit IPb-5, here correlated with unit 7 of Dane, Rothrock, and Williams (1938), crops out disconnectedly along the axis of the Porum syncline in T. 9 N., Rs. 15, 16 E.; the westernmost outcrop extends into T. 10 N., R. 15 E. Among the sandstones of the Boggy Formation, this unit stands out as second only to the Bluejacket Sandstone Member in total thickness and in the thickness and massive character of its lower lenses, which, like those of the Bluejacket, spawn large, exfoliated sandstone blocks prominent in the talus material. It is 50 to 60 feet thick, tan, and medium to coarse grained. As in the Bluejacket, the upper part is composed of thin to thick lenticular sandstone beds separated by thin, lenticular, sandy shale beds. The author correlates IPb-5 with unit IPb-5? north of the Porum syncline. The overlying shale is from 75 feet thick in T. 9 N., R. 15 E., to 140 feet thick in T. 9 N., R. 16 E. It is mostly covered but, wherever exposed, it is dark and clayey to silty.

Unit IPb-6 is the youngest sandstone unit of the Boggy Formation in McIntosh County. It appears to be younger than any sandstone unit of the Boggy mapped by Dane, Rothrock, and Williams (1938) in northern Pittsburg County to the south. It is preserved as two eroded outliers about 30 feet thick. The outliers cap hills along the axis of the Porum syncline, one southwest of Eufaula and the other northeast, east, and southeast of Vivian. Andrews (1957) described the unit east of Vivian, where it is best exposed, as consisting of interbedded sandstone and silty shale. The sandstone is buff, medium grained, and well cemented. In the lower part the sandstone and shale beds average about 2 feet thick, but the sandstone beds are thinner in the upper part. Northwest of Vivian this unit is overlain unconformably by shale that contains a few sandstone beds, here mapped as Stuart Shale.

Post-Bluejacket rocks on and north of the Warner uplift

The Bluejacket Sandstone Member on the Warner uplift and in the Rattlesnake Mountain syncline is overlain by poorly exposed dark shale that contains a coal seam which has been strip mined near the axis of the syncline, along the south side of T. 12 N., R. 18 E., where it is 30 inches thick and is about 25 feet above the Bluejacket. It has long been the practice to apply the name "Secor" to any coal seam so situated in relation to the Bluejacket, and that practice is followed here without intending to imply that this seam is continuous with coal seams called "Secor" elsewhere. Likewise the name "Secor" is applied to a coal seam 17 inches thick that virtually rests upon the Bluejacket in an exposure in sec. 3, T. 12 N., R. 17 E., and to coal exposed in secs. 22, 23, and 26. So far as is known, coal at this horizon extends only a short distance south into T. 11 N., R. 18 E. The author suspects that in McIntosh County and elsewhere numerous coal seams were deposited at various horizons in the lower part of the shale that overlies the Bluejacket, each in a swamp or marsh of limited extent, and that the name "Secor" is applied to several of them.

The unit IPb-3a (not here correlated with unit IPb-3) was mapped by Coleman (1958) as Crekola Sandstone because it seemed to be the first sandstone unit above the Bluejacket, as does sandstone mapped as Crekola by Wilson (1935) in Muskogee County. It is a lenticular, medium- to fine-grained, soft, silty sandstone which weathers brown. It varies from thin, barely distinguishable, shaly siltstone to sandstone and sandy shale several feet thick. It grades into shale along the south side of T. 12 N., Rs. 17, 18 E., where it is about 70 feet above the Bluejacket Sandstone. It is covered by alluvium north of sec. 22, T. 12 N., R. 17 E., and either grades into shale beneath the alluvium or joins the Bluejacket as a tongue, for it was not found in sec. 3, west of the outcrop of the Bluejacket.

Unit IPb-3b (not here correlated with IPb-3) is poorly exposed, tan to dark-brown, fine-grained, ripple-marked, thin-bedded sandstone. Its lower part makes a ridge along the northwest flank of the Warner uplift. The ridge curves out northward and extends nearly to the axis of the Rattlesnake Mountain syncline in sec. 35, T. 12 N., R. 17 E., where Coleman (1958) estimated the sandstone to be about 40 feet above the unit IPb-3a, and thus about 110 feet above the Bluejacket Sandstone. It was not found farther north and probably grades into shale. It is progressively thicker southwestward and is at least 20 feet thick where it passes beneath alluvium in the vicinity of S¼ cor., sec. 36, T. 11 N., R. 16 E. In contrast, the shale separating it from the Bluejacket decreases in thickness southwestward from 110 feet to probably no more than 20 feet. It grades gradually in the same direction from silty shale to extremely sandy shale. This unit, IPb3-b, may well be a tongue of the Bluejacket. It was mapped by Meek (1957) as Crekola Sandstone because in his area it seemed to be the first sandstone above the Bluejacket, just as the unit IPb-3a seems to be the first above the Bluejacket in the area mapped by Coleman in T. 12 N., Rs. 17, 18 E. These two sandstone units are typical of sandstone units heretofore mapped as Crekola Sandstone in their lenticularity and varying interval above the Bluejacket. The name "Crekola" is not applied in this report.

The Inola Limestone (IPb-i). — The Inola was first mentioned by name in print by Lowman (1933a), who stated that it was "named from an outlier on a hill east of the town of Inola, Oklahoma." Branson (1952, p. 192) stated:

> . . . 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, 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 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 *Wedekindekllina 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 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 limestone mapped as Inola by Coleman (1958) in T. 12 N., R. 17 E., is dark gray and fossiliferous and ranges from 0.3 to 0.6 foot in thickness. At most outcrops a coal from 0.5 to 1.6 inches thick lies 1 to 3 inches below the limestone. The Inola is immediately overlain by dark fissile shale containing phosphatic nodules at some places.

Meek (1957) described the Inola Limestone in T. 11 N., R. 17 E., as dark-gray to black, dense, fossiliferous limestone which weathers light gray to brown. The surface is pitted locally, probably owing to solution. A coal seam about 2 inches thick lies about 0.5 inch below the limestone at every exposure found. The limestone is overlain by black fissile shale containing radioactive black phosphatic nodules.

The Inola Limestone lies about 150 feet above the Bluejacket Sandstone along the south side of T. 12 N., R. 17 E., near the axis of the Rattlesnake Mountain syncline, but a limestone thought to be the Inola lies only about 50 feet above the Bluejacket in the W. B. Pine 1 Fuller well at C NW¼ sec. 13, T. 11 N., R. 16 E. A thin limestone, probably the Inola, is about 80 feet above the Bluejacket in the Chapman and Pollard 1 Shrimsher well in sec. 19, T. 10 N., R. 15 E. It is doubtful that the Inola was deposited south of the Warner uplift.

Unit IPb-4a (not here correlated with IPb-4) is a group of disconnected, weakly resistant, silty to clayey, fine-grained, brown sandstone bodies, each of which is without definite upper, lower, or lateral limits. These sandstone bodies occupy various stratigraphic positions in shale on the north flank of the Warner uplift and across the Rattlesnake Mountain syncline, in Tps. 11, 12 N., Rs. 16, 17 E. There are eleven mapped exposures of such sandstone. The shale that contains these sandstone bodies lies between the Inola Limestone, below, and unit IPb-5?, above. It is gray to tan, at some places black and fissile at the base, generally silty, and poorly exposed. Such data as are available indicate that it is about 300 feet thick along the north side of T. 12 N., Rs. 16, 17 E., only about 180 feet thick in the southwestern part of T. 11 N., R. 17 E., and about 360 feet thick in the Chapman and Pollard 1 Shrimsher well in sec. 19, T. 10 N., R. 15 E. Coal seams which range from 4 to 17 inches thick are exposed in the upper part of this shale at various places in secs. 13, 24, 25, 26, 35, T. 11 N., R. 16 E., and in sec. 1, T. 12 N., R. 16 E.

Unit IPb-5? is tan to brown, medium- to fine-grained, cross-bedded, ripple-marked, thin-bedded to massive, lenticular sandstone from 8 to 30 feet thick. It contains carbonized plant debris and plant impressions. It crops out continuously from sec. 2, T. 12 N., R. 16 E., southward in Rattlesnake Mountain syncline to alluvium associated with Deep Fork in secs. 10, 15, T. 11 N., R. 16 E. It crops out west of Deep Fork in secs. 15 and 16 and almost continuously into sec. 3, T. 10 N., R. 16 E., on the Warner uplift. It crops out east of Deep Fork around hills and as outliers. The author thinks that this unit is a sandstone of the shelf facies which is substantially contemporaneous with unit IPb-5 of the basin facies and that probably the two coalesced and were continuous. However, this view cannot be incontestably maintained; therefore the interrogative point at the end of the symbol.

The overlying shale is about 80 feet thick in sec. 1, T. 11 N., R. 16 E., where it extends up to unit IPb-6?, but is thinner northward to an estimated 45 feet along the north side of secs. 5, 6, T. 12 N., R. 16 E., where it is overlain by the Stuart Shale. It is mostly covered, but exposures indicate that it is composed of tan to gray silty shale, except for a zone of black, fissile shale in the lower part which contains the limestone IPb-l. Discontinuous beds of clay ironstone concretions are common and are fossiliferous locally. Meek (1957) made a collection of fossils from these beds in SW¼ SE¼ SW¼ sec. 17, T. 12 N., R. 16 E., from which he identified the following:

Aviculopecten sp.
Astartella concentrica McChesney
Astartella varica McCheseny
Nuculopsis ventricosa (Hall)
Parallelodon sangamonensis (Worthen)
Anthraconeilo taffiana Girty
Bucanopsis tenuilineata Ulrich and Schofield
Metacoceras cornutum Girty
Protocycloceras sp.

The limestone bed IPb-l crops out west

of Deep Fork in secs. 9, 17, T. 11 N., R. 16 E., and east of Deep Fork in secs. 1, 2, and 3. In this area the limestone is dark gray to black, weathers reddish brown, is platy, and ranges in thickness from 1 to 2 feet. It is composed almost entirely of extremely flattened, small pelecypod shells of the genus *Permophorus*. Limestone is exposed in about the same stratigraphic position at SW cor. sec. 25, T. 12 N., R. 16 E.

The unit IPb-6? crops out on both sides of Deep Fork in the northern part of T. 11 N., R. 16 E. It is here correlated with IPb-6. It consists of fine-grained, thin-bedded to massive, micaceous sandstone, which weathers reddish brown. It is 36 feet thick in sec. 9, T. 11 N., R. 16 E., and 25 feet thick in sec. 2, where the top is eroded. In the southern part of T. 12 N., R. 16 E., it thins northward to a ragged edge that cannot be mapped exactly, and is overlain by, merges with, and seems to be overlapped by sandy shale and silty sandstone. This sandstone is probably composed in part of debris from unit IPb-6?, and the author therefore classifies it as Stuart Shale. Two sandstone outliers are also mapped as IPb-6?, one in sec. 2, T. 10 N., R. 16 E., and the other in sec. 36, T. 11 N., R. 16 E. The unit is thought to be unconformable beneath the Stuart Shale.

Meek (1957) reported a coal seam about 2 inches thick in S½ NE¼ NW¼ sec. 4, T. 11 N., R. 16 E., which he placed in the Stuart Shale.

Unconformity at the top of the Boggy Formation

Many geologists familiar with the Boggy Formation, on the outcrop and in the subsurface, have entertained, at one time or another, for one reason or another, and in one form or another, the concept of an unconformity within or at the top of the Boggy Formation. Bloesch (1919, p. 262-268), Clawson (1928, p. 14), and Lowman (1933b) have given this concept expression in print. Bloesch called attention to the discordance between the structure of what are here called Boggy rocks and the structure of the post-Boggy rocks. Clawson discussed the difference in the character of the folds in the Boggy rocks on the one hand and in the post-Boggy rocks on the other and concluded that the Thurman Sandstone was deposited "on a previously folded surface." Lowman included the Atoka Formation in his "Cherokee group," divided his "Cherokee" into lower, middle, and upper, and said that a broad regional unconformity is at the base of his upper "Cherokee." He correlated the Thurman Sandstone with the Chelsea Sandstone, as did many other geologists at the time, including the author, and placed the Thurman-Chelsea at the base of his upper "Cherokee." He thus placed his unconformity at the top of the Boggy Formation in the area south of the Canadian River.

However, Cheney and others (1945, p. 150-151) published a cross section and a correlation chart, prepared by Lowman about 1933. The chart shows the unconformity near the middle of the Boggy in the subsurface of south-central Oklahoma, correlates the Thurman with the Chelsea, places the top of the Boggy at the base of the Chelsea in north-central Oklahoma, and indicates that most of the "upper Boggy" is missing there.

Taff (1899) fixed the top of the Boggy Formation at the base of the Thurman Sandstone by definition, and later (1901) stated:

> The Thurman sandstone represents the beginning of a marked change in the character of the sediments which were brought into the sea and spread across this region in Carboniferous time. Shale and fine sandy sediments of the Boggy shale are followed by coarse pebbles of white chert mixed with coarse quartz sand forming the Thurman sandstone.

At most places along the Thurman outcrop, from the north flank of the Arbuckle Mountains to the Canadian River, there is an escarpment at the base, and this escarpment is capped at many places by fine-grained sandstone, like the sandstone of the Boggy Formation. At a few places, this fine-grained sandstone contains fragments of chert, as do some older Pennsylvanian sandstones, even those as old as the Atoka Formation, but these are fine and sparsely distributed. Also, at many places the escarpment is capped by coarse sandstone or by coarse chert conglomerate. In at least some of the localities where the escarpment is capped by fine-grained sandstone, the coarse sandstone and coarse chert conglomerate overlie the fine-grained sandstone and crop out at some distance from the escarpment, down the dip slope. Taff's term for the Boggy Formation was "Boggy shale" and his "fine sandy sediments of the Boggy shale" may well have included the fine-grained sandstone that caps the escarpment at many places. It seems to the author that the fine-grained sandstone should be included in the Boggy Formation and that Taff so intended.

Weaver (1954, p. 33) mapped the Thurman in the southeast corner of Hughes County and chose to include the fine-grained sandstone in the Thurman Sandstone, being influenced by the sparsely distributed fine chert fragments contained in it. He stated that the evidence there points to a conformable relationship, but also stated: "The contact is not one that can be followed precisely, however, for the lower sandstones of the Thurman are not continuous along the scarps. Thus, the base of the 'zone' of the Thurman sandstones was mapped across the County."

Hendricks (1937) did not show the fine-grained sandstone on his map of the McAlester coal district; he probably mapped it with the Thurman Sandstone. He stated that the change from the Thurman Sandstone is gradational, but also stated that the lower 50 feet of the Thurman is thick-bedded and coarse grained to conglomeratic.

Dane, Rothrock, and Williams (1938, p. 167, map) worked in the Quinton-Scipio district, which adjoins the McAlester district on the north, and mapped the fine-grained sandstone as the uppermost unit of the Boggy Formation, their unit 7. They stated: "The basal conglomerate bed of the Thurman sandstone in the Quinton-Scipio district rests with a sharp contact and erosional irregularity on the underlying Boggy shale . . . Because of the distinctive character of the basal Thurman, which may imply a new source of sediments, and because of the erosional irregularity at the base, it is believed that the Thurman may rest unconformably on the Boggy shale." Like Taff, Dane, Rothrock, and Williams used the term "Boggy shale" to include both shale and sandstone. They found that the conglomeratic sandstone at the base of the Thurman extends to the southwestern part of sec. 10, T. 7 N., R. 14 E., but did not find it farther northeastward. After considerable detailed field study, the author is of the opinion that the lower coarse-grained sandstone and coarse conglomerate beds of the Thurman are overlapped by higher beds of the Thurman Sandstone, and strongly suspects that the whole of the Thurman is overlapped by the Stuart Shale beneath the alluvium associated with the Canadian River.

From the Canadian River to the Arkansas River, the sandstones of the Cabaniss Group, above the Boggy, are, in general, finer grained northward. The sandstones in the Stuart Shale and many in the Senora Formation, above the Stuart Shale, grade northward into shale. In addition, there are areas of superficial deposits several miles across. Consequently it is with considerable trepidation that the geologist ventures to draw formation boundaries from

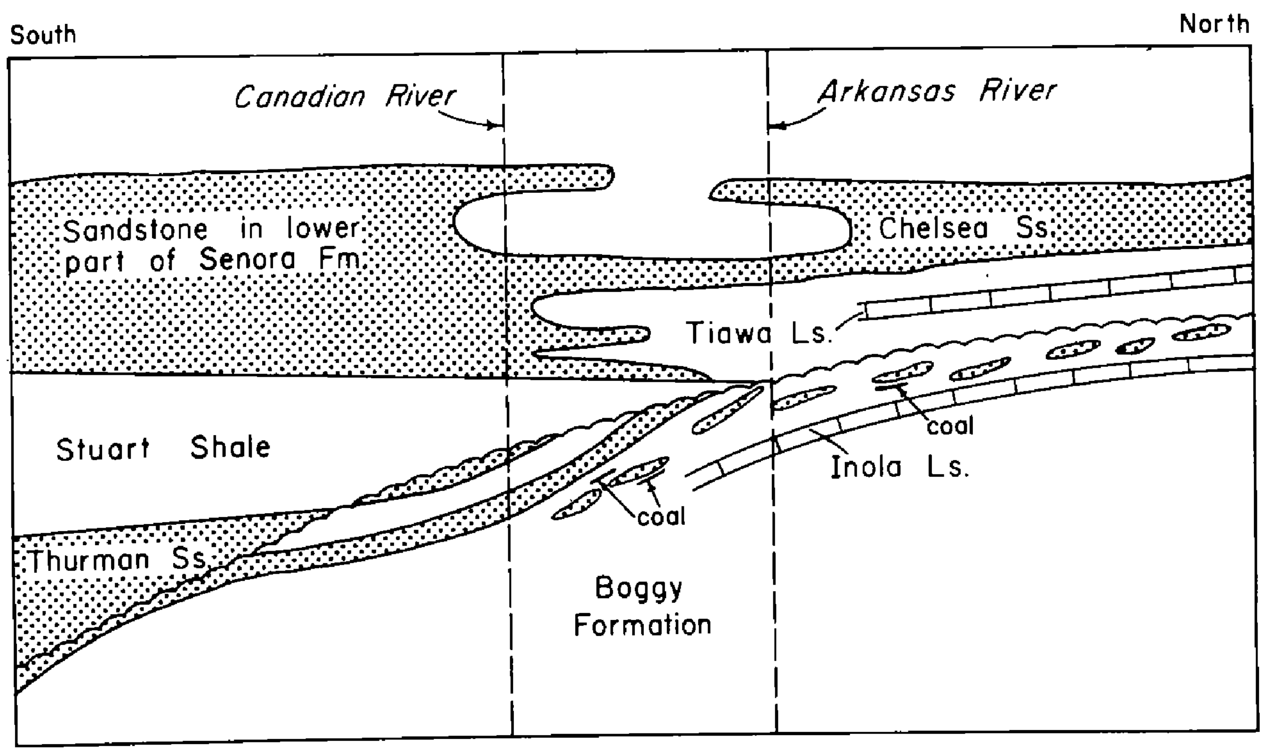

Figure 6. Generalized diagram, not to scale, showing relations between upper Boggy rocks and post-Boggy rocks south of the Canadian River, between the Canadian and Arkansas Rivers, and north of the Arkansas River.

lithologic criteria alone, and, as in most of the Pennsylvanian in this part of the country, megascopic fossils, such as could be used in the field, do not help much. However, in this latitude, Boggy and pre-Boggy rocks are more complexly folded and faulted than are the post-Boggy rocks. This fact is noticeable in a conspicuous difference in strike; Boggy rocks strike in various directions, from northeastward to southwestward, in contrast to the almost constant strike of post-Boggy rocks a few degrees east of north. It is also noticeable in a system of southwestward-trending faults, probably associated with the Ozark uplift, which cut the Boggy and pre-Boggy rocks, but in general, do not continue southwestward into post-Boggy rocks. The southwestward extension of a few is indicated in post-Boggy rocks by abnormal dips and by faults of small displacement intermittently distributed along the extensions of the trends.

Therefore, in the course of reconnaissance investigations incident to compilation of the *Geologic Map of Oklahoma* (Miser, 1954), the line between the Boggy Formation and younger rocks was drawn by the author, from the Canadian River to the Arkansas River, mostly upon the basis of structural discordance. At most places the contact is shale on shale, but the shale in the upper part of the Boggy is somewhat darker and less silty than is the post-Boggy shale; where exposures are sufficiently fresh, this is helpful in mapping the top of the Boggy Formation. In the course of the same program of reconnaissance investigations, Carl C. Branson drew the line between Boggy rocks and younger rocks, from the Arkansas River to the Kansas-Oklahoma line, somewhat below the Tiawah Limestone, for both paleontological and structural reasons.

CABANISS GROUP

The Cabaniss Group was named by Oakes (1953) from Cabaniss in T. 6 N., R. 12 E., northwestern Pittsburg County, and includes, in ascending order, the Thurman Sandstone, the Stuart Shale, and the Senora Formation. It is unconformable with the Krebs Group, below, but conformable with the Marmaton Group, above. The base of the Marmaton Group is the base of the Fort Scott Limestone north of the Arkansas River and the stratigraphically equivalent base of the Calvin Sandstone south of the Arkansas.

TABLE IV. — SUBDIVISIONS OF THE CABANISS GROUP IN OKLAHOMA

- Des Moines Series
  - Cabaniss Group*
    - Senora Formation
    - Stuart Shale
    - Thurman Sandstone
    - *unconformity*
  - Krebs Group

* Of the Cabaniss Group, only the Stuart Shale and the Senora Formation crop out in McIntosh County.

Rocks of the Cabaniss Group crop out from the northeast flank of the Arbuckle Mountains northeastward to the Kansas-Oklahoma line. They are thickest and coarsest in the latitude of Cabaniss, where they range in character from coarse chert conglomerate to clay shale. Both southwestward and northeastward they contain a greater proportion of finer grained material and are thinner both because of overlap of older units by younger units and because of thinning within units. The author thinks that the Thurman Sandstone is probably overlapped by the Stuart Shale beneath surficial deposits associated with the Canadian River. He thinks that the Stuart is overlapped, in turn, by the Senora Formation in T. 13 N., R. 15 E., and that from there to the Kansas-Oklahoma line the Senora Formation rests unconformably upon the Boggy Formation of the Krebs Group.

Stuart Shale

Nomenclator. — J. A. Taff (1901)

Type locality. — Taff mentioned no specific locality, but the name is from the town of Stuart, near the east line of southern Hughes County.

Original description. — Taff (1901, p. 4) stated:

> There is a gradational transition upward from the Thurman sandstone through thin beds of shaly sandstone and shale interstratified into the Stuart shale. This formation has a thickness of about 275 feet in the northeastern and central parts of its exposure and about 100 feet in its western part. It is composed of three members, an upper and a lower one of shale separated by a variable sandstone 10 to 50 feet thick. In the central part of the quadrangle a thin sandstone and chert conglomerate lentil occurs in the lower shale member. This lower

member of the formation has a nearly constant thickness of about 120 feet from the northwestern corner of the quadrangle southwestward to within 10 miles of the western border where it begins to contract, and at the western border probably does not exceed 50 feet. It is composed chiefly of bluish and black laminated clays. It crops in a level and rolling tract of prairie land which borders the timber belt of the Thurman sandstone on the east. The upper member of this formation is composed of bluish shales and has a thickness of 50 to 100 feet. This shale, unlike the lower member, crops in the steep slopes of the escarpments and hills which are surmounted by the succeeding Senora sandstone, and is, for the most part, wooded and concealed by talus.

History of usage. — Subsequent usage has followed Taff's original application of the term "Stuart Shale."

Distribution. — The Stuart Shale extends from the Ahloso fault, southeast of Ada, Pontotoc County, northeastward cross east-central Pontotoc County, southwestern Hughes County, northwestern Pittsburg County, and central McIntosh County to a point southwest of Council Hill, in southwestern Muskogee County, where it is overlapped by the Senora Formation.

Thickness and character. — Taff (1901, p. 4) stated that the Stuart Shale is about 275 feet thick in the northeastern and central parts of its exposure in the Coalgate quadrangle, and that the lower part is composed chiefly of bluish and black laminated clays, whereas the upper part is composed of bluish shales.

Dane, Rothrock, and Williams (1938, p. 167) found the Stuart Shale to be 315 feet thick in the southwestern part of T. 8 N., R. 13 E., Quinton-Scipio district, and stated:

> The Stuart shale consists chiefly of dark laminated shales, which at places carry ferruginous or calcareous nodules and concretionary beds. Some of these beds carry invertebrate fossils. There are some interbedded sandstones throughout the formation, but sandstone beds are thickest and most numerous in the middle portion, in a zone from 80 to 210 feet above the base, although sandstone nowhere occupies all of this interval. The sandstone in this part of the formation is massive, cross-bedded, or evenly bedded.

According to Taff (1901, p. 4), the combined thickness of the Thurman Sandstone and the Stuart Shale is about 525 feet in the vicinity of Stuart. According to Dane, Rothrock, and Williams, the combined thickness of the two formations is about 650 feet in the northwestern part of the Quinton-Scipio district, across the Canadian River from McIntosh County. This northward thickening may well be the result of downwarping and filling of the Porum syncline and adjacent area during deposition of the Thurman and Stuart.

As here mapped and measured, the Stuart Shale is about 380 feet thick in the north-central part of T. 9 N., R. 15 E., on the north flank of the Porum syncline in McIntosh County, where it consists of more or less silty shale and contains at least five silty sandstone lenses, here mapped as numbered units. The shale ranges from light gray to black and is mostly blocky. The three-fold division described by Taff and by Dane, Rothrock, and Williams is indicated by sandstone lenses for a few miles north of the Canadian River. The shale here mapped as Stuart in southern McIntosh County is thicker than the Stuart south of the Canadian River, but much thinner than the combined Thurman and Stuart there. It may or may not include shale of late Thurman age.

Unit IPst-1 is silty brown sandstone about 8 feet thick; it terminates northward against unit IPb-6 of the Boggy Formation and may have been derived in part from debris of that unit.

Unit IPst-2 is also brown silty sandstone about 8 feet thick and seems to rest on shale of the Boggy Formation older than unit IPb-6.

Unit IPst-3 is massive-bedded, somewhat silty brown sandstone. It is covered by alluvial deposits to the south, in sec. 30, T. 9 N., R. 15 E., and grades into shale in sec. 17. This unit is the most widespread sandstone of the Stuart Formation. In sec. 12, T. 9. N., R. 14 E., it lies 80 feet below the base of the Senora Formation, but in sec. 17, T. 9 N., R. 15 E., nearer the axis of the Porum syncline, it lies 140 feet below the base of the Senora.

Unit IPst-4 is a brown silty sandstone lens that averages 2 feet in thickness. It lies 22 feet above the top of unit IPst-3 in SW¼ sec. 8, T. 9 N., R. 15 E.

Unit IPst-5 is brown silty sandstone about 3 feet thick. It crops out only around the hill in secs. 7, 8, 17, 18, T. 9 N., R. 15 E., where it lies 17 feet above IPst-4 and 90 feet below the base of the Senora Formation.

The Stuart Shale is covered by alluvium

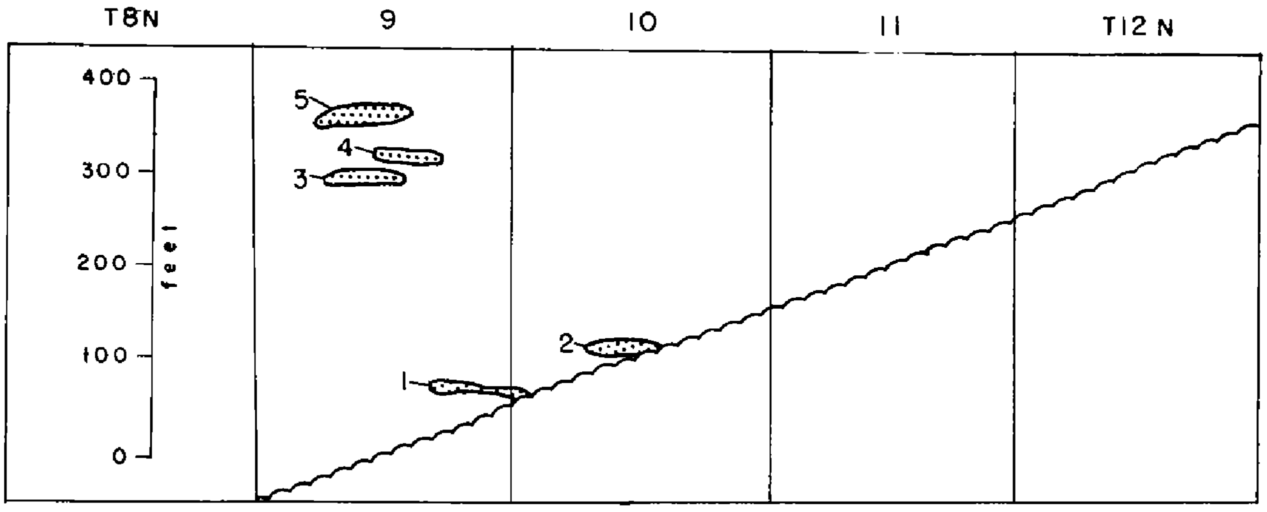

Figure 7. Diagram of the Stuart Shale, approximately to scale. The Stuart consists of more or less silty shale and at least five silty sandstone lenses sufficiently well defined to be shown on plates I and II. It is thought that the Stuart is unconformable upon the Boggy Formation, below.

across the northern part of T. 10 N., and across most of T. 11 N. In the southern part of T. 12 N., R. 16 E., the lower part contains a mixture of sandy shale and silty sandstone which rests upon, merges with, and seems to overlap unit IPb-6? of the Boggy Formation. This sandy shale and silty sandstone was probably derived, at least in part, from erosional debris of IPb-6? and possibly other Boggy sandstones. Otherwise, the Stuart in T. 12 N., consists of silty gray shale. It is about 80 feet thick at the north line of McIntosh County. The Stuart, as mapped in McIntosh County, is thought to rest unconformably upon the Boggy Formation.

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.

Original description. — The following quotation is from Taff (1901, p. 4):

> This formation is composed of interstratified sandstones and shaly beds having a thickness of nearly 500 feet in the northeastern corner of the [Coalgate] quadrangle. The thickness of the formation decreases toward the southwest chiefly by the thinning of the sandstone beds until at the western border of the quadrangle it does not exceed 150 feet. The outcrop of the formation in the northern part of the quadrangle averages about 10 miles in width. The lower 320 feet of the formation there is composed almost entirely of sandstone which forms a very rugged and stony highland with sandstone bluffs, in some places nearly 100 feet high, along the eastern side. This sandstone grades upward through thin sandy beds into shale strata which are approximately 160 feet in thickness.
>
> Near the middle of the quadrangle the lower massive sandstone becomes divided and shale beds 20 to 75 feet in thickness appear. With this change in character the surface becomes less rugged and stony. In the western part of the quadrangle the sandstone beds become quite variable in thickness and in their position in the formation. The outcrop of the formation here varies in width from 1 to 4 miles depending chiefly upon the erosion of the streams which cross it. The upper and more shaly member has a variable thickness from 100 to 120 feet in this western part.
>
> In texture the sandstones are generally fine grained and are gray or reddish brown in color. The shales, which occupy the more level land in the western and northern parts of the outcrop, are rarely well exposed and their original physical characteristics were not satisfactorily determined. Bluish clay shales and brownish sandy shales belonging in the upper part of the series, however, are exposed in the deeper cuttings of the streams which flow from the higher land of the succeeding Calvin sandstone.

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

Distribution. — The outcrop of the Senora Formation extends from the Ahloso fault in T. 3 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, across northeastern Hughes County and southeastern McIntosh County; about 12 miles of the 20 is in McIntosh County.

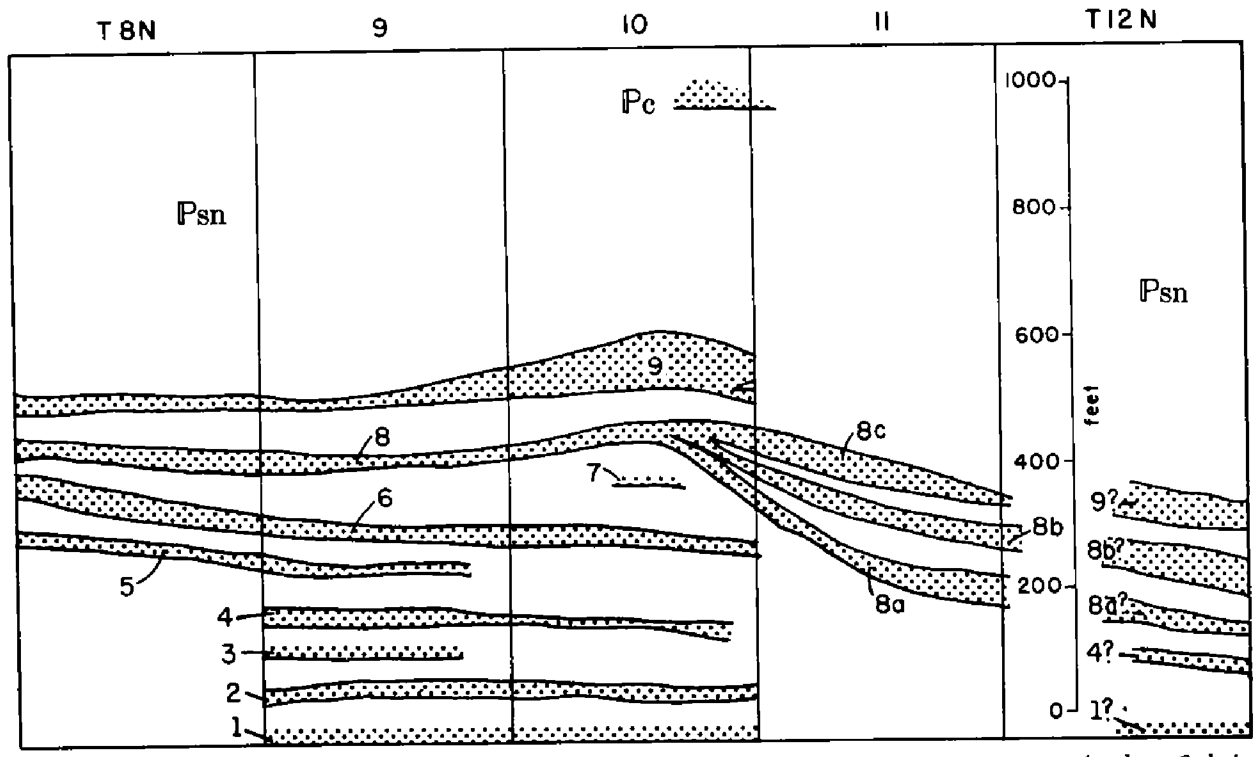

Figure 8. Diagram of the Senora Formation (IPsn) and the lower part of the Calvin Sandstone (IPc), roughly to scale. The Senora in McIntosh County consists of sandstone and sandy shale in the lower part and sandy shale to clay shale in the upper part. The sandstone lenses in the lower part are here grouped into nine map units. The overlying Calvin Sandstone is medium to fine grained and massive. Only the lower few feet crops out in the county.

Thickness and character. — Morgan (1924) mapped the Stonewall quadrangle, which adjoins the Coalgate quadrangle on the west. On page 87 of his report he stated:

> In a section measured through the central part of secs. 3 and 10, T. 3 N., R. 7 [8?] E. [Pontotoc County], the Senora was found to be 125 feet thick. At the base of the formation there is about 35 feet of sandstone with only a few thin beds of interstratified shale. This series of beds is much more resistant than the underlying Stuart shale and the differential weathering of the two results in the formation of a steep, southward facing escarpment. The Stuart shale occupies the steep face of the escarpment and the basal Senora beds extend along the crest.
>
> Above the basal sandstone, to the top of the formation, shales are prominent, but interbedded with these are brown and yellowish-brown sandstones.

Weaver (1954) mapped Hughes County and, in the course of that work, remapped most of the outcrop of the Senora previously mapped by Taff (1901). His map and descriptions of this part of the outcrop are different from Taff's only in being more detailed. In the area northward from Stuart and south of the Canadian River, his map shows only one shale lens in the lower sandstone part of the Senora, and that is near the base.

Govett (1957) mapped the lower 85 feet of the Senora across northwestern Pittsburg County, just across the Canadian River from southwestern McIntosh County. He described it as brown, medium-grained, porous, and permeable sandstone with a shale lens 20 feet thick near the base, an extension of the lens mapped by Weaver. It pinches out northeastward in Pittsburg County and southwestward in Hughes County.

Weaver (1954, p. 45) also mapped that part of the Senora outcrop north of the Canadian River in northeastern Hughes County, adjoining southwestern McIntosh County. About 300 feet of the lower sandstone crops out there and "consists of a series of medium-grained to silty, gray and light-brown sandstones interbedded with very silty, gray and maroon shales. These shale zones are irregular in thickness and contain numerous lenses of sandstone and siltstone as well as two thin limestones." The base of Weaver's "series" corresponds to the base of unit IPsn-8 in McIntosh County.

South of the Canadian River the lower part of the Senora is sandstone, about 300 feet thick, with only one shale lens that could be mapped separately. Lower Senora rocks are quite different north of the Canadian River, where they presumably lie over the north flank of the Porum syncline, which seems to continue westward beneath Stuart and Senora rocks. Just north of the river in southwestern McIntosh County and northeastern Hughes County, the lower sandstone part of the Senora is about 700 feet thick and contains many thick, resistant sandstone lenses and much sandy, silty shale. Groups of sandstone lenses cap escarpments, are separately mappable for considerable distances, and constitute the map units of the lower Senora of McIntosh County, as well as of northeastern Hughes County. At many places these map units do not stand out conspicuously either in aerial photographs or in the field, but close field observation and comparison of measured sections indicate their continuity. Each unit varies laterally in the proportions of sandstone and sandy shale it contains. Neither the base nor the top of any unit is a continuous sandstone bed. This results in great variation in the measured thicknesses of units from place to place. The sandstone units are separated by dominantly sandy shale as variable in character and thickness as the sandstone units themselves.

The base of the Senora, as mapped in McIntosh County, is the base of the lowest sandstone unit in a conspicuous escarpment. Above this basal bed of the Senora the rocks are much more sandy than older rocks mapped as Stuart Shale. Basal Senora rocks strike northeastward in both northwestern Pittsburg County and southwestern McIntosh County. Projection of the base of the Senora in the direction of strike from Pittsburg County across the Canadian River and its associated alluvium agrees reasonably well with the base of the Senora as mapped in McIntosh County.

In T. 10 N., Rs. 13, 14, 15 E., the only part of McIntosh County where the entire Senora Formation crops out, the lower sandstone part is estimated to be 600 feet thick, the upper shale part about 350 feet thick, and the total estimated outcrop thickness about 950 feet.

The Senora sandstones of McIntosh County are light gray to tan, where freshly exposed, and weather to various shades of reddish brown. Most are fine grained, micaceous, lenticular, and contain plant fossils. Ripple marks, cross-bedding, and penecontemporaneous folding are common. Most Senora shales are silty. In the southern part of the county they are blue to medium gray; in the northern part they are greenish gray to dark. One coal outcrop was found, in sec. 23, T. 10 N., R. 14 E. The seam is 7.5 inches thick. A black fissile to blocky shale that contains phosphatic nodules and is about 10 feet thick crops out in the bank of the stream near C sec. 2, T. 11 N., R. 14 E. Black fissile shale is also exposed at a place called "The Rock Slide" in the SE¼ sec. 27, T. 11 N., R. 14 E., but it does not contain phosphatic nodules.

Unit IPsn-1, the basal unit of the Senora Formation, extends from alluvium associated with the Canadian River to alluvium associated with the North Canadian River and Deep Fork. It is correlated with IPsn-1 in secs. 35, 36, T. 9 N., R. 14 E., and doubtfully correlated with IPsn-1? in T. 12 N., Rs. 15, 16 E. It is minutely cross-bedded at many places, and, for this reason, weathered surfaces have a characteristic crinkly appearance. It forms a distinct bench at most places along the basal Senora escarpment, which is actually capped by the unit IPsn-2. Consequently, it is not generally well exposed but is covered by rubble from above. Just north of the alluvium of the Canadian River, IPsn-1 is 23 feet thick, but it is thinner northward. It is virtually continuous with unit IPsn-2 for about 2 miles in secs. 1, 13, T. 9 N., R. 15 E., where their combined thickness is about 55 feet. In the cut on State Highway 9, 1.5 miles west of Vivian, it is 15 feet thick and is composed of several lenticular sandstone beds separated by thin sandy shale beds. It is 4 feet thick at the north line of sec. 19, T. 10 N., R. 15 E. From that locality northward to alluvium associated with the North Canadian River, its average thickness is about 2 feet. It is well exposed in the south-central part of sec. 17, T. 10 N., R. 15 E., where it caps the hill, and at a quarry in the outlier in SE¼ sec. 16. It is poorly exposed in Bald Hill, secs. 16, 17, T. 10 N., R. 15 E. The overlying shale ranges in thickness from virtually nothing in secs. 1, 13, T. 9 N., R. 14 E., to about 45 feet.

Unit IPsn-2 crops out southeastward in T. 9 N., R. 14 E., from sec. 7 to sec. 21 and in secs. 17, 28, 29, 34, and 35. It crops out northward from the alluvium in sec. 27, T. 9 N., R. 14 E., to secs. 12, 13, T. 10 N., R. 14 E. It is the capping sandstone of the lowest escarpment of the Senora Formation, the high escarpment above the thick Stuart Shale. At some places the outcrop extends down the dip slope as much as 2.5 miles.

Along the southern part of its outcrop it is generally massive sandstone, 10 to 20 feet thick, but locally, as in sec. 23, T. 10 N., R. 15 E., it consists of thin sandstone beds separated by sandy, silty shale. Whitesides (1957) described it in the northern part of T. 10 N., R. 15 E., as fine-grained, silty, micaceous sandstone and as being about 12 feet thick in sec. 7, but so indistinct in the southern part of the adjoining sec. 18 that he did not map it there. No sandstone outcrop found north of Deep Fork seems to correspond to this unit. The overlying shale is mostly silty in the southern part of the county, where it contains sandstone unit IPsn-3. In the northwestern part of T. 10 N., R. 15 E., it is gray, platy, and argillaceous. It is about 100 feet thick.

Unit IPsn-3 crops out in T. 9 N., R. 14 E., about 30 feet above the base of the shale that overlies unit IPsn-2. The outcrop extends from sec. 11 to sec. 27, and outliers cap the hills south of Mill Creek. A sandstone lens that crops out in sec. 16 is also called IPsn-3. The unit has a maximum thickness of about 5 feet and is not well exposed at most places. The sandstone that crops out in secs. 19 and 30 is an uncertain correlative.

The unit IPsn-4 crops out in secs. 9, 15, T. 8 N., R. 13 E., and continuously from sec. 7, T. 9 N., R. 14 E., northeastward to sec. 25, T. 10 N., R. 14 E., and thence northward to sec. 2, T. 10 N., R. 14 E. It is dubiously correlated with unit IPsn-4? in T. 12 N., R. 15 E. Sandstone caps of hills south and southeast of the outcrop in Tps. 9, 10 N., R. 14 E., are obviously outliers. Other sandstone outcrops on the tops and sides of hills in secs. 14, 15, 16, 21, 22, T. 9 N., R. 14 E., are here considered to be outliers of IPsn-4. However, it must be said that these correlations are not obvious during cursory field examination. They become convincing only after a study of aerial photographs and of the map and after careful consideration of detailed field observations. Isolated sandstone outcrops in secs. 19, 30, T. 9 N., R. 14 E., are somewhat uncertainly correlated with IPsn-4.

Pitt (1957) described the unit IPsn-4 in T. 8 N., R. 13 E., as fine-grained, micaceous, dark-brown sandstone, 38 feet thick. Andrews (1957) described it along the north line of sec. 30, T. 9 N., R. 14 E., as fine-grained, red-brown, massive sandstone, 42 feet thick, and the top is somewhat eroded there. In that locality the sandstone occupies the westward slope of a hill and is broken into a number of blocks, each of which dips steeply northwestward. The steep dip could be attributed to slumping, but, considered with other abnormal conditions along a northward trend, they are thought to be the result of minor local movement along a pre-Cabaniss fault. The sandstone in the outliers in the middle of T. 9 N., R. 14 E., is brown, lenticular, cross-bedded, and about 25 feet thick, maximum; but the top is eroded. The dips of these outliers seem to conform to the slopes of the hills, which fact suggests slumping, but there is no obvious undercutting, and the outcrop of unit IPsn-2 swings far to the south in a broad bend around these outliers. All these observations together are interpreted to mean that the outliers occupy a structurally high and complex area, but it is difficult to assess the structural conditions in pre-Cabaniss rocks (see the section on surface structure).

Along the continuous outcrop in Tps. 9, 10 N., R. 14 E., IPsn-4, like other Senora units, contains considerable sandy shale and neither the top nor base is everywhere at the same stratigraphic horizon. The over-all thickness is about 40 feet, but the local topographic expression is commonly caused by a lens of much less thickness, only 2 feet thick in sec. 2, T. 10 N., R. 14 E.

Probably the best locality in McIntosh County for collecting fossil plants is along the scarp slope below the outcrop of IPsn-4 in secs. 18, 19, T. 10 N., R. 15 E. Large casts of *Sigillaria* are abundant, and casts of *Lepidodendron, Calamites,* and *Stigmaria* are present. Fragments of fossil scale trees may be seen in the walls of Happy Hollow Schoolhouse in sec. 24, T. 10 N., R. 14 E.

A coal seam 7.5 inches thick lies 5 feet below the top of unit IPsn-4 in sec. 23, T. 10 N., R. 14 E. Below the coal is an underclay 1 foot thick, which contains much carbonaceous material. The sandstone immediately above the coal is thin-bedded and contains coal streaks and fossil pelecypods. This coal seam was not found elsewhere.

The dubious correlative, IPsn-4?, in T. 12 N., R. 15 E., was mapped by Manhoff (1957) as the lower part of his unit IPsn-2, but the correlation is the author's. In the area north of Hitchita, along the Muskogee-McIntosh county line, is a high hill around which four mappable sandstone units crop out. Each is composed of somewhat resistant sandstone lenses and less resistant sandstone and extremely sandy, silty shale strata, all of which Manhoff justifiably classified as sandstone. Each of Manhoff's units has resistant sandstone at the base sufficiently continuous to make a discernible, mappable topographic expression or escarpment. The less resistant strata extend up to the base of the next such unit, and generally culminate in extremely silty, shaly sandstone, or extremely sandy, silty shale, classified as sandy shale by the author for practical cartographic reasons. The fourth unit is a small outlier at the top of the hill, just over the line in Muskogee County. It was not mapped separately by Manhoff, but he did map its main outcrop separately farther west. It seems fairly clear that the strata that crop out in this hill should be placed in the lower sandstone part of the Senora Formation, but the correlation of its parts with Senora Sandstone units south of Deep Fork is dubious at best.

Pitt (1957) reported that the shale that overlies unit IPsn-4 is dark to medium gray and fragmental to fissile in Tps. 8, 9 N., R. 13 E., and that it is 35 feet thick in sec. 9, T. 8 N., R. 13 E. Andrews (1957) described it as silty, blue gray, blocky, and 50 feet thick in sec. 4, T. 9 N., R. 14 E. Farther east and north in this township it includes the shale that overlies IPsn-5, and is for that reason about 150 feet thick in the eastern part of sec. 4. It is, in general, poorly exposed and is thinner farther northward. Along the north line of sec. 11, T. 10 N., R. 14 E., it consists of 12 feet of black fissile shale at the base, succeeded by greenish-gray shale 70 feet thick.

Unit IPsn-5 crops out in secs. 9, 16, 17, T. 8 N., R. 13 E.; from sec. 26, T. 9 N., R. 13 E., to sec. 6, T. 9 N., R. 14 E.; and in secs. 4, 5, 6, T. 9 N., R. 14 E. Pitt reported that the unit is more than 12 feet thick in sec. 9, T. 8 N., R. 13 E.; that 38 feet of sandstone belonging to the unit is exposed in SW¼ sec. 27, T. 9 N., R. 13 E.; that it thins northward to 22 feet in NE¼ sec. 15, T. 9 N., R. 13 E.; and that it is probably more than 20 feet thick in NW¼ sec. 1, T. 9 N., R. 13 E. Andrews (1957) found it to be only 12 feet thick, maximum, in T. 9 N., R. 14 E. He did not map it farther eastward than SE¼ sec. 4, where it is 8 feet thick, but felt that the outcrop may continue somewhat farther beneath debris from higher strata.

The outcrop is peculiarly distributed in the northwestern part of T. 9 N., R. 14 E., where part of it lies on the east limb of an asymmetric anticline that trends somewhat east of north. This anticline is accompanied along its east side by a corresponding syncline, which is probably faulted from place to place near its axis.

The shale that overlies IPsn-5 is about 50 feet thick in Tps. 8, 9 N., R. 13 E. It is dark to medium gray, silty, and contains many limonitic siltstone layers and a few thin, discontinuous, greenish-gray to brown, silty sandstone beds. It is thicker eastward; Andrews (1957) found it 90 feet thick in sec. 4, T. 9 N., R. 14 E. From that locality eastward and northward it is included in the shale that overlies unit IPsn-4.

Unit IPsn-6 is a thick, prominent scarp-making sandstone unit in Tps. 8, 9, 10 N., R. 13 E. It is fine to medium grained and weathers tan to brown, brown predominating. Generally the lower half is massive and the upper half consists of beds having a maximum thickness of 2 feet, separated by silty, sandy shale. Pitt (1957) reported that it is 50 feet thick in SE¼ sec. 18, T. 8 N., R. 13 E. Andrews reported that it is about 60 feet thick in SW¼ sec. 5, T. 9 N., R. 14 E., and about 40 feet thick in SW¼ sec. 4. He also reported the following thicknesses in T. 10 N., R. 14 E.: 27 feet, with the top eroded, in sec. 35; 32 feet on the north side of sec. 26; and 60 feet along the north boundary of secs. 23 and 24. Andrews (1957) described it as fine- to medium-grained sandstone composed primarily of quartz grains, some of which have prism faces. Whitesides (1957) reported that it is nearly 70 feet thick in sec. 14, T. 10 N., R. 14 E., and that in this locality the upper 25 feet fills an erosion channel in the lower massive part. He found what appears to be the lower 15 feet exposed at the northernmost point of its outcrop, in sec. 2, T. 10 N., R. 14 E. It may be represented by sandy shale farther north, for its outcrop was not found west of the stream in secs. 10, 15, T. 10 N., R. 14 E. From a stereoscopic study of the photographs the author is led to believe that it contains a shale lens, possibly 10 to 20 feet thick, in secs. 26, 27, 34, 35, T. 10 N., R. 14 E.

The shale that overlies unit IPsn-6 in Tps. 8, 9 N., R. 13 E., is gray to tan, weathers brown, is silty to sandy, and contains locally thin layers of dark-brown siltstone which is green in fresh fractures. It extends up to IPsn-8 and ranges in thickness from 40 to 80 feet, but it is much thicker northeastward. It is divided into lower and upper parts by the sandstone unit IPsn-7 in T. 10 N., R. 14 E., where the lower part is gray shale with some red and yellow mottling, contains zones of discoid limonitic concretions and limonitic streaks, and ranges in thickness from 30 to 80 feet. The upper part, above IPsn-7, in T. 10 N., R. 14 E., is poorly exposed, medium-gray to dark-gray, silty, platy shale that ranges in thickness from 60 to 80 feet at most places.

Unit IPsn-7 is composed of light-brown, well-cemented, fine-grained, micaceous sandstone with subangular grains. Commonly, it is massively bedded, weathers into rectangular blocks, and is about 15 feet thick. However, it is no more than 5 feet thick locally. It crops out only in T. 10 N., R. 14 E. The main outcrop forms a bench on the scarp slope that is capped by the sandstone unit IPsn-8a, and extends from NW¼ sec. 31 to SE¼ sec. 15. The sandstone seems to grade into shale at both ends of that outcrop, but it is present farther north around the hill in secs. 11 and 12, where it is about 12 feet thick. It also crops out as outliers and as closed loops on and around hills east of the main outcrop, and as a closed loop in the syncline in the west-central part of the township.

Unit IPsn-8 is a persistent ridge-making group of sandstone beds which Pitt (1957) mapped as a single unit in Tps. 8, 9 N., R. 13 E. In that area the sandstone is medium to fine grained, silty, micaceous, poorly sorted, and greenish gray where fresh, but it weathers brown. It contains silty, sandy shale as partings and lenses, but no lens is continuous enough in R. 13 E. to be mapped separately. Fossil-plant fragments are abundant, conspicuously so in SW¼ sec. 16, T. 9 N., R. 13 E., along the road to Vernon. Like other Senora Sandstone units, IPsn-8 is variable in thickness. Pitt reported that it is about 40 feet thick in NE¼ sec. 8, T. 8 N., R. 13 E.

Two persistent bodies of silty, sandy shale subdivide the sandstone unit IPsn-8 into three parts in T. 10 N., R. 14 E., and farther north. They are here designated IPsn-8a,b,c in ascending order.

The unit IPsn-8a was mapped and described by Andrews (1957) in the southwestern part of T. 10 N., R. 14 E., where its top is eroded and it cannot, therefore, be distinguished as a tongue of IPsn-8. In this area it is composed most commonly of sandstone but contains a few beds and lenses of less resistant, silty shale and therefore crops out as benches in the upper part of an escarpment which is finally capped by the highest sandstone bed that remains from erosion. Beds in the upper part are commonly ripple marked. It is split off as the lowest tongue of IPsn-8 by a shale wedge in NE¼ sec. 19, T. 10 N., R. 14 E.

Whitesides (1957) mapped and described unit IPsn-8a in the northern part of T. 10 N., R. 14 E., and in T. 11 N., Rs. 14, 15 E. It contains much massive sandstone along the North Canadian River and caps most of the prominent escarpments there. The sandstone is tan, silty, and contains minor amounts of muscovite and limonite, but is composed mostly of quartz grains, some of which have well-developed prism faces. The unit is more shaly north of the North Canadian River and is somewhat less well defined there. Parts of the unit are represented by sandy, silty shale from place to place. At one place, in sec. 1, T. 11 N., R. 14 E., the exposed sandstone is only 1 foot thick, and the entire unit seems to be represented by shale in parts of secs. 8 and 16. It is thought best, therefore, to designate the remote sandstone outliers that cap hills in secs. 7, 8, 9, T. 11 N., R. 15 E., and the even more dubious correlative in T. 12 N., R. 15 E., as IPsn-8a?. Because much of the sandstone is represented by sandy shale at many places, neither the base nor the top of the unit maintains a consistent stratigraphic position everywhere, and measured thicknesses differ greatly. Some measured thicknesses in T. 10 N., R. 14 E., are: 8 feet in sec. 16; 94 feet in sec. 17; and 45 feet in sec. 18. In T. 11 N., R. 14 E.; they are 45 feet in sec. 12, and 28 feet in sec. 10.

Gray platy shale overlies unit IPsn-8a. It has a maximum thickness of 97 feet in sec. 16, T. 10 N., R. 14 E., is 58 feet thick in sec. 10, T. 11 N., R. 14 E., and decreases in thickness to a thin wedge in the southeastern part of sec. 18, T. 10 N., R. 14 E.

Unit IPsn-8b is split off from unit IPsn-8 by a thin shale wedge in the south-central part of sec. 18, T. 10 N., R. 14 E., and crops out continuously to the northwest corner of that township. In the outcrop area south of the North Canadian River, it is fine-grained, silty, micaceous, platy sandstone which weathers dark brown; the beds are massive and the unit is relatively well defined. A large outlier caps hills in secs. 5, 8, 17, 18, T. 10 N., R. 14 E., and another caps a hill in secs. 9, 10, and 16. The unit is 45 feet thick in sec. 18, T. 10 N., R. 14 E.

Sandstone that can be plausibly correlated with IPsn-8b, and is so designated, crops out in the western part of T. 11 N., R. 14 E., north of the North Canadian River, and seems to grade into shale northward, southward, and westward. Two outliers of this sandstone cap hills in NE¼ sec. 10, and one caps a hill in secs. 2 and 11. The unit is commonly about 15 feet thick and consists of silty sandstone interbedded with silty, sandy shale. East of the church in sec. 9, the sandstone is composed almost entirely of casts and molds of small plants and is weathered to a conspicuous reddish brown. Some fossils in that locality and others along the north-south road in NE¼ sec. 30 have a peculiar purplish color. Jointing, N. 30° W., is particularly clear in the two sandstones outliers in NE¼ sec. 10, where the sandstone is ripple marked.

The shale that overlies unit IPsn-8b appears as a thin wedge in the south-central part of sec. 18, T. 10 N., R. 14 E., and increases in thickness northward to about 30 feet along the east line of sec. 10, T. 11 N., R. 14 E. At most places it is gray, silty, and platy. It is best exposed along the road that follows the west line of sec. 9, T. 11 N., R. 14 E.

Unit IPsn-8c is the uppermost of the three tongues of unit IPsn-8. It crops out in secs. 1, 2, 11, 12, 13, 14, T. 10 N., R. 13 E., and as outliers on hilltops in T. 11 N., R. 14 E. It consists of cream to tan or brown, fine-grained, micaceous, limonitic, well-cemented sandstone with silty to sandy shale lenses and partings. The total maximum thickness is not known but is probably more than 50 feet. It is 38 feet thick in the vicinity of the southeast corner of sec. 8, T. 11 N., R. 14 E. Whitesides (1957) noticed small fossil plants at the top of the hill near W¼ cor. sec. 9, T. 11 N., R. 14 E. A dubious correlative in T. 12 N., R. 14 E., is mapped with unit IPsn-8b?.

Oakes (1963, pl. I) mapped sandstone that crops out in secs. 25, 35, 36, T. 11 N., R. 13 E., on both sides of the North Canadian River in Okmulgee County, as his unit IPsn-4a. At that time he was not familiar with the unit farther south and east, in McIntosh County. It is now clear that his unit IPsn-4a, as mapped in that part of Okmulgee County, includes, from place to place, various parts of the unit here mapped in McIntosh County as IPsn-8.

As reported by Pitt (1957), the shale that overlies IPsn-8 is light brown to tan or gray, fissile to splintery, and slightly silty in Tps. 8, 9, 10 N., R. 13 E. He stated that it is 40 feet thick in T. 8 N., 85 feet thick in SE¼ sec. 7, T. 9 N., and 50 feet thick in NW¼ sec. 22, T. 10 N.

Unit IPsn-9, like IPsn-8, is a persistent group of sandstone beds, mapped by Pitt as a single unit in Tps. 8, 9, 10 N., R. 13 E. It is dark-brown, silty, micaceous, fine-grained sandstone with a minor amount of silty to sandy shale as lenses and partings. Its top is not exposed anywhere in McIntosh County, but Pitt thought that the unit was more than 70 feet thick in sec. 22, T. 10 N.

Sandstone a few feet thick, split off from the lower part of unit IPsn-9 in the northeastern part of sec. 3, T. 10 N., R. 13 E., is the same as unit IPsn-5 of adjoining Okmulgee County (Oakes, 1963) and is here correlated with unit IPsn-9? in sec. 3, T. 12 N., R. 14 E., McIntosh County.

The shale that overlies unit IPsn-9 extends up to the base of the Calvin Sandstone, the top of the Senora Formation. In McIntosh County, it crops out only in T. 10 N., R. 13 E., and is there covered by Quaternary deposits except for a narrow strip along the north side; even there it is mostly concealed by colluvium. It is estimated to be about 300 feet thick. It is exposed in adjoining Okmulgee County to the north, where it contains four mappable sandstone units, the Henryetta (Croweburg) coal seam, and four sandstone tongues which split off from the overlying Calvin Sandstone and descend northward like foreset beds of a delta (Oakes, 1963).

MARMATON GROUP

Calvin Sandstone

In McIntosh County, the Calvin Sandstone is medium to fine grained and massive. Only the lower few feet crops out in the county in two exposures along the west side of sec. 6, T. 10 N., R. 13 E.

QUATERNARY SYSTEM

Terrace Deposits

Deposits of fine-grained quartz sand, silt, and clay mantle the bedrock in parts of McIntosh County at elevations as much as 100 feet above the alluvium of Recent age. They are associated with the three main streams, Canadian River, North Canadian River, and Deep Fork, and with some of their large tributaries. They are shown on plate I where they are designated by the symbol Qt. These deposits are probably mostly of Quaternary age but some may be older. Not enough fossils have been recovered from them to settle the matter of age conclusively. They are commonly called terrace deposits and are erosional remnants of flood-plain deposits that once choked the valleys of these streams. Their maximum thickness is not known, but it is probably about 100 feet. They are weakly consolidated at a few localities; the cementing material is composed of various hydrous oxides of iron. In color, they range from white through gray and various shades of red or brown, but at most places they are deep orange. Some deeply weathered sandy shale bedrock closely resembles the terrace material, and it is difficult to distinguish the one from the other in some situations. At some places, notably about Stidham, in T. 10 N., R. 15 E., McIntosh County, the terrace deposits form extensive flat areas. On the other hand, some of the highest of the terrace deposits and some adjacent to the Recent alluvium, where slopes are steep, are so dissected as to form small "badlands." Some of the gullies have almost vertical sides nearly 30 feet high. The material is so fine grained and porous that it resists slumping.

So-called pimple mounds are abundant on some of the terrace deposits. Their origin is controversial (Melton, 1954). They average 2 feet in height and 30 feet in diameter, but some are as much as 5 feet high and 50 feet in diameter. Roadside ditches have been cut through such mounds in SE¼ sec. 2, T. 10 N., R. 15 E. Sieve analyses of samples from inside the mounds and from the intervening areas reveal no significent difference in size distribution of the sand grains. However, flowering weeds appear to be concentrated on the mounds, whereas grasses are the conspicuous cover of the area between the mounds.

Flat areas, like that about Stidham, contain some of the most productive land in the county, but some areas with rolling topography have light soil most suitable for such crops as peanuts, peaches, berries, and sweet potatoes.

The terrace deposits are generally coarsest near the base and at some places contain basal gravels, according to verbal reports of one or two water-well drillers. Most of the water supply of Stidham comes from wells drilled to the contact of the terrace deposits with the underlying shale at a depth of about 40 feet. At places wells that do not reach the base of the terrace deposit produce enough water for farm needs.

Recent Alluvium

Recent alluvial deposits of sand, silt, and clay cover large areas adjacent to the Canadian River, the North Canadian River, Deep Fork, and some of their tributaries. They are designated by the symbol Qal on plate I.

There are several distinct flood plains, at least locally; the surface of each has little or no relief, and, although they are mapped as a single unit, each is at a slightly different level. Logs of wells drilled in search of oil and gas indicate that the alluvium of Recent age is as much as 100 feet thick.

The size range and distribution of the quartz grains are about the same as in the terrace deposits. Probably much of the material is either reworked from the terrace deposits or has the same origin. The streams still overflow their banks from time to time and add fresh layers of sediment. Wind-blown material accumulates in dry periods. The flood-plain deposits are well stratified. In general they are darker than the terrace deposits because of the greater content of organic matter, and some of the farmland upon them is highly productive.

FOSSILS IN McINTOSH COUNTY

Carl C. Branson and L. R. Wilson

Invertebrates

Paleontological material in McIntosh County is sparse and little known. Invertebrates have been reported from but a few places. Meek (1957, p. 21) listed *Spirifer rockymontanus, Neospirifer cameratus, Crurithyris planoconvexa,* and *Septimyalina perattenuata* from the Inola Limestone Member of the Boggy Formation near Onapa. A higher limestone in the Boggy is crowded with specimens of *Permophorus.* South of Council Hill clay-ironstone nodules in a Boggy shale yielded a small typical molluscan faunule containing the bivalves *Aviculopecten, Astartella, Nuculopsis, Parallelodon,* and *Anthraconeilo,* a species of a snail (*Bucanopsis*), and the nautiloids *Metacoceras cornutum* and *Protocycloceras* (p. 29).

Stine (1958, p. 50) found pyritized fossils in the caprock of the Secor coal in the NW¼ sec. 5, T. 12 N., R. 18 E. In the waste heaps of the Braudrick coal pit at that locality, the writers collected unpyritized specimens of *Desmoinesia* and *Mesolobus mesolobus.*

The clams *Dunbarella knighti* and *Myalina* (*Myalina*) *lepta* were found by Whitesides (1957, p. 90) in the Senora Formation about 150 feet above the base in sec. 18, T. 10 N., R. 15 E. Senora rocks in Dewar nearby in Okmulgee County carry abundant *Desmoinesia* and chonetids and presumably do so in McIntosh County. The scyphomedusan *Conostichus* has been collected in the Senora three miles north of the county and surely must occur farther south.

Invertebrate fossils occur at few places in McIntosh County and no good collecting locality is known.

Plant Megafossils

Plant megafossils in McIntosh County are reported from the Bluejacket and Taft Sandstones of the Boggy Formation and from the Stuart and Senora Formations of the Cabaniss Group. The localities are scattered and the fossils are fragmentary and generally poorly preserved. Most of the collections were made and reported by Andrews (1957), Meek (1957), and Whitesides (1957). Several additional plant localities were discovered by the writers in the summer of 1966.

The lowest stratigraphic occurrence of plant megafossils reported in McIntosh County is in the Bluejacket Sandstone at the base of the Boggy Formation. The Bluejacket contains sandstone casts of *Calamites suckowii* and sandstone impressions of *Sigillaria* sp., which were collected by the writers in a roadcut on U. S. Highway 266, SE¼ SW¼ sec. 33, T. 12 N., R. 18 E.

The writers were unable to collect Andrews' (1957) Boggy Shale plant locality in sec. 19, T. 10 N., R. 16 E., because it is now inundated by Eufaula reservoir. His second Boggy Shale locality (SW¼ sec. 31, T. 10 N., R. 15 E.) could not be found and appears to be an error. That area is mapped as Stuart. Coleman (1958, p. 4) reported molds of *Calamites* sp., *Lepidodendron* sp., and numerous specimens of *Stigmaria* sp. from the upper beds of the Bluejacket Sandstone in secs. 10, 22, and 23, T. 12 N., R. 17 E. and the writers found *Stigmaria* sp. casts below the 1½-inch coal in Rentiesville (SW¼ SE¼ sec. 10, T. 12 N., R. 17 E.). Coleman (1958, p. 45) also reported the presence of many plant fossils in the silty shale parting of the Secor coal in a strip mine 5 miles east of Checotah. The mine is not being worked and plant fossils are not available for identification. In the sandstone above, in a coal presumed to be Secor (NW¼ NE¼ sec. 26, T. 12 N., R. 17 E.), the writers found impressions of *Calamites* sp., *Lepidodendron* sp., *Sigillaria* sp., and *Stigmaria* sp. The stratigraphically highest Boggy Formation plant fossils reported are from the Taft Sandstone (Meek, 1957, p. 25). These consist of *Stigmaria* sp. and *Calamites* sp. The Stuart Formation has yielded *Calamites* sp., *Annularia* sp., and *Pecopteris* sp. impressions, but no locality was given by Meek (1957, p. 31).

The Senora Formation plant fossils reported by Whitesides (1957, p. 32, 40) are *Calamites* sp., *Lepidodendron* sp., *Sigillaria* sp., *Stigmaria* sp., and *Neuropteris* sp. He stated that large casts are present and abundant in sec. 18, T. 10 N., R. 15 E. Andrews (1957, p. 29) reported *Calamites* sp., *Lepidodendron* sp., *Sigillaria* sp., and *Stigmaria* sp. to be relatively common in the Senora sandstones and shales of the Raiford area.

Plant Microfossils

Studies of plant microfossils in McIntosh County are presently restricted to two coal deposits in the Boggy Formation, one by Wilson (reported here) is of a 1½-inch coal on the eastern edge of Rentiesville that occurs in a shale lens near the top of the Bluejacket Sandstone, and the other is of the Secor coal, reported by Clarke (1961).

The coal at Rentiesville contains a palynological assemblage of *Laevigatosporites desmoinesensis, L. minutus, Lycospora* sp., *Calamospora* sp., *Cirratriradites maculatus, Punctatisporites* sp., and the recently described palynomorph *Cappasporites distortus,* which Urban (1966) described as being known only from the Boggy Formation.

Clarke's (1961) Secor coal samples, collected from a 30-inch-thick exposure in the strip mine of the Magic City Coal Company at SW cor. sec. 29, T. 12 N., R. 18 E., yielded the following forms:

Leiotriletes sp.
Punctatisporites latigranifer
P. obliquus
P. provectus
P. cf. *P. punctatus*
Calamospora flexilis
C. cf. *C. liquida*
C. cf. *C. microrugosa*
C. cf. *C. parva*
C. straminea
Granulatisporites granularis
G. pallidus
G. parvus
G. cf. *G. tuberculatus*
G. verrucosus
Planisporites microtuberosus
Lophotriletes cf. *L. gibbosus*
Apiculatisporis cf. *A. baccatus*
Acanthotriletes sp.
Raistrickia imbricata
R. saetosa (?)
R. solaria
Convolutispora cf. *C. florida*
Converrucosisporites sp.
Verrucosisporites cf. *V. verrucosus*
Schopfites colchesterensis
Microreticulatisporites foveatus
M. cf. *M. punctatus*
Reticulatisporites lacunosus
R. cf. *R. reticulocingulum*
Triquitrites additus
T. bransonii
T. dividuus
T. exiguus
Lycospora brevijuga
L. granulata
Cadiospora sp.
Simozonotriletes sp.
Cirratriradites annulatus
Laevigatosporites desmoinesensis
L. minutus
L. ovalis
L. pseudothiessonii
L. punctatus
L. robustus
Endosporites angulatus
Wilsonites vesicatus
Vestispora profunda
Florinites pellucidus
Alatisporites hexalatus

Clarke (1961, p. 5) stated that his study of the Secor coal supports the conclusion of Higgins (1960) that the Secor coal is correlative with the Weir-Pittsburg coal of northeastern Oklahoma. Wilson believes that the error of this conclusion is explained by the fact that Higgins recognized the palynological similarity of the Secor coal in Muskogee County to a coal in Mayes County that had been identified as Weir-Pittsburg coal. Palynologically the coal in Mayes County is more closely related to the Secor coal seam than it is to the Weir-Pittsburg seam studied by Bond (1963). The spore genera *Acanthotriletes, Convolutispora, Gravisporites, Knoxisporites, Kosankeisporites, Reinschospora, Schopfipollenites, Schopfites, Simozonotriletes,* and *Vesicaspora* are present in the Secor coal but are not reported from the Weir-Pittsburg coal; and the spore genera *Anapiculatisporites, Illinites, Potonieisporites,* and *Thymospora* occur in the Weir-Pittsburg coal and are not known to occur in the Secor coal. Bond (1963, p. 88) has shown that only 16.5 percent of palynological species of the Weir-Pittsburg coal occurs in the Secor coal; consequently 83.5 percent of the species of the Weir-Pittsburg spore assemblage differs from those of the Secor coal. Wilson, therefore, concludes that coal in Mayes County cannot be identified with the Weir-Pittsburg coal and the Secor coal seam is not correlative with the Weir-Pittsburg coal seam.

SURFACE STRUCTURE

It was not the purpose of this investigation to make a detailed study of the structure of the rocks at the surface in McIntosh County, such as would have been made in virgin territory thought to have important accumulations of oil and gas. However, the more obvious structural features that came under observation are here discussed briefly.

Two adjoining areas south of the Canadian River and outside McIntosh County are shown on the geologic map (pl. I). One of the two, an area of about 31 square miles, mostly in T. 9 N., R. 17 E., Pittsburg County, had not been mapped in detail before. The other, which includes all of T. 9 N., R. 18 E., and about 9 square miles in the southern part of T. 10 N., R. 18 E., Haskell County, is taken from Oklahoma Geological Survey Bulletin 67 (Oakes and Knechtel, 1948, pl. I) to complete the presentation of the geological environment of the Eufaula dam. The structure of these two adjoining areas is here discussed with the structure of McIntosh County. The most conspicuous structural feature in these two areas is the Brooken Creek syncline.

The south limb of the Brooken Creek syncline is continuous with the north limb of the Enterprise anticline to the south. Its axis trends nearly westward across the middle of T. 9 N., R. 18 E., curves sharply to the southwest in T. 9 N., R. 17 E., and passes out of the mapped area over the south line of sec. 32. Its north limb merges into the south limb of an unnamed anticline, the broad and ill-defined crest of which enters the mapped area from the southwest near NE cor. sec. 31, T. 9 N., R. 17 E., and curves eastward to sec. 36, T. 10 N., R. 18 E. The north limb of this unnamed anticline is continuous with the south limb of the Porum syncline.

The structure of the rocks that crop out in eastern McIntosh County is dominated by three major folds and two major faults. The folds are, from south to north, the Porum syncline, the Warner uplift, and the Rattlesnake Mountain syncline. The two faults are named, descriptively, the south fault of the Warner uplift and the north fault of the Warner uplift. As the names imply, the faults separate the uplift from the synclines on either side. Structural movements were at least intermittent if not continuous during deposition, and the synclines acted as sediment traps, with the result that most units are thicker in the synclines than on the uplift. These east-west structural features are probably the result of the same forces that produced the folds and faults of the Ouachita Mountains.

The Porum syncline to the east, in Muskogee County, was named and briefly described by Wilson (1937, p. 83) as follows:

> The axis of the Porum syncline extends from sec. 19, T. 10 N., R. 19 E., northeastward in the general direction of Webbers Falls. The steep northwestern limb of this fold, which shows dips as high as 25 degrees, is associated with the downthrown side of the south fault of the Warner uplift. The broad, gently sloping southeastern limb of this syncline has a dip that is commonly a little less than 2 degrees NW. Along the axis of this fold members of the Savanna formation extend as far northeastward as sec. 18, T. 11 N., R. 20 E.

The axis of the Porum syncline has a sinuous southwestward trace across southern McIntosh County. The syncline is most plainly discernible in rocks of the Boggy Formation and in older rocks. Its presence in post-Boggy rocks, in the southwestern part of the county, is indicated by abnormal but less pronounced dips.

Webb (1957, 1960) believed that a fault exists along the south side of the Porum syncline, upthrown to the south, but concealed by the Recent alluvium of the Canadian River. This postulated fault is here called the Standing Rock fault because it is drawn near the local landmark of that name, a great block of sandstone standing in the lake in SE¼ NE¼ NW¼ sec. 34, T. 10 N., R. 17 E. Other such blocks rest at various elevations up the steep scarp slope that is capped by the thick sandstone unit IPb-5 north of the lake. Their prismatic shape and great size suggest that they may have been formed by forces such as might result in a fault in the vicinity, rather than by the usual agencies of jointing and erosion alone. Probably all reached their present positions by slumping. Other large sandstone blocks are similarly distributed along the outcrop of IPb-5 near the trace of the Standing Rock fault, and the unit IPb-5 dips uncommonly steeply northward into the Porum syncline. Later, Neff (1961, p. 27) discussed a subsurface fault, also upthrown to the south, which passes through secs. 29, 30, T. 9 N., R. 16 E. This could well be the Standing Rock fault.

A small anticline on the north side of the Porum syncline in sec. 1, T. 10 N., R. 18 E., extends 3.5 miles southwestward to a point near S¼ cor. sec. 9, where it is covered by alluvium. Its north flank is cut by the south fault of the Warner uplift, and its south flank extends to the axis of the Porum syncline. The axis of this small anticline curves northeastward into Muskogee County and is cut by the south fault of the Warner uplift within a mile.

The south fault of the Warner uplift, as it appears in Muskogee County to the east, is described by Wilson (1937, p. 77) as extending from sec. 3, T. 12 N., R. 20 E., southwestward to the Muskogee-McIntosh county line in NW¼ sec. 6, T. 10 N., R. 19 E. He thought that at some places it might be a steep fold rather than a fault. It extends at least 3 miles farther westward into McIntosh County, to the west line of sec. 3, T. 10 N., R. 18 E., where the Spiro Sandstone Member of the Savanna Formation is in contact with the Cameron-Lequire Sandstone unit of the McAlester Formation. Webb stated that the throw is about 300 feet. The fault is concealed by alluvium farther west in McIntosh County.

Wilson (1937, p. 83) described the Warner uplift as follows:

> . . . a raised block between faults on the north and south. The strata are relatively flat-lying on this uplift, except for the gentle westward regional dip. Close to the north fault the strata are flexed steeply northward, and in localities where the fault passes locally into a monoclinal fold they dip unbroken into the steeply dipping limb of the Rattlesnake Mountain syncline. In a similar way the flat-lying strata are flexed steeply southward at the south fault and, where this fault passes into a monoclinal fold, the strata dip unbroken into the steep limb of the Porum syncline.

The Warner uplift is nearly 7 miles wide where it enters McIntosh County, mostly along the east line of T. 11 N., R. 18 E. It is discernible in outcrops of the Boggy Formation as far southwest as the east side of R. 16 E. Data from logs of wells drilled for oil and gas indicate that it is broader farther west and merges into other structural features, not yet well known in detail.

The Warner uplift was probably rising nearly continuously throughout most of Boggy time. The interval from the base of the Boggy to the base of unit IPb-6, the youngest Boggy Sandstone unit preserved from post-Boggy erosion, is estimated to be about 1,350 feet in the Porum syncline and only about 500 feet on the Warner uplift. The water over the uplift was probably shallow enough to permit wave action to keep the sediment load sufficiently agitated to prevent deposition of the finer particles most of the time. The upper part of the Bluejacket Sandstone is fine grained and shaly, as if composed of the coarser material winnowed out from sediment that would otherwise have been deposited as sandy mud, the parent material of sandy shale. The Secor coal which is present in both the Porum and Rattlesnake Mountain synclines seems to be absent from the uplift, indicating that the uplift probably stood too high to support coal marshes in Secor time. On the other hand, thinner coal seams younger than Secor are present on the uplift but not in the synclines, as if marshy conditions prevailed on the uplift at times when the water was too deep in the synclines for the growth of marsh vegetation.

Three secondary structural features on the Warner uplift in McIntosh County deserve brief mention. Stine (1958) mapped a small anticline, the axis of which crosses SE cor. sec. 36, T. 11 N., R. 18 E., and extends northeastward into Muskogee County across secs. 31, 32, 29, 28, T. 11 N., R. 19 E. He also mapped a syncline, the axis of which lies across secs. 22, 23, 24, 13, T. 11 N., R. 18 E.; dips into the syncline are of the order of one degree. The author postulated a fault, downthrown to the north, across secs. 35, 36, T. 12 N., R. 18 E., to account for the distribution of the outcrops of some lenticular sandstones.

The north fault of the Warner uplift was described by Wilson (1937, p. 78). It enters McIntosh County from Muskogee County, to the east, near E¼ cor. sec. 25, T. 12 N., R. 18 E., and extends southwestward to N¼ cor. sec. 23, T. 11 N., R. 17 E., where the throw is insufficient to offset completely the thick Bluejacket Sandstone. It is not clearly discernible farther southwest. The throw probably does not exceed 300 feet anywhere in McIntosh County.

The Rattlesnake Mountain syncline was mapped in Muskogee County, to the east, by Wilson (1937). The axis extends from the Arkansas River, near NE cor. sec. 19, T. 13 N., R. 20 E., southwestward to E¼ cor. sec. 24, T. 12 N., R. 18 E. It continues into McIntosh County, first southwestward, then westward, to the vicinity of Checotah in the southwestern part of T. 12 N., R. 17 E. The Rattlesnake Mountain syncline is somewhat asymmetric; outcrops on the south limb dip northwestward from the Warner uplift as much as 90 feet per mile and on the north limb dip southwestward about 50 feet per mile.

In western McIntosh County, the outcrops are mostly post-Boggy in age and have been much less strongly folded and faulted than have the Boggy and pre-Boggy rocks of eastern McIntosh County. In general, the outcropping rocks dip a little north of west at a rate of about 1 degree, or less. In a few localities the dips are as great as 2 degrees. The simple general structure is broken by a few local features. The most noticeable of these is a syncline, here called the Hanna syncline, as much as 6 miles long, that trends nearly parallel to the strike of the rocks from the alluvium associated with the Canadian River in the western part of sec. 30, T. 9. N., R. 14 E., northeast of Hanna, to the North Canadian River in the western part of sec. 4, T. 10 N., R. 14 E., and possibly farther. The axis follows drainage lines closely wherever the streams flow on bedrock, but it is concealed across broad areas of alluvial terrace deposits. The eastward dip of the west limb, as much as 2 degrees, is conspicuous in a region where the dips at most places are half that amount and in the opposite direction. At some places the westward dip of the east limb is as great but, being in the expected direction, is not so arrestingly noticeable. The change in dip along the axis is so abrupt as to suggest a fault, but the accumulated debris along the streams makes exact correlation of beds from side to side uncertain. However, the author feels that if a fault is at the surface the displacement is not great.

Apparent eastward dip along the south side of SE¼ sec. 9, T. 11 N., R. 14 E., suggests that the Hanna syncline may extend that far north; the writer finds it difficult to dismiss this apparent dip as mere hillside slump.

The unusual shape and distribution of the outcrop of unit IPsn-9? in secs. 3, 10, T. 12 N., R. 14 E., and apparent small displacements within the sandstone prompted Manhoff (1957) to draw the three faults shown in that vicinity on the geologic map (pl. I). Clark (1928, p. 9, pl. I) showed a northward trending subsurface fault in Ordovician rocks in that vicinity with a displacement of about 200 feet.

Unusually steep north dip of the sandstone unit IPsn-5 across secs. 26, 27, T. 9 N., R. 13 E., northwest of Hanna, suggested to Pitt (1957) the fault shown across secs. 34 and 35, on the geologic map (pl. I).

A complex structure in the middle of T. 9 N., R. 14 E., may be most easily described as an east-west anticline with a southward-plunging syncline on its south limb. The anticlinal aspect is probably the result of orogenic compression transmitted from the Ouachita Mountains region; the synclinal feature is probably the result of post-Senora movement along a fault in the Boggy and pre-Boggy rocks, caused by epeirogenic forces related to the Ozark uplift. The area covered by this complex structure is also a high hill on which are eroded outliers of unit IPsn-4 as much as 25 feet thick. In this locality, IPsn-4 consists of several sandstone beds or lenses. Andrews (1957) felt that the outliers may be at several slightly different stratigraphic positions. In general, the outliers dip in conformity with the slopes on which they lie, but no other evidence of slumping exists, such as undercutting and differential settling of adjacent joint blocks. The outcrop of IPsn-2 passes around this hill, and dips of IPsn-2 and the outliers of IPsn-4 are in general agreement. It is interesting to observe that the southward-plunging syncline on the south flank and the apparently synclinal hill capped by a promontory of IPsn-6 in secs. 3, 4, T. 9 N., R. 14 E., mark a trend nearly parallel to the trend of the Hanna syncline to the west. Such north-south synclinal trends probably indicate faults in the Boggy and pre-Boggy rocks along which movement has occurred in post-Senora time.

ECONOMIC GEOLOGY

McIntosh County has produced limited amounts of oil, gas, and coal. The surface rocks are mostly shales and sandstones, deposited in relatively shallow water. The extremely few limestone beds are too thin and shaly to be useful. Old sandstone buildings in the towns and a few in the surrounding rural areas indicate that useful sandstone is available. Probably the best massive sandstone is that in unit IPb-5 south of Eufaula. Thin veneer stone has come mostly from the upper part of the Bluejacket Sandstone, unit IPb-b. Shale and clay suitable for making common brick and, possibly, ware of higher grade could probably be found in McIntosh County. At most places the sand found in the recent alluvium and in the terrace deposits is fine grained but suitable for some uses. No large deposits of good gravel are known to the writer. The consolidated rocks, as well as Recent alluvium and terrace deposits, contain sufficient ground water for rural domestic requirements at most places. At some places sufficient ground water is available to supply communities and small towns. However, properly constructed ponds and small lakes are the best and most dependable source for modest requirements. Lake Eufaula supplies abundant water for all industrial purposes, as well as for a considerable amount of hydroelectric power.

The occurrence and production of oil and natural gas in McIntosh County are discussed in part II of this bulletin.

COAL

McIntosh County has little workable coal. For the record, all known exposures of coal except a few erratic seams less than 1 inch thick are here listed and discussed. Most are of academic interest only.

Stine (1958) mapped an exposure of coal in the upper part of the Warner Sandstone Member of the McAlester Formation, in SW¼ sec. 25, T. 11 N., R. 18 E., but did not describe it. Coal is common at this position in the Warner over much of Haskell and Muskogee Counties. At few places is it as much as 12 inches thick, and it has not been mined for any but local use.

Coleman (1958) reported a number of coal exposures in T. 12 N., Rs. 17, 18 E. The oldest is correlated with the Stigler coal of McAlester age. It is 8 to 10 inches thick and has been mined from several small strip pits, now abandoned, in secs. 3, 12, T. 12 N., R. 18 E. Coleman saw a coal seam less than 1 inch thick and less than 1 inch above the Spaniard Limestone of the Savanna Formation, near C sec. 12, T. 12 N., R. 18 E., but nowhere else. He also saw the Rowe coal (lower Boggy coal of Wilson, 1937, p. 53), with its closely superjacent Doneley Limestone cap rock, at several places across the northeastern part of T. 12 N., R. 18 E. The Rowe in this area ranges in thickness from 6 to 17 inches. Webb (1957, 1960) found an outcrop containing the Rowe coal and the Doneley Limestone in NW¼ SW¼ NE¼ sec. 11, T. 10 N., R. 18 E. The Rowe at this locality is 6 inches thick. Webb also found the Rowe coal seam in NE¼ NW¼ SE¼ sec. 7, T. 10 N., R. 18 E.

The Bluejacket Sandstone of the Boggy Formation contains many extremely thin coal seams of small lateral extent and also contains many small lenses of similar thickness and appearance which prove to be bituminous residue. Farther west the Bluejacket is known to the oil fraternity as the Bartlesville, or Salt, sand and is one of the main sources of oil and gas. One of the thin coal seams is exposed on the south side of the road along the north side of sec. 15, T. 12 N., R. 17 E., in Rentiesville.

The name "Secor" is commonly applied to one or possibly several coal seams that lie at various distances, from a few feet to 100 feet or more, above the Bluejacket Sandstone with no conspicuously thick sandstone between. Because of this practice, a coal seam that has been strip mined in sec. 5, T. 11 N., R. 18 E., and in secs. 31, 32, T. 12 N., R. 18 E., is here called Secor. It lies about 25 feet above the Bluejacket Sandstone near the axis of the Rattlesnake Mountain syncline. Coleman (1958) stated that in this locality the Secor is 30 inches thick, is divided in half by a shale parting from 2 to 20 inches thick, and is overlain at some places by a hard compact bed of dark-gray calcareous siltstone generally less than 12 inches thick. The coal is pyritic, as is the Secor at most places. So far as is known, this coal has not been found immediately south of the mined area, and it may not have been deposited over the Warner uplift. Coal exposed in secs. 3, 22, 23, 26, T. 12 N., R. 17 E., is also here called Secor. It is 17 inches thick in the exposures in SW¼ sec. 3 and lies only 6 inches above sandstone thought to be the youngest tongue of the Bluejacket in that vicinity. Webb (1957, 1960) found an outcrop of coal 18 inches thick in the north bank of the Canadian River in SE¼ NW¼ NE¼ SE¼ sec. 22, T. 10 N., R. 18 E., which he called Secor because of its relation to the Bluejacket Sandstone Member of the Boggy Formation. Ten feet of fine-grained, thin-bedded sandstone crops out a few feet below the coal. The sandstone has distorted bedding and contains fossil plants, *Lepidodendron* sp. A coal seam from 0.5 to 2 inches thick lies from 0.5 to 3 inches below the Inola Limestone at most exposures of the Inola, as mapped in McIntosh County.

The interval between the Inola Limestone and the base of sandstone unit IPb-5? represents a time of changing and shifting local depositional environments. It is filled with silty shale, intergrading with sandstone bodies, and contains thin coal seams of limited extent; some have been mined for local use. Meek (1957) found coal at several places in secs. 13, 24, 25, 26, 35, T. 11 N., R. 16 E. Some of the exposures are as much as 25 feet below the base of IPb-5?, and more than one seam may be represented. At some of these exposures the coal is as much as 17 inches thick. A coal seam, generally less than 12 inches thick, crops out about 60 feet below IPb-5?, near water level around Onapa Lake, in sec. 25, and a seam, possibly the same, crops out along the westward-flowing stream in the northern part of sec. 35.

Andrews (1957) stated that a coal was reported as being exposed above unit IPst-4 in a stream bed in sec. 8, T. 9 N., R. 15 E., but he was unable to find it. He did collect some coal specimens along a gully in sec. 24, T. 9 N., R. 14 E. He found a coal seam 7.5 inches thick and 5 feet below the top of sandstone unit IPsn-4 in sec. 23, T. 10 N., R. 14 E., and collected a sample.

Whitesides stated in his thesis (1957, p. 78-79):

> The writer found no beds of coal, but coal has been reported at four localities in the area. All reports are at least ten years old. Coal has been reported near "Bald Hill," probably associated with black, fissile Stuart shale observed by the writer in sec. 16, T. 10 N., R. 15 E. This may be the same bed that has been reported at three other places in the area: in sec. 18, T. 10 N., R. 15 E.; sec. 36, T. 11 N., R. 14 E.; and sec. 18, T. 11 N., R. 15 E. Presumably all are in the Stuart Formation. "About 1941" Alfred Mitchell (personal communication, August, 1956) found a bed of coal 28 inches thick and 50 feet below the surface while cleaning out a well in the NE¼ NE¼ SE¼ sec. 18, T. 10 N., R. 15 E. A blacksmith, "General" Lancaster, "about 1924" dug enough coal for his personal use at the junction of Alluvium and Terrace deposits in C NE¼ SW¼ sec. 36, T. 11 N., R. 14 E. The coal is about 8 feet deep (A. L. Spirlock, personal communication, August, 1956). Rubin Cindle of Henryetta "about 1940" found some coal in a deep gully in terrace sands in the N½ SW¼ SE¼ sec. 18, T. 11 N., R. 14 E., and guided the writer to the place. The writer dug to a depth of 3 feet with a hand auger at the last two localities mentioned and found no coal.

Manhoff (1957) found a coal seam 4 inches thick in the north side of U. S. Highway 266 and 400 yards east of SW cor. sec. 15, T. 12 N., R. 15 E., where it is overlain by a black, extremely carbonaceous limestone which resembles hard black shale, and is underlain by a few inches of soft gray underclay. The coal was exposed only at the highway and the limestone was exposed for a distance of not more than 1.5 miles northward and 0.7 mile southward.

Pitt (1957) reported that he found no coal cropping out in Tps. 8, 9, 10 N., R. 13 E. However, the Croweburg (Henryetta) coal should be present beneath surficial cover across the northwestern part of T. 10 N., R. 13 E. It should be about 10 inches thick, extrapolating from exposures in T. 11 N., R. 13 E., Okmulgee County.

LIMESTONE

Limestone is represented in McIntosh County by a few beds of sandy, argillaceous, calcareous rock, one foot or less thick at most places, and not economically important. The Inola Limestone is the most extensive. It crops out from place to place in the Boggy Formation in the north part of the county.

Building Stone

Sandstone suitable for building can be obtained in many parts of the county. The Bluejacket sandstone, at the base of the Boggy Formation, and the sandstone unit IPb-5, near the top, are capable of supplying blocks several feet thick as well as thin veneer stone.

Clay and Shale

Both clay and shale suitable for common brick and tile could probably be found by appropriate search, sampling, and testing.

Ground Water

Sufficient water for farm use can be obtained from wells drilled into sandstones, at most places. Larger supplies can be obtained from the alluvium along some of the streams. However, artificial ponds and lakes have been the mainstay for most stock raisers. Really large amounts of water can be obtained readily from Eufaula reservoir.

PART II. PETROLEUM GEOLOGY OF McINTOSH COUNTY

Terry Koontz*

INTRODUCTION

McIntosh County has been a producer of gas since 1912, although development in the county has been slow since the completion of the first well. A slight increase in drilling activity during the period from 1959 to 1962 resulted in the completion of 17 gas wells, but after 54 years of exploration, the results show a total of 186 producers out of 442 attempts (table V, p. 56). Only 19 wells have been completed as oil wells, with the last producer being drilled in 1958. At the end of 1965, there were 13 wells producing an average of 3 barrels of oil per day, and 28 gas wells producing more than 1,800 MMCF per year.

Production is primarily from Pennsylvanian sandstone reservoirs found at depths ranging from 600 to 3,700 feet.

Previous investigations. — The surface geology of McIntosh County is described in part I of this bulletin. A summary of previous surface investigations is contained therein, and only those investigations most pertinent to the subsurface geology of the area are mentioned below.

Portions of the subsurface geology of the county have been mapped by Logan (1957), Busch (1953), Howell and Lyons (1959), Hendricks and Parks (1950), and Neff (1961).

Snider (1914) described the geology of east-central Oklahoma, which includes the eastern part of the county. This report consisted of a brief discussion of the stratigraphy and major structures of the county. The Oklahoma Geological Survey (1917, p. 328-329) published a brief summary of the geology of McIntosh County, devoted mostly to areas of oil and gas production.

Clark (1928) wrote the section on McIntosh County which appears in *Oil and Gas in Oklahoma,* Bulletin 40, of the Oklahoma Geological Survey.

History of development. — There have been 442 wells drilled in McIntosh County since the first well was drilled in 1912. Success ratio in the county has been moderate, with 186 wells completed as producers (167 gas wells and 19 oil wells).

Gas production has increased the past 10 years due to increase of gas prices resulting in new gas-pipeline outlets. This factor also caused an increase in drilling activity from 1959 to 1962.

OIL AND GAS FIELDS

Salem Field

The Salem field consists of a single gas well that was completed in 1960. The Snee and Eberly 1 Kinney well, sec. 4, T. 10 N., R. 13 E., was drilled to a total depth of 3,945 feet in the "Wilcox" sandstone (Ordovician). A drill-stem test of the Wilcox sandstone from 3,868 to 3,878 feet flowed at the rate of 240 MCF of gas per day and recorded a shut-in pressure of 1,725 psi in 30 minutes. Attempts to complete in the Wilcox sandstone were unsuccessful and the operators plugged back to test the Jefferson sandstone (Morrow) at 3,202 to 3,214 feet. This sand, with 12 feet of net pay, was completed for an open-flow potential of 871 MCF per day through a ¾-inch choke. A confirmation attempt in sec. 3, T. 10 N., R. 13 E., was unsuccessful.

Production in this field is controlled by both structural and stratigraphic factors, the small dome in section 4 and the grading of

* Oklahoma Natural Gas Company, Tulsa, Oklahoma.

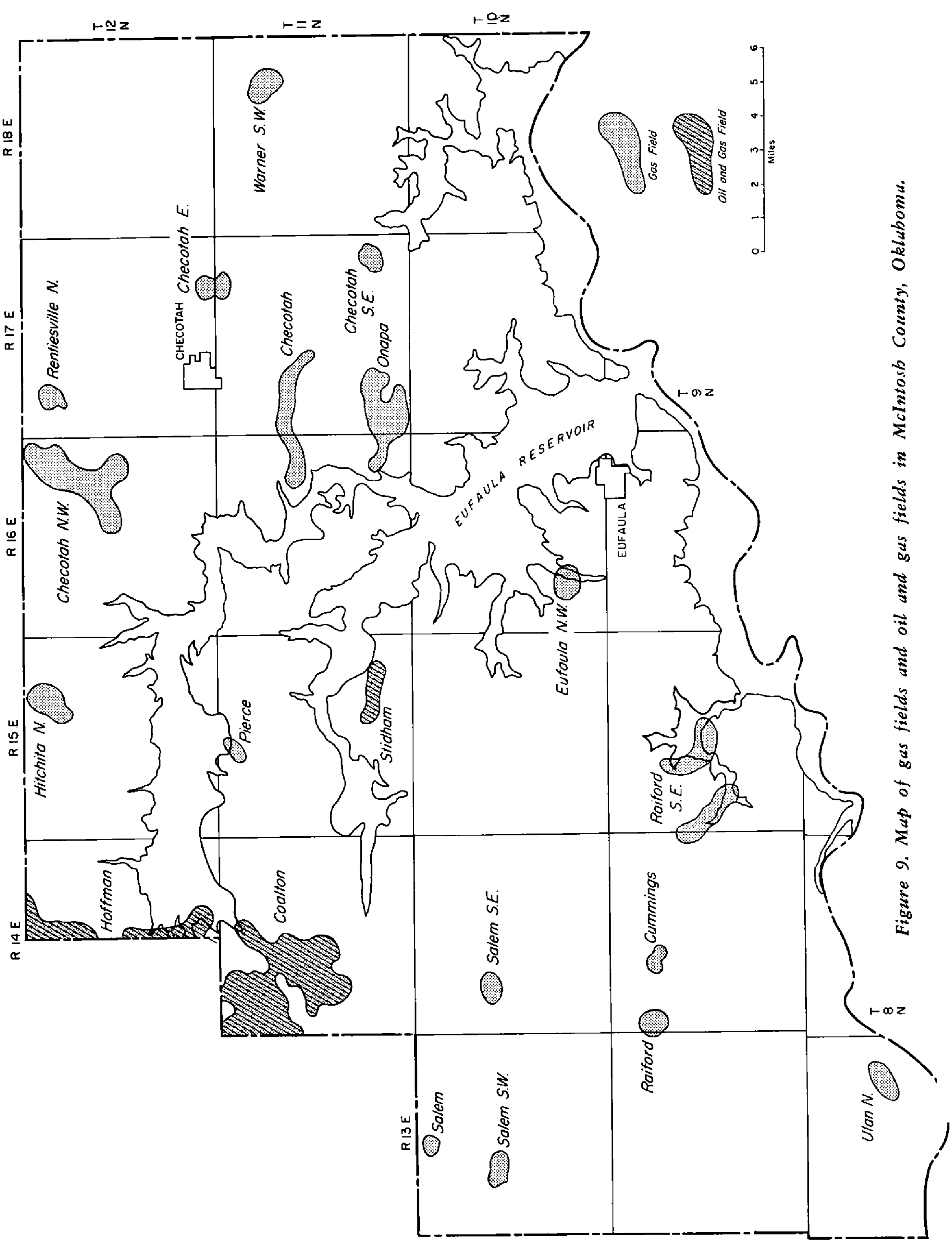

Figure 9. Map of gas fields and oil and gas fields in McIntosh County, Oklahoma.

the porous sandstone laterally into a tightly cemented nonporous sandstone.

Southwest Salem Field

Oklahoma Natural Gas Company discovered the Southwest Salem field (fig. 10) in 1957 with the completion of the 1 Popejoy gas well in NW¼ SW¼ NE¼ sec. 17, T. 10 N., R. 13 E., for 4.3 MMCF per day from the Upper Gilcrease sandstone at 2,598 to 2,630 feet, 1.3 MMCF per day from the Lower Gilcrease sandstone at 2,758 to 2,764 feet, 3.9 MMCF from perforations at 3,138 to 3,176 feet in the Cromwell sandstone, and 4.1 MMCF from the Jefferson sandstone at 3,265 to 3,275 feet. This well was drilled to a total depth of 4,065 feet into the basal Oil Creek sandstone. No shows of oil or gas were reported in any zones below the Jefferson sandstone.

The field's second producer was added early in 1959 with the Gulf Oil Corporation 1 Popejoy well in SW¼ SE¼ NW¼ sec. 17, T. 10 N., R. 13 E., a southwest offset to the discovery well. Drilled to 3,395 feet, the well was plugged back to 3,140 feet and completed for 219 MCF per day from the Upper Gilcrease sandstone, perforated at 2,663 to 2,672 feet. Operators attempted to complete in the Cromwell sandstone, but the initial test indicated an uneconomical completion.

A Cromwell producer and east extension was completed in 1960 at the Snee and Eberly 1 Harjo well, SE¼ SW¼ NW¼, sec 16, T. 10 N., R. 13 E. The well rated a potential of 3.9 MMCF per day from a series of perforations at 3,187 to 3,235 feet in the Cromwell sandstone.

Production in the Cromwell sandstone is controlled by closure on a westward-trending anticline, located up dip from a normal fault that is downthrown to the south. Gilcrease production is the result of erratic porosity development on structure. The Gilcrease sandstone grades rapidly laterally to a shale, and the occurrence of the sandstone lenses is extremely erratic.

Seismic exploration suggested by subsurface studies led to the drilling of the discovery well.

Hoffman Field

The eastern edge of the Hoffman field is located in the portion of T. 12 N., R. 14 E., that lies in McIntosh County. The majority of the production is located in Okmulgee County, with production occurring in the Bartlesville, Gilcrease, and Cromwell sandstones.

In June 1916, W. C. Newman drilled the 1 Sergo well in section 10 and completed it

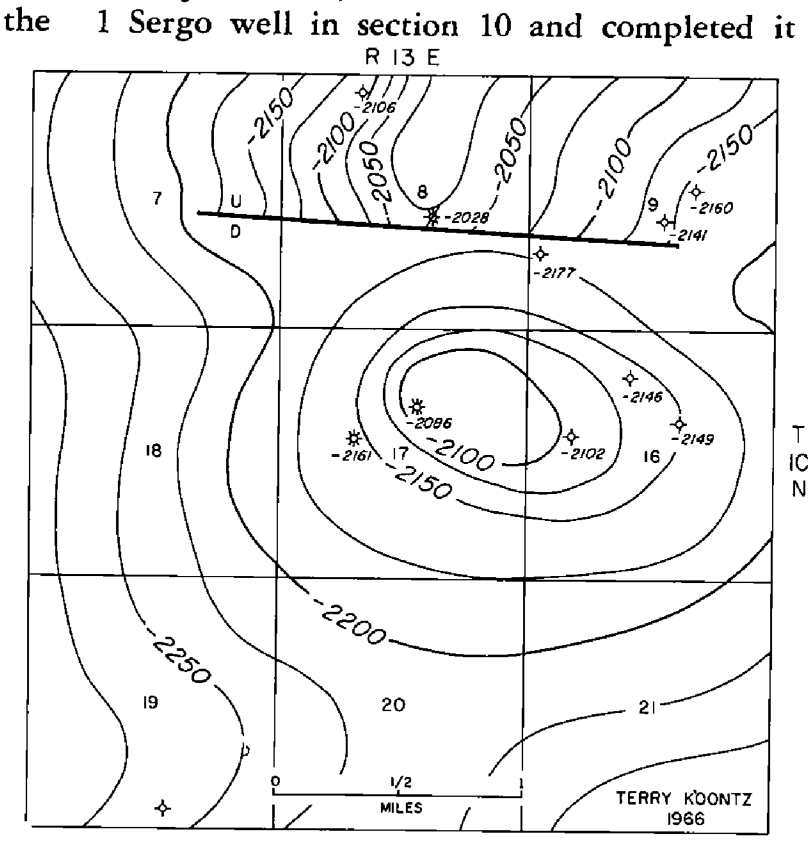

Figure 10. Subsurface structure map of Southwest Salem field. Reference surface: top of Wapanucka limestone. Contour interval: 25 feet. Datum: sea level.

in the Gilcrease sandstone for an initial potential of 1.5 MMCF feet per day. By 1940, approximately 20 gas wells and 12 oil wells were completed in the township. At present, there are no producing gas wells and only two producing oil wells.

The Bartlesville sandstone is commonly referred to as the "Salt sand" on the old drillers' logs and was the primary objective during the early development of the Hoffman field. This reservoir characteristically has a high initial potential, but production declines rapidly within a few years.

The Cromwell sandstone at 3,100 feet is the most prolific reservoir in the Hoffman field. Production is primarily gas, with structure and stratigraphic factors forming the trap. Locally the sandstone grades laterally to a limestone facies.

In the Hoffman area, the accumulation of

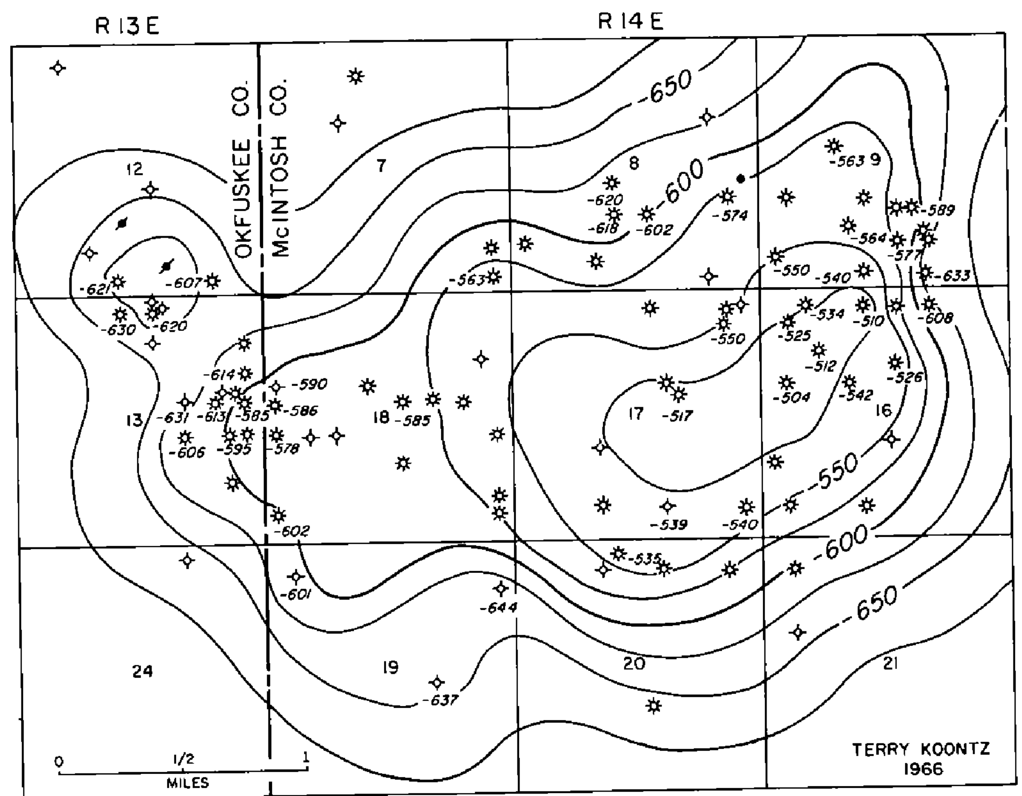

Figure 11. Subsurface structure map of Coalton field. Reference surface: top of Booch sandstone. Contour interval: 25 feet. Datum: sea level.

gas and oil is controlled by stratigraphic factors and a northeastward-trending normal fault. The anticline enters the Hoffman gas area in sec. 16, T. 12 N., R. 14 E. A normal fault, downthrown to the east, defines the east side of the anticline. The average throw of the fault is approximately 280 feet in pre-Mississippian rocks, decreasing to about 45 feet at the base of the Bartlesville sandstone.

Coalton Field

The Coalton field (fig. 11) was discovered by the Okmulgee Producing and Refining Company 1 Twine well, sec. 6, T. 11 N., R. 14 E., which was drilled to a total depth of 1,312 feet in the Gilcrease sandstone. This well was completed for 10 MMCF of gas per day from the "Salt sand" at 740 feet.

Subsequent drilling continued in the northwestern corner of the township, resulting in the completion of 73 gas wells and 28 small oil wells. There are now no producing oil wells, and 6 gas wells still produce in this field.

The principal producing horizons are the Bartlesville sandstone at 700 feet and the Booch sandstone at 1,400 feet. Figure 11 is a map contoured on the Booch sandstone. Production in this field is associated with an eastward-trending anticline that has 75 to 80 feet of closure. Although most of the better wells are located on the apex of the structure, several dry holes, also drilled on structure, indicate the importance of sand conditions in controlling the accumulation of gas.

Southeast Salem Field

A discovery of gas production from the Booch sandstone in the Southeast Salem field was established in 1965 by the RWIT Drilling Co. 1 Bailey well, NE¼ SW¼ NW¼ sec. 17, T. 10 N., R. 14 E., slightly more than 0.5 mile north of an old gas producer that is now abandoned. The abandoned well, with a total depth of 1,700 feet, was offset to the southeast by two failures, one drilled to 4,480 feet and the other to 2,750 feet.

The RWIT Drilling Co. 1 Bailey was drilled to a total depth of 3,408 feet by Otha H. Grimes and operations then assumed by RWIT Drilling Company. The Upper Booch sandstone at 1,655 to 1,659 feet was completed for an initial potential of 300 MCF per day.

Southeast Raiford Field

The Southeast Raiford field is approximately two miles southeast of Raiford. In February 1956, Southern Union Gathering Company completed the 1 Follansbee well,

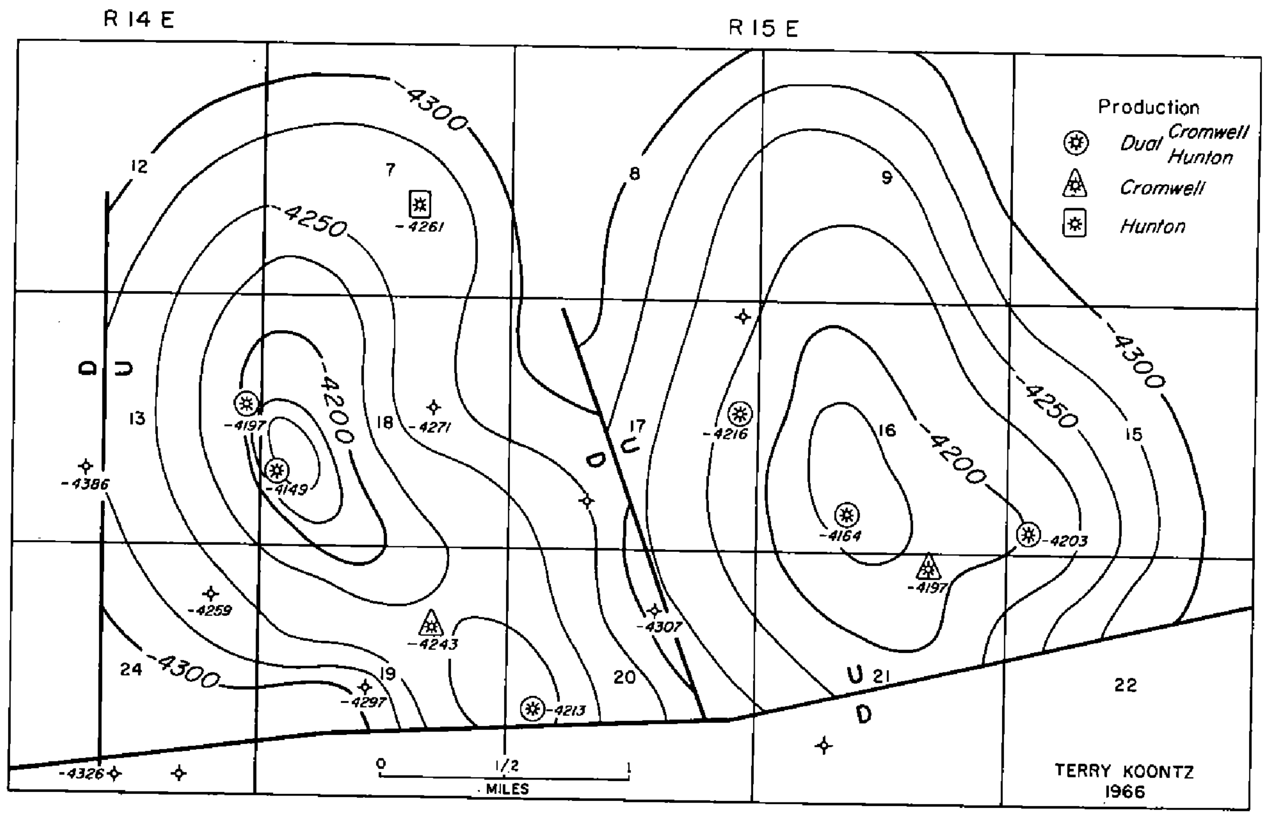

Figure 12. Subsurface structure map of Southeast Raiford field. Reference surface: top of Hunton limestone. Contour interval: 25 feet. Datum: sea level.

SW¼ NW¼ SW¼ sec. 18, T. 9 N., R. 15 E., as the discovery well, with an initial potential of 9.3 MMCF of gas daily on a ¾-inch choke from the Hunton limestone at 4,826 to 4,872 feet. This well was originally drilled by Carter Oil Company (Humble) in 1950 and abandoned as a dry hole. It was again reworked by Southern Union in 1961 and dually completed with pay added from the Cromwell sandstone. The Cromwell yielded an initial potential of 4.3 MMCF of gas daily through a ¼-inch choke from perforations in the sand at 4,280 to 4,300 feet.

Hall-Jones Oil Corporation completed two producers in the area during 1962, one of which extended production 1.5 miles northward. This well, the 1 Martin, NW¼ SE¼ sec. 7, T. 9. N., R. 15 E., was completed for an open-flow potential of 5 MMCF of gas per day through a 16/64-inch choke from the Hunton limestone pay at 4,957 to 4,969 feet.

Limits of the Southeast Raiford field have been fairly well defined by four failures; the Southern Union Oil Corporation 1 Wood, NW¼ SE¼ SW¼ sec. 17, T. 9. N., R. 15 E., recovered gas-cut salt water on a drill-stem test of the Hunton limestone at 4,449 to 4,555 feet.

The Ward M. Edinger 1 Crabtree well, NE¼ NE¼ SW¼ sec. 19, T. 9 N., R. 15 E., was abandoned in 1961 with no shows being reported in the Cromwell sandstone or Hunton limestone. J. C. Mann abandoned the 1 Cosar Unit, SW¼ NE¼ SW¼ sec. 13, T. 9 N., R. 14 E., at a total depth of 5,188 feet after failing to encounter any shows in the Cromwell or Hunton. One mile southeast of production, Mason and Company abandoned the 1 Creek Tribe, SW¼ SW¼ NE¼ sec. 29, T. 9 N., R. 15 E. Operators did set casing and tested the Booch sandstone through perforations at 1,719 to 1,725 feet, but the best recovery in testing was a show of gas and one gallon of 39°-gravity oil per hour.

The North Mellette field, discovered in September 1959 by the Southern Union Oil Corporation 1 Brown well, NW¼ SE¼ SW¼ sec. 16, T. 9 N., R. 15 E., has now been combined with the Southeast Raiford field. Located 2.25 miles east of the Southeast Raiford discovery the 1 Brown well reported an open-flow potential of 3.2 MMCF of gas daily from perforations in the Cromwell sandstone at 4,203 to 4,290 feet, and 2.2 MMCF of gas daily from Hunton limestone perforations at 4,750 to 4,826 feet.

Figure 12 is a map contoured on the Hunton limestone. The structure and primary trapping mechanism consists of two domes separated by a normal fault with approximately 75 feet of displacement. The Hunton limestone has an average net pay of 50 feet and the Cromwell sandstone a net pay of 20 feet.

Raiford Field

Oklahoma Natural Gas Company discovered the Raiford field in July, 1965, with the completion of the 1 Hale well in NE¼ SW¼ NW¼ sec. 7, T. 9 N., R. 14 E., which was drilled to a total depth of 4,400 feet into rocks of the Simpson Group. The productive sandstone, Cromwell, is 20 feet thick at a depth of 3,472 feet. Perforations from 3,477 to 3,497 feet produced a flowing potential of 7 MMCF of gas daily. The well had a shut-in pressure of 1,392 psi and flowing tubing pressure of 645 pounds.

Confirmation attempts to the northwest and west have been unsuccessful. The Cromwell sandstone was tight and lacked porosity in the Oklahoma Natural Gas Company's 1 Dorsey well, SW¼ NE¼ sec. 12, T. 9 N., R. 13 E., and the 1 Hopkins well, N½ NW¼ sec. 1, T. 9 N., R. 13 E.

Northwest Checotah Field

Northwest Checotah field, approximately 4 miles northwest of Checotah, contains four gas producers and is offset to the north, south, and west by three dry holes (fig. 13).

The Oklahoma Natural Gas Company 1 Covey well, NW½ NW¼ SE¼ sec. 14, T. 12 N., R. 16 E., drilled to a total depth of 3,480 feet into rocks of Arbuckle age, was completed in February 1958. This well was dually completed from the Gilcrease sandstone at 2,261 to 2,294 feet for an initial potential of 6 MMCF of gas daily and 4.3 MMCF of gas daily from a basal Atoka sandstone at 2,386 to 2,394 feet.

In February 1959, Branan and Farrell completed one of the largest producers in the area with their 1 Lackey well, SE¼ SE¼ NE¼ sec. 14, T. 12 N., R. 16 E., which had an initial potential of 48.7 MMCF of gas daily from the basal Atoka sandstone at 2,245 to 2,256 feet. The field now has four producing wells and its limits are defined by five dry holes.

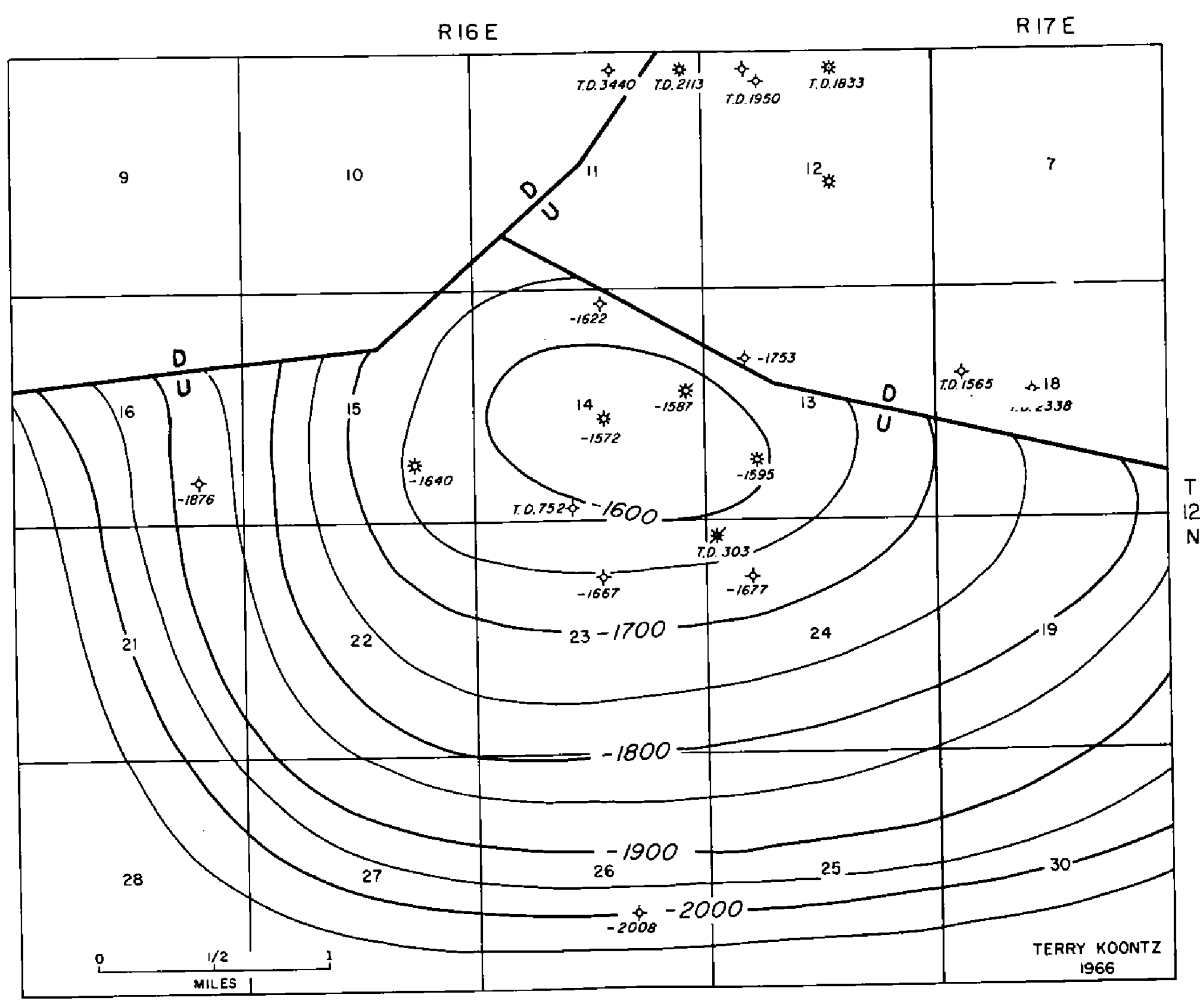

Figure 13. Subsurface structure map of Northwest Checotah field. Reference surface: top of basal Atoka sandstone. Contour interval: 50 feet. Datum: sea level.

TABLE V. — EXPLORATORY AND DEVELOPMENT WELLS DRILLED IN McINTOSH COUNTY, 1912-1966

YEAR	GAS WELLS	OIL WELLS	DRY HOLES	YEAR	GAS WELLS	OIL WELLS	DRY HOLES
1912	1			1941	3		3
1913	7			1942	1		6
1914				1943	1		3
1915	7		2	1944			2
1916	3		1	1945	1		7
1917	11		4	1946			4
1918	13		3	1947	1		6
1919	20	2	4	1948		1	1
1920	11	5	15	1949			2
1921	2	5	13	1950			7
1922	13		15	1951			6
1923	5		19	1952		2	1
1924	7		5	1953	2		2
1925	2	2	5	1954	2		2
1926	4		9	1955	5	1	7
1927	3		4	1956	2		2
1928	1		1	1957	1		2
1929			6	1958	4	1	3
1930	1		7	1959	5		13
1931	1			1960	4		16
1932			1	1961	5		7
1933			1	1962	3		10
1934	2		2	1963	1		2
1935	1			1964			4
1936			5	1965	4		7
1937				1966	3		3
1938							
1939	1		4				
1940	3		2	Total	167	19	256

Production is controlled by closure against a normal fault and its associated spur fault. Location of the fault with approximately 200 feet of displacement was made by the Snee and Eberly 1 Buckmaster well, C NW¼ sec. 13, T. 12 N., R. 16 E.

Since completion of pipeline connections in 1959, this field has produced 2,510,457 MCF of gas, with average annual production of 144,000 MCF.

CUMMINGS FIELD

This shut-in gas field was discovered in June 1936 by the Indian Territory Illuminating Oil Company 1 Tancred well, SW¼ NW¼ SE¼ sec. 9, T. 9 N., R. 14 E. The well was drilled to a total depth of 4,536 feet into the Wilcox sandstone. Operators reported a flow of 25 MMCF of gas per day from the Gilcrease sandstone at 2,700 feet, but, after casing was set and the sand tested, the best gauge was 750 MCF of gas per day. The discovery well was never produced, and it was abandoned shortly after its completion.

During the period 1945-1948, Sherrod and Apperson drilled eight wells near the ITIO discovery, but only two were completed as gas wells. The 1 Culbertson well, NW¼ SE¼ SW¼ sec. 9, T. 9 N., R. 14 E., southwest offset to the ITIO discovery and the first well drilled by Sherrod and Apperson, was completed in August 1945 for 14.2 MMCF of gas daily from the Gilcrease sandstone at 2,722 to 2,734 feet. After drilling three dry holes, Sherrod and Apperson completed the 2 Cities Service well, SE¼ SE¼ NW¼ sec. 9, northwest of the discovery, in March 1947. Gas flow was reported at the rate of 12 MMCF daily with a shut-in pressure of 800 psi from the Gilcrease sandstone at 2,667 to 2,688 feet.

SOUTHEAST CHECOTAH FIELD

The Tidewater Oil Company 1 Sizemore-Winkel, SE¼ SW¼ sec. 25, T. 11 N., R. 17 E., discovery well of the Southeast Checotah field, was completed in December 1959 with perforations in "Georges Fork" sandstone (middle Atoka) at 1,110 to 1,123 feet. The initial flow was reported at 2.5 MMCF of gas daily with a shut-in pressure of 310 psi. Following completion of the discovery, Tidewater drilled two dry holes in an attempt to confirm the discovery well. The 1 Abott well, NW¼ SE¼ NE¼ sec. 36, T. 11 N., R. 17 E., 0.75 mile southeast of the discovery, was abandoned in July 1960, at a total depth of 2,100 feet in rocks of Mississippian age. Drill-stem tests of all potential producing horizons failed to recover any commercial shows. One and one-half miles southeast of the discovery, Tidewater abandoned the 1 Suitor well, SE¼ NE¼ sec. 1, T. 10 N., R. 17 E., in September 1960, at a total depth of 2,506 feet.

Production in the discovery well appears to be associated with local lensing of the middle Atoka sandstone.

North Rentiesville Field

The one-well North Rentiesville gas field was discovered by the Steve Gose 1 Matthews well, NW¼ SE¼ NW¼ sec. 5, T. 12 N., R. 17 E., in July 1960. The basal Atoka sandstone at 2,070 to 2,090 feet was completed for an open-flow potential of 4.4 MMCF of gas daily with a shut-in pressure of 907 psi. The well produced 50,135 MCF of gas in an 11-month period, but it was abandoned when operators could not handle the excessive amount of salt water produced with the gas.

The discovery well appears to be located on the south flank of a northward-trending anticline that extends into Muskogee County. A well drilled north of the discovery well, in Muskogee County, is located on the downthrown side of a fault that appears to be the same fault that defines the northern limits of the Northwest Checotah field.

North Hitchita Field

In 1922, the Beggs Oil and Gas Company 1 Harding well, sec. 2, T. 12 N., R. 15 E., discovered a small volume of gas from the Booch sandstone at 1,250 feet. Three additional gas wells were completed from the Booch sandstone at 1,300 feet and the Gilcrease sandstone at 1,750 feet. These wells are no longer producing and no production history is available for prior production.

Stidham Field

Several shallow oil and gas wells were drilled in this area during the 1920's, but completion and production information is available on only a few of them. One of the earliest tests was the H and H Oil and Gas Company 1 Bart Hill well, sec. 27, T. 11 N., R. 15 E. This well was completed for 5 barrels of oil and 100 MCF of gas per day from the Booch sandstone at 1,075 feet. The last oil completion reported in this area was the A. L. Carry 5 Bart Hill well, NW¼ SE¼ sec. 27, T. 11 N., R. 15 E. This well was completed in July 1954 for 60 barrels of oil per day from the Booch sandstone at 1,105 to 1,130 feet.

At the present time there are no producing oil or gas wells in the Stidham field area.

The Bell Oil and Gas Company 1 Buck, NE¼ NW¼ sec. 26, T. 11 N., R. 15 E., is significant because it is the deepest stratigraphic test in the Stidham field area and one of the few wells to penetrate the Arbuckle limestone in McIntosh County. This well was drilled to a total depth of 3,485 feet and faulted from Mississippian to lower Simpson, with the Arbuckle limestone reported at 3,465 feet.

Checotah Field

Gas production was discovered in 1919 by the Graham Brothers Oil Company 1 Robinson well, NW¼ NW¼ sec. 17, T. 11 N., R. 17 E., from the Booch sandstone at 775 feet and an unnamed Atoka sandstone at 1,810 feet. The well was completed for a potential of 2.8 MMCF of gas daily with a shut-in pressure of 730 pounds. Five gas wells were completed in the area and all are now abandoned.

Onapa Field

The Onapa field was discovered by the Gladys Belle Oil Company 1 Scott well, SW¼ SE¼ sec. 29, T. 11 N., R. 17 E. This well was completed in 1915 for 11.4 MMCF of gas daily from the "Green River" sandstone at 2,010 feet. This sandstone is early Atokan in age and probably equivalent to the basal Atoka sandstone in the Northwest Checotah field. Twelve gas wells were completed in secs. 29-32, T. 11 N., R. 17 E., and secs. 25, 36, T. 11 N., R. 16 E., but all are now abandoned. Cummulative production for this field was 4,200 MMCF of gas.

Southwest Warner Field

The Bell Oil and Gas Company 1 Young, SW¼ SE¼ NE¼ sec. 11, T. 11 N., R. 18 E., is the only well completed in the Southwest Warner field. During drilling operations, the well blew out at 932 feet and was brought under control. The Atoka sandstone was perforated at 902 to 942 feet and, after treatment, was completed for an initial potential of 1.04 million cubic feet of gas daily.

Initial confirmation attempts resulted in failure of the Bell Oil and Gas Company 1 Dunagan well, NW¼ NW¼ NE¼ sec. 12, T. 11 N., R. 18 E., a 0.5-mile northeast offset to the discovery well.

STRATIGRAPHY

Rocks encountered by wells drilled for oil and gas in McIntosh County range in age from Cambrian to Late Pennsylvanian.

The Pennsylvanian sediments include rocks of the Des Moines and Atoka Series. Cropping out in northeastward-trending bands, rocks of the Des Moines Series include the following formations (youngest to oldest): Senora, Stuart, Boggy, Savanna, and McAlester. The Atoka Formation crops out in the northeastern part of the county on the Warner uplift. (The general lithology is alternating tan sandstones and gray shales associated with thin limestone and coal beds.)

Precambrian Rocks

No Precambrian rocks have been penetrated by any well in McIntosh County. In the Hamon & Cox 19 Reynolds well, sec. 26, T. 12 N., R. 13 E., just west of McIntosh County, in Okmulgee County, the Arbuckle limestone was topped at 3,248 feet, and 1,082 feet of limestone was penetrated before operators reached the granite at 4,330 feet. Approximately 1 mile northwest of this well in sec. 22, T. 12 N., R. 13 E., the Hamon & Cox S-1 Doneghy well reached the Arbuckle limestone at 3,320 feet and penetrated 1,494 feet without reaching the basement.

Twenty feet of granite was drilled in the USSRAM 1 Marshall well, sec. 23, T. 13 N., R. 19 E., Muskogee County, 6 miles northwest of the Muskogee-McIntosh county line. The Precambrian samples of the Marshall well represent green, pink, and black granite wash and massive pink granite.

The unweathered igneous rock is holocrystalline, granophyric, porphyritic rhyolite.

Ordovician System

Rocks of Ordovician age overlie Precambrian granite and consist of the following units (ascending order): Arbuckle, Simpson Group, Viola and Fernvale limestones, and Sylvan Shale.

The formations of the Ordovician System are composed of dolomites, limestones, and shales.

Arbuckle limestones. — The Tenneco Oil Company 1 Hill well, sec. 4, T. 11 N., R. 15 E., penetrated 315 feet of Arbuckle limestone. In this well the Arbuckle is white or shades of gray to light tan, is exceedingly dolomitic, and contains minor amounts of sand. The prevailing texture is fine to medium crystalline, but it may be lithographic to coarsely crystalline.

The Producers Drilling and Service Company 3 Turner well, SW¼ SE¼ NW¼ sec. 5, T. 11 N., R. 14 E., penetrated 469 feet of Arbuckle limestone, the deepest penetration of the Arbuckle in the county. The top of the Arbuckle is at 3,131 feet and the total depth is 3,600 feet.

The nearest well in which the entire Arbuckle section was penetrated is the USSRAM 1 Marshall, sec. 23, T. 13 N., R. 19 E., Muskogee County. The Arbuckle was encountered at 1,840 feet and the basement at 3,274 feet for a total thickness of 1,434 feet.

Simpson Group. — Less than 10 percent of the wells drilled in McIntosh County have penetrated the Simpson Group; of this total, only 10 tests have electric-log data available.

The Simpson consists of a series of dolomites, sandstones, shales, and a few limestones. Subdivision of the group into the familiar nomenclature of Joins, Oil Creek, McLish, and Bromide Formations is extremely difficult because of the paucity of control points and the complicated facies changes.

The top of the Simpson Group is arbitrarily placed at the top of the almost universally occurring dense, lithographic limestone marker referred to as the "Simpson Dense" at the base of the Viola limestone, which overlies the Simpson with apparent disconformity. The widespread and persistent occurrence of the "Simpson Dense," or its equivalent, at the top of the Simpson suggests that the "disconformity" at the Simpson-Viola contact is due to a reduced rate of subsidence and deposition (producing a thinner Simpson section than found in areas to the south) rather than to erosion or nondeposition. The Simpson ranges in thickness from 251 feet in T. 11 N., R. 17 E., to slightly more than 370 feet in T. 11 N., R. 18 E.

In McIntosh County, this group consists

of the "Dense" zone, at the top, underlain by a series of sandstones, interbedded near the top with green shales and dolomitic sandstones, and sandy dolomites interbedded with gray shales.

In Oklahoma, the Simpson is an important oil reservoir, but in McIntosh County the group has produced little oil or gas.

Fernvale-Viola. — Geologists rarely distinguish between the Fernvale and Viola limestones of McIntosh County. The top of this carbonate sequence is the most reliable datum for mapping Ordovician structure.

The Viola overlies the Simpson Group with apparent disconformity. Its contact with the overlying Fernvale is conformable and probably represents a facies change. The Fernvale-Viola section is 30 feet thick in T. 10 N., R. 13 E., and 70 feet thick in T. 11 N., R. 16 E. The Fernvale is characteristically a mottled gray, coarsely crystalline, crinoidal limestone.

Pink crinoidal fragments, as well as free Simpson-type sand grains, are common. In contrast, the Viola contains dark-gray, dense, white or light-tan, crystalline limestone. It may have occasional thin beds of fine or coarse-grained sandstone. Chert layers are common, usually in the color of the enclosing limestone.

Sylvan Shale. — The Sylvan Shale occurs conformably between the Fernvale-Viola below and the Hunton Group above. This shale displays a nearly uniform thickness of 50 to 70 feet throughout the county. It is a distinctive greenish-gray shale, grading downward into a dark-gray, splintery, dolomitic shale. The finely "granular" texture and notable absence of accessory minerals, other than occasional phosphate pellets, are distinctive features of the Sylvan.

Silurian-Devonian Systems

Hunton Group. — The Hunton Group lies conformably upon the Sylvan Shale, and unconformably beneath the Misener sandstone or Woodford Shale. The group attains a maximum thickness of 150 feet in T. 9 N., R. 16 E., and is absent in the extreme northwestern part of the county. The thinning and absence of the Hunton is a result of regional erosion during the post-Hunton uplift (epeirogeny) and local, differential erosion over pre-existing positive features.

The Hunton Group of McIntosh County is characterized by three distinct limestone units. The lowermost unit of the Hunton consists of a basal oölitic limestone grading to a medium-crystalline, pink crinoidal limestone. A dominant and almost universally occurring white to gray chert bed lies near the base. The middle limestone unit is finely crystalline to finely granular, dolomitic, and slightly greenish gray.

The uppermost unit of the Hunton is white, tan or mottled gray, coarsely crystalline crinoidal limestone. The presence of white or blue-gray chert is common.

The top of the Hunton underlies one of the most profound unconformities in the Mid-continent area, and it is weathered in many places. This weathering alters the limestone to a chalky earthy texture, with additional weathering producing a soft, vuggy limestone having excellent reservoir characteristics.

Hunton rocks have recently become important reservoirs of gas in McIntosh County, with production being established in the Raiford field in T. 9 N., R. 14 E. Shows of gas have been reported in other wells drilled into the Hunton in the county.

Misener sandstone. — The Misener sandstone rests unconformably upon the Hunton limestone in McIntosh County. The sandstone is nowhere more than 5 feet thick and is absent at many places. Where present, it is composed of reworked Simpson-type sand, and at many places it contains sand-sized fragments of Hunton and Viola chert. Where the sandstone is absent, the basal unit of the Woodford contains numerous glossy sand grains.

Woodford Shale. — The Woodford Shale is characteristically a dark chocolate-brown, organic, noncalcareous shale, with thin streaks of brown chert and varying amounts of chert. The thickness of the Woodford ranges from 10 feet in T. 9 N., R. 15 E., to 40 feet in the southeastern part of the county.

Mississippian System

In McIntosh County, the upper part of the Mississippian sequence consists of a lower silty limestone unit, referred to as the "Mayes lime." This unit is probably equivalent to the lower part of the surface Moorefield Formation of northeastern Oklahoma. An upper shale unit, the Caney Shale ("Mississippian

Caney"), overlies the "Mayes lime." The Caney Shale is correlated with the Pitkin, Fayetteville, and Hindsville Formations, although the Pitkin may be slightly younger.

MERAMEC SERIES

The Mayes unit lies disconformably upon the Woodford Shale and conformably beneath the Caney Shale. Across McIntosh County, the Mayes displays a uniform thickness of 120 feet.

The Mayes consists of a sequence of dark-brown, silty, calcareous limestones or marlstones. The basal part of the unit is a gray, finely sucrosic, dolomitic limestone. The rock sequence exhibits an electric-log resistivity reading exceeding that of the Caney. This characteristic, together with the unique dark-brown color and gritty texture, allows recognition of the Mayes over wide areas.

CHESTER SERIES

The Caney Shale grades downward into the marlstone of the Mayes. Upon the basis of characteristic electric-resistivity curves, the Caney is divided into upper and lower units. The upper portion of the Caney Shale is present only in southern and southwestern parts of McIntosh County. A maximum thickness of more than 150 feet is encountered in T. 10 N., R. 13 E. The upper beds consist of a medium- to dark-gray, splintery shale, with thin lenses of brown-black, dense, siliceous limestone. The upper part of the Caney contains sandstone lenses near the top.

The lower part of the Caney Shale, which averages 160 feet in thickness, exhibits a high-resistivity electrical curve. The shales become darker colored, calcareous, and pyritic downward. In the lower part of the Caney, typical Mayes lithology appears first as thin streaks, then as interbeds of the dark shales. Predominance of typical Mayes lithology determines the top of the Mayes.

PENNSYLVANIAN SYSTEM

The Pennsylvanian rocks consist of a series of shales and sandstones with a few beds of limestone and thin coals. The Pennsylvanian in McIntosh County includes rocks of the Morrow, Atoka, and Des Moines Series. The general lithology is alternating tan sandstones and gray shales. The most common association is the gray-shale suite.

MORROW SERIES

Union Valley-Cromwell. — In McIntosh County the Union Valley-Cromwell occupies the stratigraphic interval between the Caney Shale and the Wapanucka Limestone. This is the lowest limestone member of the Morrow Series and, although fairly uniform in thickness (150 to 200 feet), it is quite variable in lithology. The top of the Union Valley Formation is a gray to tan, medium-crystalline limestone. This limestone is underlain by a medium-grained, glauconitic, calcareous sandstone.

Locally, several sandstones occur in this interval, interbedded with thin streaks of dark-gray, silty shale. These sandstones are similar in appearance and difficult to distinguish as separate sandstone members. They range from calcareous to quartzitic and fine-grained to medium-grained beds and are commonly gray to dark gray.

The sandstone is known as the Cromwell, and at present is the most important gas reservoir in McIntosh County, with total sand thickness reaching a maximum of 100 feet. Cromwell gas production is reported from the Salem, Southwest Salem, Southeast Raiford, and Hoffman fields.

Wapanucka Formation. — The Wapanucka Formation consists of two members, an upper limestone and a lower shale. In general the upper part of the Wapanucka is a dark-tan to medium-gray, mottled limestone, fine to medium crystalline, locally oölitic, glauconitic, and highly fossiliferous. It reaches a maximum thickness of 100 feet.

Along the northern portion of the county the limestone member of the Wapanucka exhibits lateral variations. This is clearly shown in the Oklahoma Natural Gas Company 1 Covey well, sec. 14, T. 12 N., R. 16 E., and the Bell Oil and Gas Company 1 Buck, sec. 26, T. 11 N., R. 15 E. In the 1 Covey well the Wapanucka consists of a dark-gray shale, with minor amounts of dark-gray to brown microcrystalline limestone; in the 1 Buck well this interval consists of a predominantely brown-gray, finely crystalline limestone.

The lower shale member is light gray; it thins northward and eastward.

The limestone member of the Wapanucka Formation is absent in several wells in the northeastern and northwestern portions of the county, where it has been removed by pre-

Atoka erosion. The Wapanucka is conformable upon the Union Valley Formation.

ATOKA SERIES

Rocks of Atokan age consist essentially of sandstone and shale and attain a maximum thickness of 2,400 feet in the southeastern part of the county.

The thickness ranges from 717 feet in the W. E. Steelman 1 Stephens well, sec. 5, T. 11 N., R. 14 E., to 2,490 feet in the Pure Oil Company 1 James, sec. 21, T. 9 N., R. 16 E. The general rate of thickening of the Atoka across McIntosh County is 130 feet per mile from the northwest toward the southeast.

The Atoka Formation in McIntosh County consists predominantly of dark shales, usually gray to black or dark brown. Intercalated throughout the shales are micaceous siltstones and fine-grained sandstones that are locally carbonaceous. These sandstones range in color from gray to black and from brown to tan. Thin limestones are present but must be considered rare. Local concentrations of ankerite, siderite, and pyrite are found in the Atoka at many places. No identifiable fossils have been observed from samples of the many wells examined.

In the middle and lower part of the Atoka are one to three sandstones. Nomenclature for these sandstones is inconsistent partly because of the difficulty in correlating them throughout the county. The upper sandstones are usually called Gilcrease, and the lower sandstones are called Dutcher or Basal Atoka.

The Gilcrease is a glauconitic, siliceous, medium-grained sandstone interbedded with dark-gray to black, sandy to silty shales.

The Dutcher, or Basal Atoka, sandstone is present in the north and northwestern parts of the county, occurring at the base of the Atoka. It is fine grained to medium grained, glauconitic and locally calcareous. In some places the sandstone exceeds 60 feet in thickness.

Locally, the Basal Atoka sandstone exhibits lateral variations in cementation. The sand changes from a loose and porous type, to a tight, almost quartzitic sand. Although this sand is widespread in the northern part of the county, subsurface evidence suggests channeling or local lensing. An angular unconformity separates the Atoka and Wapanucka Formations.

DES MOINES SERIES

During Desmoinesian time a series of shales and sandstones with beds of thin limestones and coal were deposited on the northwestern shelf area of the Arkoma basin of eastern Oklahoma, within which McIntosh County lies. Two distinct lithologic associations are recognized which characterize the Des Moines Series. The most prevalent association is the gray-shale sequence. The sandstones associated with these shales are light gray to white, slightly calcareous and fine grained.

The second lithologic association is the variegated maroon shale. These shales are gray, greenish-gray, and maroon. The associated sandstones are light gray to white, fine grained, usually calcareous. Locally these sandstones grade to a sandy limestone in the upper part. This sequence is at many places associated with a brown, dense to finely crystalline, fossiliferous limestone.

Hartshorne Formation. — The Hartshorne Sandstone lies above the Atoka shale, apparently conformably. This formation is a cyclothem sandstone unit consisting of micaceous, carbonaceous, sideritic siltstones and gray to white, fine-grained sandstones, overlain by a gray, sandy shale. The unit may or may not be overlain by a coal bed. The Hartshorne interval ranges in thickness from 200 feet in the southeastern part of the county to zero in the northwestern, with an average thickness of 50 to 100 feet for most of the county.

McAlester Formation. — Overlying the Hartshorne is the McAlester Formation, within which occurs the Booch sandstone of the subsurface. The McAlester increases in thickness from 250 feet in the eastern part of the county to 650 feet in the western part. It is primarily a gray, silty to sandy shale sequence characterized by several coal beds near the base.

Subsurface mapping by Busch (1954) and Logan (1957) in Okmulgee County depicts the major deep channel of Booch sandstone, trending generally southeastward from T. 15 N., R. 11 E., to T. 11 N., R. 13 E., where mapping was discontinued. The thicker Booch channel continues southward into McIntosh County, where a maximum thickness of 300 feet has been reported.

Because of the lenticular nature of the Booch sandstone, the Booch interval in a particular well may include several sandstones or none. The upper Booch is generally a medium-grained, slightly calcareous sandstone, while the lower Booch is more silty and contains interstitial clay and heavy minerals.

In surrounding counties, as well as in McIntosh County, the Booch is an important oil and gas reservoir. Production from the Booch sandstone has been found at the Coalton, Southeast Salem, and Checotah fields.

Savanna Formation. — Normally, the Savanna Formation is approximately 150 feet thick, except in the Porum syncline area, where its maximum thickness slightly exceeds 200 feet. Lying conformably upon the McAlester Formation, the Savanna is lithologically uniform everywhere in the county. It is essentially a dark-gray, fissile shale, interbedded with siltstones, coals, and brown limestones. The "brown limes" are easily recognized and are an important subsurface datum. This formation is recognized on electric logs by the characteristic high-resistivity peaks.

Boggy Formation. — The Boggy Formation consists of medium-grained, calcareous sandstones interbedded with fossiliferous, locally silty, gray to dark-gray shales. Sandstone and shale beds may be traced across the county with little change of facies. The formation is approximately 500 feet thick and conformably overlies the Savanna Formation. The Bartlesville sandstone is located near the base of the Boggy Formation and is correlated with the Bluejacket Sandstone Member of the surface.

Stuart Formation. — The thickness of the Stuart Formation averages 305 feet. In general, it consists of a tan, medium- to fine-grained sandstone overlain and underlain by shales. The Stuart Formation appears to have been deposited unconformably upon the underlying Boggy Formation.

Senora Formation. — The Senora Formation consists of medium- to dark-gray shale with thin stringers of white, fine-grained, slightly calcareous sandstone. Several brown, silty, fossiliferous, thin limestone beds are found in this sequence. The Senora crops out in the western part and covers more than 25 percent of the county.

REGIONAL STRUCTURE

Structure Map

The structure map of the Wapanucka limestone (pl. III) is based upon information from all available electric logs and, where electric logs were not available, upon "drillers' logs" filed with the Oklahoma Corporation Commission (Neff, 1961).

The Wapanucka limestone of late Morrowan age was chosen as the reference surface because it is the stratigraphically highest reliable, correlatable subsurface unit easily recognized throughout the county. In areas where density of tests is low all available control was used in construction of the map, but in areas of high well density only one well per quarter section was used.

Geologically McIntosh County is a transition zone between the Atoka shelf area of the Arkoma basin to the north and the basin to the southeast. The Atoka hinge line of the Arkoma basin divides McIntosh County into two essentially equal parts; the shelf and the basin.

The structure of the Wapanucka limestone is the result of deformation that started in Atokan time and continued to middle Desmoinesian time. This uplift resulted in the erosion and modification of the Wapanucka surface.

The subsurface structure of the county is characterized by a general southward dip that is interrupted by faults, generally downthrown to the south and east. The surface rocks have a regional westward dip as opposed to the southward dip of the Wapanucka limestone. The subsurface structure is complicated by the high-angle faulting which breaks through the surface rocks and the numerous faults which are not exposed at the surface. Many of the major faults that have an essentially east-west trend appear to be related to the Arbuckle Mountains structural province. Other high-angle faults are generally southwestward trending and appear to be related to the Ozark-Boston Mountains region.

All of the structural closures in the county are less than 100 feet and appear in all cases to be related to faulting. Most of the subsurface faults have throws ranging from less than 100 feet to as much as 400 feet, with the average being between 100 and 200 feet.

Cross Section

Plate IV is a north-south structural cross section extending from T. 12 N., R. 15 E., to T. 9 N., R. 15 E., through west-central McIntosh County.

The Des Moines section is relatively uniform with the exception of the Booch sandstone interval. This sandstone is of deltaic origin and the thick areas of Booch sandstone represent channels of the deltaic distributaries. The Carter 1 Follansbee well, sec. 8, T. 9 N., R. 15 E., penetrated a thick channel deposit of sandstone that was mapped by Busch (1954) and Logan (1957) and previously discussed in the section on Des Moines stratigraphy.

The cross section depicts a general thickening of the entire Atoka section southward. The thicker Atoka section in the southern wells of the cross section is a result of more rapid subsidence in the Arkoma basin to the south. The northernmost well in the cross section contains numerous well-defined sandstones throughout the Atoka interval as contrasted with the thicker, predominantly shale sequence of the southernmost well. This illustrates the transition, or hinge-line, position of McIntosh County during Atoka deposition.

The post Wapanucka-pre-Atoka unconformity is illustrated by the rapid northward thinning of the Wapanucka limestone. The absence of Wapanucka limestone in the Allied Materials 1 Shannon well, sec. 5, T. 12 N., R. 15 E., is a result of local channeling and calls attention to the problem of identifying the limestone on the northern shelf area where it thins rapidly and, in some instances, has been completely removed by erosion.

The Meramec and Chester maintain a uniform thickness in wells used in the cross section. Much confusion exists concerning the subsurface nomenclature of the Pitkin, Fayetteville, and Moorefield Formations. As a result, no attempt was made to correlate or subdivide the Meramec and Chester series other than using the subsurface nomenclaure of Mayes and Caney.

A fairly uniform interval of Woodford is observed in the wells used throughout the cross section. As mentioned previously, the Woodford maintains a thickness of 10 to 40 feet throughout the county. In places there is a fine-grained, thin sandstone at the base of the Woodford, called the Misener sandstone, with the post-Hunton, pre-Woodford unconformity separating the Woodford and underlying Hunton limestone. This south-to-north thinning is readily observed in the cross section.

A study of formations older than Hunton in the McIntosh County area is handicapped by the paucity of deep-well control. In the two wells of the cross section that penetrated the Simpson Group (wells 2, 4) south-to-north thinning is not observable. Other available subsurface information indicates that the Viola-Arbuckle (Simpson) interval is thinner in the northern part of the county. As the Viola interval remains fairly constant throughout the cross section, the thinning observed in the Viola-Arbuckle (Simpson) interval is due to unconformities within the Simpson and to depositional thinning. Any thinning of the Viola is a result of onlap of the Viola upon the Simpson; however, such a relationship is not shown by the cross section.

REFERENCES

Andrews, R. E., Jr., 1957, Geology of the Raiford area, McIntosh County, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 56 p.

Bloesch, Edward, 1919, Unconformities in Oklahoma and their importance in petroleum geology: Amer. Assoc. Petroleum Geologists, Bull., vol. 3, p. 253-285.

Bond, T. A., 1963, Palynology of the Weir-Pittsburg coal (Pennsylvanian) of Oklahoma and Kansas: Okla., Univ., unpublished Master of Science thesis, 102 p., 5 pls.

Branson, C. C., 1952, Marker beds in the lower Desmoinesian of northeastern Oklahoma: Okla. Acad. Science, Proc., vol. 33, p. 190-192.

—— 1956, Pennsylvanian history of northeastern Oklahoma: Tulsa Geol. Soc., Digest, p. 83-86.

Busch, D. A., 1953, The significance of deltas in subsurface exploration: Tulsa Geol. Soc., Digest, vol. 21, p. 71-80.

Chance, H. M., 1890, Geology of the Choctaw coal field: Amer. Inst. Mining Engineers, Trans., vol. 18, p. 653-661.

Cheney, M. G., and others, 1945, Classification of Mississippian and Pennsylvanian rocks of North America: Amer. Assoc. Petroleum Geologists, Bull., vol. 29, p. 125-169.

Chrisman, L. P., 1951, Geology of the Big Cabin Creek area, Craig County, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 66 p.

Clark, R. W., 1928, McIntosh County, **in** Oil and gas in Oklahoma: Okla. Geol. Survey, Bull. 40-W, 14 p., **also in** Bull. 40, vol. 3, p. 149-158 (1930).

Clark, R. W., and **Bauer, C. M.**, 1921, Notes on geology of the Okmulgee district: Amer. Assoc. Petroleum Geologists, Bull., vol. 5, p. 282-292.

Clarke, R. T., 1961, Palynology of the Secor coal (Pennsylvanian) of Oklahoma: Okla., Univ., unpublished Master of Science thesis, 131 p.

Clawson, W. W., Jr., 1928, Pittsburg and Coal Counties, **in** Oil and gas in Oklahoma: Okla. Geol. Survey, Bull. 40-JJ, 14 p., **also in** Bull. 40, vol. 3, p. 399-410 (1930).

Coleman, W. F., 1958, Geology of the Rentiesville area, Muskogee and McIntosh Counties, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 100 p.

Dane, C. H., and **Hendricks, T. A.**, 1936, Correlation of the Bluejacket sandstone, Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 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. Geol. Survey, Bull. 874-C, p. 151-253.

Drake, N. F., 1897, A geological reconnaissance of the coal fields of the Indian Territory: Amer. Philos. Soc., Proc., vol. 36, p. 326-419.

Dunham R. J., and **Trumbull, J. V. A.**, 1955, Geology and coal resources of the Henryetta mining district, Okmulgee County, Oklahoma: U. S. Geol. Survey, Bull. 1015-F, p. 183-225.

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

Govett, Ray, 1957, Geology of the Cabaniss-Arpelar area, Pittsburg County, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 60 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. Geol. Survey, Bull. 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. Geol. Survey, Bull. 674-D, p. 255-300.

Hendricks, T. A., and **Parks, Bryan**, 1950 [1951], Geology of the Fort Smith district, Arkansas: U. S. Geol. Survey, Prof. Paper 221-E, p. 67-94.

Higgins, M. J., 1960, Stratigraphic position of the coal seam near Porter, Wagoner County, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 82 p., 6 pls.

Howe, W. B., 1951, Bluejacket sandstone of Kansas and Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 35, p. 2087-2094.

Howell, J. V., and **Lyons, P. L.**, 1959, Oil and gas possibilities of the Ouachita province, **in** The geology of the Ouachita Mountains — a symposium: Dallas Geol. Soc. and Tulsa Geol. Soc., p. 57-61.

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

Koontz, Terry, 1963, Henryetta-Salem [area, Okmulgee, Okfuskee, and McIntosh Counties], **in** Oil and gas fields of Oklahoma: Oklahoma City Geol. Soc., Reference Rept., vol. 1, p. 13B-15B.

Logan, D. M., 1957, Geology of the Okmulgee district: Okmulgee Geol. Engineering Soc., 8 p.

Lowman, S. W., 1933a, Lower and Middle Pennsylvanian stratigraphy of Oklahoma east of the meridian and north of the Arbuckle Mountains (abs.), **in** Summaries and abstracts of technical papers presented before the Tulsa Geological Society, 1932: Tulsa Daily World, unpaged booklet, paper of December 19, 1932 (booklet represents vol. 1 of Tulsa Geol. Soc. Digest).

—— 1933b |1934?| Cherokee structural history in Oklahoma: Tulsa Geol. Soc., Digest, vol. 2, p. 31-34.

Manhoff, C. N., Jr., 1957, Geology of the Hitchita area, Okmulgee and McIntosh Counties, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 50 p.

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

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: Amer. Assoc. Petroleum Geologists, Bull., vol. 5, p. 541-584.

Meek, R. A., 1957, Geology of the Onapa-Council Hill area, Muskogee and McIntosh Counties, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 67 p.

Melton, F. A., 1954, "Natural mounds" of northeastern Texas, southern Arkansas, and northern Louisiana: Okla. Geol. Survey, The Hopper, vol. 14, p. 88-121.

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

—— 1954, Geologic map of Oklahoma: Okla. Geol. Survey and U. S. Geol. Survey.

Morgan, G. D., 1924, Geology of the Stonewall quadrangle, Oklahoma: [Okla.] Bur. Geology, Bull. 2, 248 p.

Neff, E. R., 1961, Subsurface geology of McIntosh County, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 54 p.

Newell, N. D., 1937, Carboniferous System, **in** Wilson, C. W., Jr., Geology of the Muskogee-Porum district, Muskogee and McIntosh Counties, Oklahoma: Okla. Geol. Survey, Bull. 57, p. 18-57.

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: Amer. Assoc. Petroleum Geologists, Bull., vol. 37, p. 1523-1526.

—— 1963, Geology of Okmulgee County, **pt. 1 of** Geology and water resources of Okmulgee County: Okla. Geol. Survey, Bull. 91, p. 1-80, 129-164.

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

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

Pitt, W. D., 1957, Summary report of parts of northwestern McIntosh and southernmost Okmulgee Counties, Oklahoma: Okla. Geol. Survey, open-file report.

Snider, L. C., 1914, Geology of east-central Oklahoma: Okla. Geol. Survey, Bull. 17, 25 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: Okla., Univ., unpublished Master of Science thesis, 81 p.

Stine, J. G., 1958, Geology of southern Muskogee County, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 89 p.

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

—— 1901, Description of the Coalgate quadrangle [Indian Terr.]: U. S. Geol. Survey, Geol. Atlas, Folio 74, 6 p.

—— 1902, Description of the Atoka quadrangle [Indian Terr.]: U. S. Geol. Survey, Geol. Atlas, Folio 79, 8 p.

—— 1906, Description of the Muscogee quadrangle [Indian Terr.]: U. S. Geol. Survey, Geol. Atlas, Folio 132, 7 p.

Taff, J. A. and **Adams, G. I.**, 1900, Geology of the eastern Choctaw coal field [Indian Terr.]: U. S. Geol. Survey, 21st Ann. Rept., 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. Geol. Survey, unnumbered map, prelimina·y edition.

Urban, L. L., 1966, **Cappasporites**, a new Pennsylvanian spore genus from the Des Moines Series of Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 26, p. 111-114, 1 pl.

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

Webb, F. S., 1957, Geology of the Eufaula-Texanna area, McIntosh and Pittsburg Counties, Oklahoma: Okla., Univ., unpublished Master of Sciense thesis, 60 p.

—— 1960, Surface geology of the Eufaula-Texanna area, McIntosh and Pittsburg Counties, Oklahoma: Okla. City Geol. Soc., Shale Shaker, vol. 10, no. 8 (Apr.), p. 2-14; **also in** Shale Shaker Digest, vol. 3, p. 273-284.

Whipple, A. W., 1855, Report of explorations for a railway route, near the 35th parallel of latitude, from the Mississippi River to the Pacific Ocean: U. S. 33d Cong., 1st sess., H. Ex. Doc. 129, vol. 18, pt. 2, p. 15; **also in** U. S. 33d Cong., 2d sess., S. Ex. Doc. 78 and H. Ex. Doc. 91 (1856). (See also Foreman, Grant, A pathfinder in the southwest: Norman, Univ. Okla. Press, 1941.)

Whitesides, V. S., Jr., 1957, Geology of the Stidham area, McIntosh County, Oklahoma: Okla., Univ., unpublished Master of Science thesis, 109 p.

Wilson, C. W., Jr., 1935, Age and correlation of Pennsylvanian surface formations, and of oil and gas sands of Muskogee County, Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 19, p. 503-520.

—— 1937, Geology of Muskogee-Porum district, Muskogee and McIntosh Counties, Oklahoma: Okla. Geol. Survey, Bull. 57, 184 p.

APPENDIX TO PART I

Measured Sections

1

Sec. 7, T. 8 N., R. 13 E. Measured on north side of hill capped by sandstone unit IPsn-9 in NW¼, by W. D. Pitt.

	Thickness (feet)
SENORA FORMATION	
9 Sandstone: irregularly bedded, brown, micaceous; beds 0.5 to 2 feet thick; weathers gray	5.0
Sandstone: brown, massive; weathers gray	4.0
Covered	2.0
Sandstone: brown; thin beds with brown shale partings	0.75
Sandstone: brown, fine-grained	0.3
Sandstone: laminated; 1/16- to ½-inch laminae	0.5
Covered: probably interbedded sandstone and shale	2.4

2

Sec. 9, T. 8 N., R. 13 E. Measured just east of the power line, near old road to meadow near center of S½, by W. D. Pitt.

	Thickness (feet)
SENORA FORMATION	
5 Covered: probably sandstone	3.0
Sandstone: in layers 4 to 8 inches thick	6.0
Sandstone: brown, massive, fine-grained, micaceous, ripple-marked	3.5

3

Sec. 6, T. 8 N., R. 15 E. Measured along north section-line road, by R. E. Andrews, Jr.

	Thickness (feet)
SENORA FORMATION	
1 Sandstone: interbedded with shale	30.0
STUART SHALE	
Shale: gray, silty; base covered by Qt	65.0

4

Sec. 2, T. 9. N., R. 13 E. Measured along east section-line road just south of NE cor., by W. D. Pitt.

	Thickness (feet)
SENORA FORMATION	
6 Covered: probably sandstone and shale	5.0
Sandstone: brown, extremely micaceous, ferruginous; beds 4 to 12 inches thick; contains plant remains	5.2
Covered: probably interbedded thin sandstone and shale	4.2
Sandstone: beds 2 to 6 inches thick separated by shale partings	6.7

5

Sec. 15, T. 9 N., R. 13 E. Measured along the east section-line road in NE¼, by W. D. Pitt.

	Thickness (feet)
SENORA FORMATION	
5 Sandstone: thin-bedded; not well exposed; may be some shale	14.0
Sandstone: brown, massive, fine-grained, micaceous; the cap rock of this cuesta	3.0
Sandstone: brown; beds ½ to 8 inches thick	5.0

6

Sec. 22, T. 9 N., R. 13 E. Measured along the road from State Highway 9 to Vernon, near W¼ cor., by W. D. Pitt.

	Thickness (feet)
SENORA FORMATION	
6 Covered	24.5
Sandstone: massive; in beds as thick as 3 feet	7.0
Shale: gray to tan, fissile, fragmental	4.0
Sandstone: massive; numerous bedding joints at base	2.0
Sandstone: brown	0.2
Shale: massive; with some jointing at base	0.3
Sandstone: brown	0.1
Covered	0.1
Sandstone: brown, ripple-marked	0.1
Sandstone: laminated; numerous shale partings	0.8
Sandstone: gray to brown, platy	0.1
Shale: gray	0.2
Sandstone: brown	0.2
Sandstone: brown	0.2
Shale: gray, fissile, fragmental; limonite staining along joints	0.5
Covered: not measured	

7

Sec. 4, T. 9 N., R. 14 E. Measured up ridge in SE¼, by R. E. Andrews, Jr.

		Thickness (feet)
	SENORA FORMATION	
6	Sandstone: massive-bedded; massive at top	40.0
	Shale: medium-gray, silty	90.0
5	Sandstone: brown, fine-grained, hard	8.0
	Shale: blue to gray, blocky; contains many limonite streaks	50.0
4	Sandstone: brown, massive, hard	15.0

8

Sec. 5, T. 9 N., R. 14 E. Measured northwestward in SW¼, by R. E. Andrews, Jr.

		Thickness (feet)
	SENORA FORMATION	
6	Sandstone: brown, massive-bedded	56.0
	Shale: blue to gray; some coal streaks	33.0
5	Sandstone: brown, fine-grained	12.0

9

Sec. 6, T. 9 N., R. 14 E. Measured up hill in SE¼?, by R. E. Andrews, Jr.

		Thickness (feet)
	SENORA FORMATION	
5	Sandstone: brown; top eroded	5.0
	Shale: medium-gray; some limonite streaks	39.0
	Sandstone: fine-grained	1.0
	Shale: mostly covered	13.0
	Sandstone: thin-bedded, contorted; contains plant remains	4.5

10

Sec. 7, T. 9 N., R. 14 E. Measured northward along west line, by R. E. Andrews, Jr.

		Thickness (feet)
	SENORA FORMATION	
5	Sandstone: massive-bedded; northwest jointing	12.0
	Shale: dark-gray; many limonite streaks	67.0
	Sandstone: cross-bedded	3.0
	Shale: gray to yellow; some concretionary zones	119.0

11

Sec. 16, T. 9 N., R. 14 E. Measured up ridge in SW¼, by R. E. Andrews, Jr.

		Thickness (feet)
	SENORA FORMATION	
4	Sandstone: massive-bedded, lenticular	15.0
	Shale: gray, silty	100.00
2	Sandstone: brown, hard	9.0
	Shale: medium-gray, blocky; limonite streaks	50.0

12

Sec. 20, T. 9 N., R. 14 E. Measured northward along half-section-line road, by R. E. Andrews, Jr.

		Thickness (feet)
	STUART FORMATION	
3	Sandstone: brown, massive-bedded, cross-bedded	26.0
	Shale: gray, silty, micaceous; base covered by Qt	34.0

13

Sec. 22, T. 9 N., R. 14 E. Measured northward up hill in SW¼, by R. E. Andrews, Jr.

		Thickness (feet)
	SENORA FORMATION	
4	Sandstone: massive, cross-bedded	20.0
	Shale: medium-gray, silty	80.0
3	Sandstone: brown, fine-grained	2.0
	Shale: gray, silty; many silt and limonite streaks	66.0

14

Secs. 23, 24, T. 9 N., R. 14 E. Measured westward along north section-line road, by R. E. Andrews, Jr.

		Thickness (feet)
	SENORA FORMATION	
3	Sandstone: fine-grained, hard	1.5
	Shale: medium-gray, silty	30.0
2	Sandstone: brown, thin-bedded	10.0
	Shale: light-gray, blocky	45.0
1	Sandstone: fine-grained; eroded surfaces crinkly	7.0
	STUART SHALE	
	Shale: light-gray to black	28.0
3?	Sandstone: clean, light-gray; contains coal streaks	5.0

15

Sec. 30, T. 9 N., R. 14 E. Measured eastward along north section line, by R. E. Andrews, Jr.

		Thickness (feet)
	SENORA FORMATION	
4	Sandstone: red-brown, massive, fine-grained	42.0
	Shale: silty; contains limonite streaks	51.0
3	Sandstone: brown; mostly covered	3.0
	Shale: gray, silty	31.0

16

Sec. 34, T. 9 N., R. 14 E. Measured along south section-line road, by R. E. Andrews, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
3	Sandstone: red-brown, hard	1.5
	Shale: medium-gray, silty	86.0
2	Sandstone: buff; contains some plant fossils	10.0
	Shale: gray, silty	25.0
1	Sandstone: brown, massive-bedded	20.0
	STUART SHALE	
	Shale: base covered by Qt	72.0

17

Sec. 3, T. 9 N., R. 15 E. Measured southward along west section-line road, by R. E. Andrews, Jr.

		THICKNESS (FEET)
	STUART FORMATION	
1	Sandstone: tan; contains limonite concretions; some fossil plants; top eroded (outlier)	8.0
	Shale: gray, silty, micaceous	46.0

18

Sec. 8, T. 9 N., R. 15 E. Measured up hill in SW¼, by R. E. Andrews, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
2	Sandstone: brown, massive-bedded; top eroded	8.0
	Shale; gray, silty; mostly covered	33.0
1	Sandstone: not well exposed	4.0
	STUART SHALE	
	Shale: gray, silty, micaceous	88.0
5	Sandstone: fine-grained	3.0
	Shale: gray; contains limonite streaks	17.0
4	Sandstone: brown, massive-bedded	3.0
	Shale: gray, silty; mostly covered	22.0
3	Sandstone: brown, fine-grained; a single bed	5.5

19

Sec. 10, T. 9 N., R. 15 E. Measured southeastward up hill in NW¼, by R. E. Andrews, Jr.

		THICKNESS (FEET)
	BOGGY FORMATION	
6	Sandstone: brown, hard	8.0
	Shale: medium-gray; many limonite streaks; base not exposed	70.0

20

Sec. 15, T. 9 N., R. 15 E. Measured southwestward up hill in SW¼, by R. E. Andrews, Jr.

		THICKNESS (FEET)
	STUART FORMATION	
3	Sandstone: brown, hard; top eroded	7.0
	Shale: gray, silty; mostly covered	111.0

21

Sec. 18, T. 9 N., R. 15 E. Measured eastward up the hill along the half-section-line road, by R. E. Andrews, Jr.

		THICKNESS (FEET)
	STUART FORMATION	
3	Sandstone: brown, massive, cross-bedded	26.0
	Shale: gray, fissile; base not exposed	12.0

22

Sec. 3, T. 9. N., R. 16 E. Measured eastward up the hill in SW¼, by R. E. Andrews, Jr.

		THICKNESS (FEET)
	BOGGY FORMATION	
6	Sandstone: brown; interbedded with shale	30.0
	Shale: gray, silty; mostly covered	137.0
5	Sandstone: buff, soft; base not exposed	15.0

23

Sec. 3, T. 9 N., R. 16 E. Measured from State Highway 9 eastward along south line to top of escarpment, by F. S. Webb.

		THICKNESS (FEET)
	BOGGY FORMATION	
5	Sandstone: tan, fine- to medium-grained, thin- to massive-bedded; weathers brown to gray	35.0
	Shale: covered	115.0
	Covered by Qt	

24

Sec. 3, T. 9 N., R. 16 E. Measured from road at northeast corner of NW¼ SE¼ SW¼ southward to top of escarpment, by F. S. Webb.

		THICKNESS (FEET)
	BOGGY FORMATION	
6	Sandstone: tan, fine-grained, thin-bedded; alternates with thin beds of silty shale; some sandstone beds distorted	43.0
	Covered: probably silty shale	137.0

THICKNESS (FEET)

25

Sec. 5, T. 9 N., R. 16 E. Measured southward along east section-line road, by R. E. Andrews, Jr.

BOGGY FORMATION		
5	Sandstone: buff, soft, massive; top eroded	30.0
	Shale: dark, fissile; base covered by Qt	35.0

26

Sec. 7, T. 9 N., R. 16 E. Measured southward along west section-line road, by R. E. Andrews, Jr.

BOGGY FORMATION		
5	Sandstone: buff, soft; contains limonite concretions; lower 2 feet channeled	58.0
	Shale: black, fissile; contains limonite streaks and limonite concretions; base covered by Qt	67.0

27

Sec. 13, T. 9 N., R. 16 E. Measured from the north end of the State Highway 9 bridge over Canadian River northward to top of ridge, by F. S. Webb.

BOGGY FORMATION		
5	Sandstone: tan, fine- to medium-grained, thin- to massive-bedded; weathers brown	51.0
	Shale: gray, fissile to blocky; upper part silty	233.0

28

Sec. 17, T. 9 N., R. 16 E. Measured northward up side of ridge in NE¼, by R. E. Andrews, Jr.

BOGGY FORMATION		
5	Sandstone: buff, contains limonite concretions; top eroded	32.0
	Shale: dark, fissile; base covered by Qt	90.0

29

Sec. 25, T. 9 N., R 16 E. Measured from NE¼ SE¼ SW¼ to NE¼ NW¼ SE¼, by F. S. Webb.

BOGGY FORMATION		
	Covered: probably shale	55.5
3	Sandstone: tan, fine-grained; weathers brown; contains interbedded shale	20.0

THICKNESS (FEET)

30

Secs. 1, 2, 11, 12, T. 9 N., R. 17 E., and secs. 34, 35, T. 10 N., R. 17 E. Compiled from several sections measured with barometer, by F. S. Webb.

BOGGY FORMATION		
4	Sandstone: tan, fine-grained, thin- to medium-bedded; weathers brown; some local distortion	34.0
	Shale: largely covered; where exposed is gray to black; weathers gray or blue; upper part sandy	65.0
3	Sandstone: tan, fine-grained, thin- to massive-bedded, locally cross-bedded; weathers brown; contains limonite concretions	44.0

31

Sec. 18, T. 9 N., R. 17 E. Measured from abandoned farm house in NE¼ SW¼ NW¼, northward to top of ridge, by F. S. Webb.

BOGGY FORMATION		
5	Sandstone: fine- to medium-grained, massive-bedded; weathers brown or gray; contains limonite concretions	40.0
	Shale: largely covered; where exposed is gray or tan; fissile; silty or sandy in upper part	209.0

32

Sec. 35, T. 9 N., R. 17 E. Measured from NW¼ SE¼ SW¼ northward along washed-out trail to top of escarpment, by F. S. Webb.

BOGGY FORMATION		
3	Sandstone: not measured	
	Shale: largely covered; where exposed is gray, green, blocky, silty, and contains a few thin lenticular sandstone beds	56.0
	Shale: black, fissile; weathers gray or buff; a few limonite stains	5.5
	Shale: gray to green, blocky, clayey; weathers light gray; contains limonite concretions and a few thin sandstone beds	22.0
	Shale: gray to green, blocky; weathers light gray or tan	11.0
	Sandstone: tan, fine-grained; weathers brown; beds about 2 feet thick	6.0
	Shale: largely covered; where exposed is gray to green, silty; contains limonite concretions and a few thin siltstone beds	77.0

33

T. 9 N., R. 18 E., Haskell County. Adapted from measured section 25 of Oakes and Knechtel (1948, p. 127).

Unit		Thickness (feet)
	BOGGY FORMATION	
3	Sandstone and silty shale: occupies the high western part of the township. The sandstone is generally fine grained, thin bedded to massive, and occurs as lenses. Sandstone lenses of this unit form the cap above the escarpment but, owing to their lenticularity, the base of the cap ranges through several feet of section. These sandstone and silty shale beds are continuous with sandstone unit 4 of Dane, Rothrock, and Williams (1938) in Pittsburg County	100.0
	Covered: probably dark shale	180.0
2	Sandstone: thin-bedded to massive; weathers brown; continuous with sandstone unit 3A of Dane, Rothrock, and Williams	40.0
	Covered: shale	190.0
1	Sandstone: thin-bedded, fine-grained; weathers brown; crops out locally in secs. 27, 28; sandstone unit 2 of Dane, Rothrock, and Williams	10.0
	Shale: dark	5.0
	Limestone: fossiliferous	0.1
	Shale: dark	4.8
	Coal	0.1
	Covered: probably dark shale	90.0
	Coal: Secor	2.0
	Covered: probably dark shale	98.0
b	Sandstone (Bluejacket): Generally, this member contains one or more sandstone beds in the lower part, each of which is several feet thick, fine to medium grained, massive, and weathers by exfoliation to form conspicuously large rounded boulders. These massive basal beds are separated from and succeeded by softer, less resistant beds of sandstone and sandy shale, the debris of which occupies the dip slope, making it difficult to map the top of the member exactly	100.0

34

Sec. 22, T. 10 N., R. 13 E. Measured along northeast face of escarpment capped by outlier of IPsn-9, in NW¼ NW¼, by W. D. Pitt.

Unit		Thickness (feet)
	SENORA FORMATION	
9	Sandstone: brown, massive, fine-grained, micaceous	4.0
	Sandstone; brown, massive	6.1
	Sandstone: massive	2.3
	Sandstone: massive	2.4
	Sandstone: massive	4.7
	Covered	1.0
	Sandstone: massive	2.5
	Sandstone: massive	3.4
	Covered	2.0
	Sandstone: beds 2 to 8 inches thick	5.5
	Sandstone: massive except at base and top where it is markedly laminated and cross-bedded	2.2
	Sandstone: massive, locally laminated	4.0
	Sandstone: massive, locally laminated	8.3
	Sandstone: cross-bedded; beds 1 to 2 inches thick	1.7
	Sandstone: massive, locally jointed; cross-bedding at base	8.2
	Sandstone: jointed into beds 4 to 6 inches thick	2.7
	Covered	1.0
	Sandstone	6.0
	Sandstone: massive; with local concentrations of bedding joints	3.5
	Covered: probably mostly shale and sandstone	1.5
	Sandstone: laminated; weathering to vuggy and thinly laminated surface	4.3

35

Sec. 2, T. 10 N., R. 14 E. Measured westward along south line from SE cor. to top of hill, by V. S. Whitesides, Jr.

Unit		Thickness (feet)
	SENORA FORMATION	
8b	Sandstone: tan, massive; prominent jointing trending northwestward; top eroded	12.0
	Shale: gray, silty; partly covered	52.0
8a	Sandstone: tan, massive	12.0
	Covered: probably gray silty shale	73.0
6	Sandstone: tan	15.0
	Shale: greenish-gray, silty; mostly covered	68.0
	Shale: fissile	12.0
4	Siltstone: greenish-gray; abundant small plant fossils	2.0
	Covered: probably gray shale	28.0

36

Secs. 13, 14, T. 10 N., R. 14 E. Measured westward along south line in SW¼ sec. 13 and SE¼ sec. 14, by V. S. Whitesides, Jr.

Unit		Thickness (feet)
	SENORA FORMATION	
6	Sandstone: tan; weathers brown; lower part massive; prominent jointing trending northwestward; top eroded	60.0
	Covered: probably gray silty shale and probably includes IPsn-5	111.0
4	Sandstone: tan; weathers brown; not well exposed	19.0
	Covered: probably gray silty shale	28.0

37

Sec. 16, T. 10 N., R. 14 E. Measured northeastward from top of IPsn-8a to top of hill in east-central part, by V. S. Whitesides, Jr.

		Thickness (feet)
	SENORA FORMATION	
8b	Sandstone: tan, silty; weathers brown; locally ferruginous along bedding planes; top eroded	5.0
	Shale: gray, silty to sandy	97.0
8a	Sandstone: not measured	

38

Sec. 16, T. 10 N., R. 14 E. Measured northeastward from stream in north-central part to top of hill, by V. S. Whitesides, Jr.

		Thickness (feet)
	SENORA FORMATION	
8b	Sandstone: tan; weathers darker brown; prominent joints trending northwestward; top eroded	27.0
	Shale: gray, silty, platy	83.0
8a	Sandstone: tan to olive-drab	8.0
	Shale: gray, silty, platy	66.0
	Covered: probably gray shale	38.0

39

Sec. 17, T. 10 N., R. 14 E. Measured from trail in SE¼, southward to base of IPsn-7, by V. S. Whitesides, Jr.

		Thickness (feet)
	SENORA FORMATION	
7	Sandstone: not measured	
	Shale: gray, silty; partly covered	44.0
6	Sandstone: tan, well-cemented; weathers brown; small *Calamites*	4.0
	Shale: partly covered	35.0
	Covered by road fill; not measured	

40

Secs. 17, 18, T. 10 N., R. 14 E. Measured westward along road from abandoned house at base of hill to top of ridge, by V. S. Whitesides, Jr.

		Thickness (feet)
	SENORA FORMATION	
8a	Sandstone: tan, ripple-marked; weathers brown; interbedded with shale	45.0
	Shale: gray, silty	82.0
7	Sandstone: tan, massive; weathers brown	5.0
	Shale: steel-gray; weathers brownish gray; contains beds of limonite concretions; also contains pelecypods; platy	103.0
	Covered: not measured	

41

Sec. 18, T. 10 N., R. 14 E. Measured westward in east-central part west of trail from top of IPsn-8b to top of hill, by V. S. Whitesides, Jr.

		Thickness (feet)
	SENORA FORMATION	
8c	Sandstone: tan; weathers brown; locally ferruginous, particularly on weathered surfaces; beds about 2 inches thick; prominent jointing trends northwestward; top eroded	9.0
	Covered: possibly shale	8.0
	Sandstone: tan; weathers dark brown	3.0
	Shale: gray, silty; mostly covered	17.0
8b	Sandstone: not measured	

42

Sec. 18, T. 10 N., R. 14 E. Measured northward from base of IPsn-8b to top of hill near eastward bend in trail in east-central part, by V. S. Whitesides, Jr.

		Thickness (feet)
	SENORA FORMATION	
8b	Sandstone: tan, ferruginous; weathers brown; interbedded with shale; prominent jointing trends northwestward; includes part of IPsn-8c	45.0
	Shale: gray; not measured	

43

Secs. 19, 29, T. 10 N., R. 14 E. Measured westward along north line, by R. E. Andrews, Jr.

		Thickness (feet)
	SENORA FORMATION	
8a	Sandstone: ripple marked; interbedded with shale	45.0
	Shale: gray, silty	82.0
7	Sandstone: buff to brown, massive	5.0
	Shale: medium-gray; contains limonite streaks and concretions, a few pelecypods	103.0

44

Secs. 23, 24, T. 10 N., R. 14 E. Measured westward along north line, by R. E. Andrews, Jr.

		Thickness (feet)
	SENORA FORMATION	
6	Sandstone: tan; lower part massive-bedded; northwest jointing	60.0
	Shale: blue to gray, silty	111.0
4	Sandstone: mostly covered	19.0
	Shale: gray, silty	27.0

45

Sec. 26, T. 10 N., R. 14 E. Measured westward up hill along north line, by R. E. Andrews, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
6	Sandstone: brown, massive-bedded	32.0
	Shale: gray, blocky; mostly covered	57.0
	Sandstone: brown; northwest jointing	3.0
	Shale: dark-gray, platy; contains limonite streaks	62.0
4	Sandstone: thin-bedded; contains coal streaks	3.5

46

Sec. 28, T. 10 N., R. 14 E. Measured northward up ridge in SW¼, by R. E. Andrews, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
8a	Sandstone: pit and cusp type of weathered surface	22.0
	Shale: gray, silty	57.0
7	Sandstone: brown to red brown	10.0
	Shale: gray, silty	30.0
6	Sandstone: brown, hard; mostly covered	22.0
	Shale: blue to gray, silty	21.0

47

Sec. 35, T. 10 N., R. 14 E. Measured up ridge in NE¼, by R. E. Andrews, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
6	Sandstone: massive-bedded; top eroded	27.0
	Shale: gray, silty; mostly covered	117.0
5?	Sandstone; buff, hard	5.0
	Shale: mostly covered	39.0
4	Sandstone: buff, ripple-marked, slightly contorted	12.0
	Shale: gray, silty; some limonite streaks	73.0

48

Sec. 7, T. 10 N., R. 15 E. Measured southward from a well just west of road along west line, by V. S. Whitesides, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
4	Sandstone: tan, massive; weathers to darker brown; joints that trend N. 30° W. are clearly exposed; top eroded	8.0
	Covered: probably gray shale	128.0
2	Sandstone: tan, silty, massive; weathers dark brown	12.0
	Covered: probably gray shale	22.0
1	Siltstone: greenish-gray; minutely cross-bedded; weathers tan; weathered surfaces crinkly	8.0
	STUART SHALE	
	Covered: probably gray shale	60.0

49

Sec. 16, T. 10 N., 15 E. Measured northeastward from the top of IPsn-7 to top of hill in S½, by V. S. Whitesides, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
8a	Sandstone: tan, well-cemented, thin-bedded; weathers light brown; prominent joints trend northwestward; top eroded	9.0
	Shale: gray, silty; contains limonite concretions	85.0
7	Sandstone: not measured	

50

Sec. 16, T. 10 N., R. 15 E. Measured southward from road along north line of top of a small hill in NE¼, by V. S. Whitesides, Jr.

		THICKNESS (FEET)
	STUART FORMATION	
2	Sandstone: tan, micaceous, silty, thin-bedded; weathers light brown	3.0
	BOGGY FORMATION	
	Shale: gray, platy; base covered by Qt	32.0

51

Sec. 17, T. 10 N., R. 15 E. Measured northward from road on south line to top of Bald Hill in E½, by V. E. Whitesides, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
5	Sandstone: tan, silty; contorted bedding; top eroded	4.0
	Covered: probably gray silty shale	36.0
4	Sandstone: tan, silty	5.0
	Covered: probably gray silty shale	38.0
3?	Sandstone: tan, silty	4.0
	Covered: probably gray silty shale	83.0
1	Siltstone: greenish-gray, minutely cross-bedded	3.0
	STUART SHALE	
	Covered: probably gray shale	30.0

52

Sec. 18, T. 10 N., R. 15 E. Measured westward from well near abandoned farm house in SE¼, along path to top of hill, by V. S. Whitesides, Jr.

		Thickness (feet)
	Senora Formation	
4	Sandstone: tan, silty, massive, friable; weathers dark brown; prominent joints trend northwestward; contains *Lepidodendron, Sigillaria, Stigmaria, Calimites,* and the pelecypod *Myalina (Myalina) lepta* Newell	16.5
	Shale: gray, silty, platy; contains limonite concretions; partly covered by sandstone rubble	132.0
1	Siltstone: greenish-gray; weathers tan	5.0
	Stuart Formation	
	Shale: gray, silty; mostly covered	55.0

53

Secs. 19, 20, 21, 22, T. 10 N., R. 15 E. Measured westward along the south line, by R. E. Andrews, Jr.

		Thickness (feet)
	Senora Formation	
4	Sandstone: red; contains plant fossils; top eroded	12.0
	Shale: gray, fissile; mostly covered	95.0
2	Sandstone: brown; some beds contorted	11.0
	Shale: light-gray; some limonite streaks	28.0
1	Sandstone: light-gray; cross-bedding renders eroded surfaces crinkly	4.0
	Stuart Formation	
	Shale: dark-blue to gray, fissile to blocky; contains IPst-2 in lower 5 feet	330.0
	Boggy Formation	
	Shale: black, fissile; base covered by Qt	30.0

54

Sec. 27, T. 10 N., R. 15 E. Measured southwestward up hill in SW¼, by R. E. Andrews, Jr.

		Thickness (feet)
	Boggy Formation	
6	Sandstone: interbedded with shale; top eroded	28.0
	Shale: gray; many limonite streaks; base covered	40.0

55

Secs. 32, 33, T. 10 N., R. 15 E. Measured westward along south section-line road, by R. E. Andrews, Jr.

		Thickness (feet)
	Senora Formation	
2	Sandstone: interbedded with shale; top eroded	8.0
	Shale: gray, silty	34.0
1	Sandstone: lenticular; some shale beds; cross-bedding gives some sandstone surfaces a crinkly appearance	12.0
	Stuart Shale	
	Shale: gray, silty; many limonite streaks	300.00
4	Sandstone: gray, micaceous	2.0
	Shale: gray, silty; mostly covered	63.0

56

Sec. 35, T. 10 N., R. 15 E. Measured along State Highway 9, by R. E. Andrews, Jr.

		Thickness (feet)
	Boggy Formation	
6	Sandstone: interbedded with shale; some cross-bedding, ripple marks near top	28.0
	Shale: gray, silty; mostly covered	77.0
5	Sandstone: buff, massive; base covered by Qt	17.0

57

Sec. 10, T. 10 N., R. 16 E. Measured up the east side of the hill in SW¼, by R. E. Andrews, Jr.

		Thickness (feet)
	Boggy Formation	
6	Sandstone: brown, fine-grained; top eroded	34.0
	Shale: dark-gray, silty	30.0
	Sandstone: red-brown, massive-bedded	6.0
	Shale: gray, silty; mostly covered	54.0
	Sandstone: brown, hard	5.0
	Shale: light-gray to dark-gray, silty	174.0
5	Sandstone: buff, soft; base not exposed	5.0

59

Sec. 34, T. 10 N., R. 16 E. Measured up the east side of the hill in SW¼, by R. E. Andrews, Jr.

		Thickness (feet)
	Boggy Formation	
5	Sandstone: massive; top eroded	30.0
	Shale: dark, fissile; base covered by Qt	35.0

60

Sec. 23, T. 10 N., R. 17 E. Measured from 0.6 mile south of the NE cor., southwestward to top of hill, by F. S. Webb.

		Thickness (feet)
	Boggy Formation	
5	Sandstone: thin- to massive-bedded; ripple-marked	25.0
	Covered: probably silty shale and thin sandstone	78.0

		Thickness (feet)
	Shale: gray to black, fissile to blocky; contains limonite concretions; grades upward into silty shale and thin sandstones	144.0

61

Sec. 27, 34, T. 10 N., R. 17 E. Measured from the Canadian River at Standing Rock in sec. 34, northward to top of escarpment in NW¼ SE¼ SW¼ sec. 27, by F. S. Webb.

BOGGY FORMATION

5	Sandstone: tan, fine- to medium-grained, thin- to massive-bedded; weathers light brown to buff	46.6
	Covered: probably shale	221.7

62

Sec. 2, T. 10 N., R. 18 E. Measured along trail in NE¼ SW¼ SE¼, by F. S. Webb.

SAVANNA FORMATION

ss	Sandstone: tan, fine-grained, thin- to massive-bedded; weathers brown	27.0

63

Sec. 7, T. 10 N., R. 18 E. Measured from SE cor. of NE¼ NW¼ SE¼, northward to top of section, by F. S. Webb.

BOGGY FORMATION

b	Sandstone: tan, fine- to medium-grained, massive; weathers brown; weathers by exfoliation to rounded boulders	21.0

SAVANNA FORMATION

	Covered: probably silty shale with a few thin sandstone and siltstone beds	88.0
	Covered: probably black to gray fissile shale	53.0
	Coal	0.5
	Covered: probably shale	20.0

64

Sec. 10, T. 10 N., R. 18 E. Measured from about ⅛ mile south of NE cor. to top of escarpment, by F. S. Webb.

BOGGY FORMATION

b	Sandstone: tan, fine-grained, thin- to massive-bedded; weathers brown	30.0

SAVANNA FORMATION

		Thickness (feet)
	Covered: probably shale and silty shale	184.0
ss	Sandstone: tan, fine-grained; thin- to massive-bedded; weathers brown	35.0
	Covered for the greater part: where exposed, it is shale with a few thin sandstones and siltstones	102.4

65

Sec. 10, T. 10 N., R. 18 E. Measured from creek in NE cor. of NE¼ NE¼ SE¼, northwestward to SE cor. of NE¼ NE¼ NW¼, by F. S. Webb.

SAVANNA FORMATION

ss	Sandstone: tan, fine- to medium-grained, thin- to massive-bedded; weathers brown to gray	40.0
	Covered: probably silty gray shale with thin siltstones	24.0
	Sandstone: tan, fine-grained; weathers brown	0.5
	Shale: light-gray; alternating with thin fine-grained sandstone and siltstone beds	11.0
	Sandstone: light-gray, fine-grained; weathers brown; distorted bedding	3.0
	Shale: gray, silty; alternating with thin light-brown to gray siltstone beds	25.5
	Shale: dark-gray, blocky; silty in upper part	40.0

66

Sec. 1, T. 10 N., R. 18 E. Measured from 0.6 mile north of SE cor., northward to top of escarpment, across the south fault of the Warner uplift, by F. S. Webb.

MCALESTER FORMATION

cl	Sandstone: tan, fine-grained, well-indurated; limonite concretions; weathers brown to gray	45.0
	Covered: probably sandy shale	13.0
	Sandstone: tan, fine-grained; weathers brown; contains limonite concretions	40.0
	Shale: gray, blocky, silty; contains limonite concretions; weathers light gray to tan	26.0

Fault

SAVANNA FORMATION

	Shale: largely covered; where exposed is black to blue or gray, fissile to blocky	74.0
	Shale: black, fissile	0.1
	Clay: gray to green, fossiliferous; weathers light gray to buff	1.5
sp	Limestone: gray to black, fossiliferous; weathers dark gray to brown; limonite stains	0.5

		Thickness (feet)
	McAlester Formation	
	Shale: largely covered; where exposed is gray to green; weathers tan to buff; blocky	57.8

67

Sec. 1, T. 11 N., R. 14 E. Measured southeastward from farm house near NW cor. to top of hill, by V. S. Whitesides, Jr.

		Thickness (feet)
	Senora Formation	
8b	Sandstone: tan, ferruginous, massive; weathers brown; prominent jointing trends northwestward; contorted locally; top eroded	12.0
	Shale: gray, silty; mostly covered	66.0
8a	Siltstone: olive-drab; weathers brownish gray, micaceous along laminae; prominent joints trend northwestward	1.0
	Shale: gray, silty, platy; contains limonite concretions as large as 3 inches in diameter; contains siltstones about 1 inch thick; partly covered.	121.0
	Covered by Qt	

68

Secs. 3, 10, T. 11 N., R. 14 E. Measured southward from east-central part of sec. 3 along road on east line to top of hill in sec. 10, by V. S. Whitesides, Jr.

		Thickness (feet)
	Senora Formation	
8c	Sandstone: tan, silty; weathers brown; contains interbedded shale; top eroded	20.0
	Shale: gray; mostly covered	32.0
8b	Sandstone: tan, silty; weathers brown; contains interbedded shale	34.0
	Shale: gray, silty; mostly covered	58.0
8a	Sandstone: tan, silty; weathers brown; contains interbedded shale	28.0
	Shale: gray, silty; upper part shows evidence of slumping before lithification	140.0
	Covered by Qal.	

69

Secs. 4, 9, T. 11 N., R. 14 E. Measured southward along road on west line from west center sec. 4 to top of hill in west center sec. 9, by V. S. Whitesides, Jr.

		Thickness (feet)
	Senora Formation	
8c	Sandstone: tan, silty; weathers brown; contains interbedded shale and small plant fossils; some beds are contorted	32.0
	Shale: gray, silty; partly covered	28.0
8b	Sandstone: tan, silty; weathers brown	8.0
	Shale: gray, silty, platy; contains beds of siltstone 1 to 3 inches thick that show penecontemporaneous deformation and conspicuous joints that trend northwestward; also contains beds of limonite concretions	178.0
	Covered by Qal.	

70

Sec. 8, T. 11 N., R. 14 E. Measured northward in south-central part from top of IPsn-8b to top of hill, by V. S. Whitesides, Jr.

		Thickness (feet)
	Senora Formation	
8c	Sandstone: tan; weathers buff; beds 0.5 to 1.5 feet thick; locally ferruginous, ripple-marked; top eroded	38.0
	Shale: gray, silty; mostly covered	60.0
8b	Sandstone: not measured	

71

Sec. 12, T. 11 N., R. 14 E. Measured westward from bridge near east line to top of IPsn-8a at SW cor., by V. S. Whitesides, Jr.

		Thickness (feet)
	Senora Formation	
8a	Sandstone: tan, silty, micaceous, ripple-marked; weathers brown; lower part massive; upper part thin-bedded; contains interbedded shale; top eroded	45.0
	Shale: gray, silty, platy; contains bedded concretions and interbedded siltstones 1 to 3 inches thick; partly covered	195.0

72

Sec. 22, T. 11 N., R. 14 E. Measured in NW¼ where intermittent stream flows into North Canadian River, by V. S. Whitesides, Jr.

		Thickness (feet)
	Boggy Formation	
?	Sandstone: tan, micaceous, limonitic, ripple-marked, cross-bedded, weathers brown; contains carbonaceous matter; prominent jointing trends northwestward; top eroded	2.5
	Shale and interbedded sandstone: gray to brown, thin-bedded	8.0
	Sandstone: brownish green to tan, soft, micaceous; upper part conspicuously cross-bedded; lower part massive	5.5
	Covered by water; not measured	

73

Sec. 27, T. 11 N., R. 14 E. Measured southward from road in east-central part to top of ridge at the "Rock Slide," by V. S. Whitesides, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
8a	Sandstone: tan; weathers brown; in two parts, both massive, lower part channeled; top eroded	39.0
	Shale: greenish-gray, silty, platy; contains limonite; partly covered	205
	Shale: black, fissile; upper part covered	10.0
	Covered by Qal: not measured	

74

Sec. 29, T. 11 N., R. 14 E. Measured northward from bed of intermittent stream in NW¼ to NW cor., by V. S. Whitesides, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
	Shale: mostly covered; not measured	
8b	Sandstone: tan, ferruginous; weathers brown	11.0
	Covered: probably gray shale	54.0
8a	Sandstone: not measured	

75

Sec. 30, T. 11 N., R. 14 E. Measured northward along road in NE¼, from intermittent stream to top of hill, by V. S. Whitesides, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
8b	Sandstone: tan; weathers brown; lower part massive; upper part contains interbedded shale and remains of small plants	20.0
	Covered: not measured	

76

Sec. 1, T. 11 N., R. 15 E. Measured eastward along north boundary, from bottom of stream bed to top of hill, by V. S. Whitesides, Jr.

		THICKNESS (FEET)
	STUART FORMATION	
	Shale, grayish-brown, micaceous; weathers tan; mostly siltstone at the base; becomes progressively more shaly upward; top eroded	90.0
	Covered by Qt	

77

Sec. 8, T. 11 N., R. 15 E. Measured northward from top of hill immediately behind house in SW¼ to top of outlier, by V. S. Whitesides, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
8a?	Sandstone: tan, massive; weathers brown; top eroded	10.0
	Shale: gray, silty; mostly covered	20.0
	Sandstone: tan; weathers brown; thin-bedded with interbedded shale	20.0
	Shale: gray, silty; mostly covered	130.0

78

Sec. 9, T. 11 N., R. 15 E. Measured from point in road on east line opposite Pierce School to top of hill in central part, by V. S. Whitesides, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
8a?	Sandstone: tan, massive; weathers brown; top eroded	30.0
	Shale: gray, silty	46.0
	Covered: not measured	

79

Sec. 23, T. 11 N., R. 15 E. Measured northward in north-central part, from water level in North Canadian River to top of bank, by V. S. Whitesides, Jr.

		THICKNESS (FEET)
	BOGGY FORMATION	
?	Sandstone: grayish-brown, micaceous, ferruginous; weathers brown; prominent jointing trends northwestward; top eroded	6.5
	Shale and sandstone: interbedded, variegated, gray, green, brown, thin-bedded; weathers brownish gray	14.0
	Sandstone: greenish-brown, micaceous, silty, limonitic, thin-bedded	2.0
	Covered by water: not measured	

80

Sec. 34, T. 11 N., R. 15 E. Measured in central part, east of Canadian River, from Qal eastward to top of ridge, by V. S. Whitesides, Jr.

		THICKNESS (FEET)
	SENORA FORMATION	
8a	Sandstone: cream; weathers tan; consists of upper and lower parts, both massive; a middle part is 1 to 4 feet thick, channeled, cross-bedded, and cut by normal faults with dis-	

	THICKNESS (FEET)
placements of 2 to 3 inches, ferruginous along the fault planes; top eroded	28.0
Shale: gray, silty; contains limonite concretions; mostly covered	280.0
Covered by Qt: not measured	

81

Secs. 1, 2, T. 11 N., R. 16 E. Measured from SW cor. sec. 1 to top of ridge in sec. 2, by R. A. Meek.

BOGGY FORMATION

6?	Sandstone: tan, platy to blocky, fine-grained, thin-bedded; weathers reddish brown	25.0
	Shale: mostly covered; where exposed, upper part is sandy and black and lower part is fissile	66.0
1	Limestone: dark-gray to black, platy; weathers reddish-brown; locally, small pelecypods are so numerous as to make the limstone a coquinoid	1.9
	Shale: black and fissile to gray and silty; contains clay ironstone beds	15.0

82

Sec. 4, T. 11 N., R. 16 E. Measured in NW¼ from top of sandstone escarpment to top of hill, by R. A. Meek

BOGGY FORMATION

Shale: silty; contains thin sandstone beds and a thin coal seam	73.0

83

SE¼ sec. 8, W½ sec. 9, NE¼ sec. 17, T. 11 N., R. 16 E. A composite of several measured sections, by R. A. Meek.

BOGGY FORMATION

6?	Sandstone: massive to thin-bedded, fine-grained, micaceous; weathers brown	36.0
	Shale: gray to tan, silty to sandy	15.0
	Shale: black, fissile; contains clay ironstone beds	41.7
1	Limestone: dark-gray; weathers reddish brown; small pelecypod fossils so numerous locally as to make a coquina	1.5
	Shale: black, fissile; contains three clay ironstone beds	27.0

84

Sec. 12, T. 11 N., R. 16 E. Measured from base to top of high hill in south part, by R. A. Meek.

BOGGY FORMATION

		THICKNESS (FEET)
6?	Sandstone: tan, fine-grained, massive; weathers reddish-brown; top eroded	10.0
	Covered: probably shale that contains IPb-1	72.0
5?	Sandstone: not measured	

85

Sec. 22, T. 11 N., R. 16 E. Measured from W¼ cor. southwestward to top of sandstone-capped escarpment, by R. A. Meek.

BOGGY FORMATION

5?	Sandstone: tan, fine-grained, massive to thin-bedded; weathers brown	15.0
	Covered: probably shale; upper part sandy where exposed	178.0
i	Limestone: dark-gray, dense, blocky, pitted, fossiliferous; weathers gray to brown	0.5
	Shale: gray	0.1
	Coal: unnamed	0.1
	Underclay	0.4

86

Sec. 25, T. 11 N., R. 16 E. Measured from northeast corner of Onapa Lake northward to top of hill, by R. A. Meek.

BOGGY FORMATION

5?	Sandstone: tan, fine-grained, massive; weathers dark brown	8.0
	Shale: mostly covered but upper part is sandy where exposed	60.0
	Shale: black, fissile; contains thin clay ironstone beds	4.0
	Limestone: fossiliferous; much weathered	0.2
	Shale: dark-gray to black	1.5
	Shale: gray, argillaceous	1.0
	Coal: unnamed	0.3
	Underclay: gray	0.3
	Shale: tan, silty	22.7

87

Sec. 26, T. 11 N., R. 16 E. Measured from water level in Deep Fork, SW¼ SW¼ SW¼, westward to top of sandstone ridge, by R. A. Meek.

		THICKNESS (FEET)
	BOGGY FORMATION	
5?	Sandstone: tan, thin-bedded; weathers brown; contains interbedded silty shale in upper part	30.0
	Covered: probably shale	55.0
	Shale: light-gray to tan, silty	2.0

88

Sec. 27, T. 11 N., R. 16 E. Measured in NE¼ NE¼ NE¼, in stream just west of road on east line, by R. A. Meek.

	BOGGY FORMATION	
	Shale: black, fissile	15.0
i	Limestone: dark-gray, dense, blocky, fossiliferous; weathers gray to brown	0.6
	Shale: gray	0.1
	Coal: unnamed	0.1
	Underclay	0.5
	Shale: black; contains phosphatic nodules	1.0

89

Sec. 35, T. 11 N., R. 16 E. Measured from confluence of creek and river in SW¼, southeastward up steep hill, by R. A. Meek.

	BOGGY FORMATION	
5?	Sandstone: tan, fine-grained, massive; weathers brown	4.0
	Shale: gray, silty; weathers buff; contains ironstone concretions	8.0
	Sandstone: tan, fine-grained	0.5
	Shale: silty; upper part gray; lower part dark gray	14.3
	Coal: unnamed	0.8
	Underclay	0.3
	Shale: gray, silty; contains clay ironstone beds	36.2
	Sandstone: buff, fine-grained	0.2
	Shale: gray, silty to sandy; weathers brown	8.3
	Sandstone: buff, fine-grained	1.3
	Shale: gray, silty	10.3
	Sandstone: floors creek bed; not measured	

90

Secs. 1, 12, T. 11 N., R. 17 E. Measured along road on east line from SE¼ SE¼ sec. 12 to stream in SE¼ SE¼ sec. 1, by R. A. Meek.

		THICKNESS (FEET)
	BOGGY FORMATION	
3b	Sandstone: fine-grained, slabby, ripple-marked; weathers dark brown; estimated	10.0
	Shale: tan, silty and sandy; estimated	12.0
b	Sandstone: tan, fine-grained, soft, massive to thin-bedded; weathers brown	71.0
	SAVANNA FORMATION	
	Covered: probably shale; not measured	

91

Sec. 3, T. 11 N., R. 17 E. Measured in SE cor. just west of road on east line, in creek, by R. A. Meek.

	BOGGY FORMATION	
	Shale: black, fissile; contains phosphatic nodules	1.0
i	Limestone: dark-gray to black, pitted, fossiliferous; weathers gray to brown	0.4
	Shale: gray	0.1
	Coal: unnamed	0.1
	Underclay: not measured	

92

Sec. 3, T. 11 N., R. 17 E. Measured in a creek in NE¼, about 600 feet south of U. S. Highway 266, by R. A. Meek.

	BOGGY FORMATION	
	Shale: black, fissile; contains phosphatic nodules	1.0
i	Limestone: dark-gray to black, fossiliferous; weathers brown	0.4
	Coal: unnamed	0.1
	Shale and underclay	3.0

93

Secs. 3, 11, 12, T. 11 N., R. 17 E. Composite of several sections computed from barometric data, by R. A. Meek.

	BOGGY FORMATION	
	Shale: not measured	
i	Limestone: dark-gray, dense, fossiliferous; weathers gray to brown	0.4
	Shale: gray	0.1
	Coal: unnamed	0.1
	Covered: probably shale	15.0
3b	Sandstone: tan, fine-grained, thin-bedded; weathers brown	8.0
	Shale: mostly covered; sandy where exposed	20.0
b	Sandstone: not measured	

94

Secs. 6, 8, T. 11 N., R. 17 E. Composite of several sections computed from barometric data, by R. A. Meek.

		Thickness (feet)
	Boggy Formation	
5?	Sandstone: tan, fine-grained, thin-bedded; weathers reddish brown	15.0
	Covered: probably shale	150.0
	Shale: black, fissile	1.0
i	Limestone: dark-gray to black, pitted, fossiliferous; weathers gray	0.4
	Shale: gray, argillaceous	0.1
	Coal: unnamed	0.1
	Shale: black, fissile	1.0

95

Sec. 9, T. 11 N., R. 17 E. Measured in bed of stream in SE¼ SE¼ NE¼, by R. A. Meek.

		Thickness (feet)
	Boggy Formation	
	Shale: black, fissile; contains phosphatic nodules; lower part fossiliferous	1.2
i	Limestone: dark-gray, fossiliferous; weathers gray to brown	0.8
	Shale: gray, argillaceous	0.1
	Coal: unnamed	0.1
	Underclay: bluish-gray	2.0
	Shale: silty; partly covered; estimated	10.0
3b	Sandstone: fine-grained, blocky; weathers brown; contains fossil plant impressions	8.0

96

Sec. 12, T. 11 N., R. 17 E. Measured along road on north line from NE cor., westward to top of escarpment, by R. A. Meek.

		Thickness (feet)
	Boggy Formation	
b	Sandstone: tan, fine-grained, soft, massive to thin-bedded; weathers gray to brown; top eroded	71.0
	Savanna Formation	
	Covered: probably shale	74.0

97

Sec. 25, T. 11 N., R. 17 E. Measured from a point 300 feet east of the main stream that crosses the north line westward to top of escarpment, by R. A. Meek.

		Thickness (feet)
	Boggy Formation	
b	Sandstone: buff, fine-grained, massive to thin-bedded; weathers light brown; top eroded	29.0
	Savanna Formation	
	Shale: upper part silty to sandy; lower part black, fissile, and contains clay ironstone beds	143.0
ss	Sandstone: tan, fine-grained, micaceous; weathers brown; contains fossil plant impressions	5.0
	Shale: gray to tan, silty to sandy	22.0
sc	Limestone: gray, platy, fossiliferous; weathers light reddish brown	0.3
	Shale: mostly covered; fossiliferous in upper few feet where exposed	48.0

98

Sec. 26, T. 11 N., R. 17 E. Measured in SE¼, by R. A. Meek.

		Thickness (feet)
	Boggy Formation	
b	Sandstone: tan, fine-grained; weathers brown; lower part massive and weathers to exfoliated boulders; upper part thin-bedded; top eroded	27.0
	Savanna Formation	
	Shale: silty in lower part; grades to sandy in upper part	148.0

99

Sec. 35, T. 11 N. R. 17 E. Measured from bend in road on south section line in SW cor. to top of escarpment, by R. A. Meek.

		Thickness (feet)
	Boggy Formation	
b	Sandstone: tan, fine-grained; weathers brown; lower part massive; upper part thin-bedded; channeled at base; top eroded	34.0
	Savanna Formation	
	Shale: mostly covered; silty where exposed	160.0

100

Secs. 10, 11, T. 12 N., R. 14 E. Measured along the north line, from a point 0.2 mile west of bridge in sec. 11, by C. N. Manhoff, Jr.

		Thickness (feet)
	Senora Formation	
8b?	Sandstone: tan, fine-grained, thin-bedded to massive, micaceous; weathers gray or dark brown	26.0
	Sandstone: tan to ochre, thin-bedded, hard, very fine-grained, silty, micaceous	16.0
	Sandstone: tan, very fine-grained, ripple-marked; weathers brown; somewhat thicker bedded than unit next above and less silty	19.0
8a?	Siltstone: tan to ochre, thin-bedded; interbedded with silty, gray to ochre shale	23.0

		Thickness (feet)
	Shale: black, thin-bedded, friable; weathers ochre; micaceous, especially at bedding planes	11.0

101

Sec. 11, T. 12 N., R. 14 E. Measured southwestward from bridge in NE¼ to top of hill in middle, by C. N. Manhoff, Jr.

		Thickness (feet)
	Senora Formation	
8b?	Sandstone: tan to gray, fine-grained, massive; poorly exposed; lower 15 feet seems thinner bedded and siltier	19.0
	Covered: probably sandstone	20.0
	Sandstone: tan to gray, very fine-grained, silty, thin- to medium-bedded, micaceous	12.0
	Covered: probably silty, sandy shale	20.0
	Sandstone: tan to gray, medium-bedded to massive, micaceous, porous; weathers dark reddish brown; relatively little silt; poorly exposed	32.0
	Covered: probably sandy shale interbedded with thin sandstones	40.0
8a?	Sandstone: tan to gray, medium-bedded to massive, micaceous; weathers dark brown; fine-grained with very little silt; poorly exposed	23.0
	Shale: light-gray to tan, sandy; interbedded with thin sandstones	19.0

102

Sec. 9, T. 12 N., R. 15 E. Measured westward up side of hill in NW¼, by C. N. Manhoff, Jr.

		Thickness (feet)
	Senora Formation	
8b?	Sandstone: light-gray to tan, fine-grained, medium-bedded to massive, micaceous; weathers dark brown; top eroded	33.0
	Covered: silty sandstone is exposed in patches and is probably interbedded with shale	96.0
8a?	Sandstone: light-gray to tan; fine-grained, medium-bedded, slightly micaceous; poorly exposed	10.0
	Sandstone: tan to ochre, fine-grained, thin-bedded, silty; interbedded with silty shale	27.0

103

Secs. 2-6, T. 12 N., R. 16 E. Computed from barometer readings in the vicinities of the southwest corners of secs. 2, 4, 6, by R. A. Meek.

		Thickness (feet)
	Stuart Formation	
	Shale: mostly covered; gray and silty where exposed	30.0
	Boggy Formation	
	Covered: probably shale	100.0
5?	Sandstone: not measured	

104

Secs. 11, 12, T. 12 N., R. 16 E. Computed from barometric data secured along the north line, from NE cor. sec. 12 to the escarpment capped by IPb-5? west of NE cor. sec. 11, by R. A. Meek.

		Thickness (feet)
	Boggy Formation	
5?	Sandstone: tan, soft, fine-grained, thin-bedded; weathers brown	18.0
	Covered: probably shale	100.0
4a	Siltstone: tan, dense, calcareous, thin-bedded	3.0
	Shale: mostly covered; gray where exposed	26.0

105

Sec. 25, T. 12 N., R. 16 E. Measured in the vicinity of SW cor., by R. A. Meek.

		Thickness (feet)
	Boggy Formation	
	Shale: black, fissile; contains scattered small selenite crystals	10.0
1	Limestone: dark-gray to black, platy; weathers reddish brown; many small pelecypods make it coquinoid	1.9
	Shale: black, fissile	1.0

106

Sec. 3, T. 12 N., R. 17 E. Measured in bank of creek, SE¼ NW¼, by W. F. Coleman.

		Thickness (feet)
	Boggy Formation	
	Shale: not measured	
b	Sandstone: brown, medium-grained, massive to thin-bedded; scattered irregularly bedded siltstone and shale lenses; grades to brown siltstone at base	11.0
	Siltstone: brown, thin-bedded; contains shale partings; stained with limonite	2.9
	Siltstone: light-gray, thin-bedded; with shale partings	0.5
	Shale: gray, fissile; contains fossil plant impressions	0.2
	Coal	0.1
	Shale: gray, blocky; stained brown with limonite; black impressions of fossil plants throughout all that is exposed; not measured	

107

Secs. 15, 16, T. 12 N., R. 17 E. Measured westward along north line, by W. F. Coleman.

		Thickness (feet)
	BOGGY FORMATION	
i	Limestone: gray, fossiliferous	0.5
	Covered: probably shale	38.0
b	Sandstone: brown	3.0
	Shale: brown	12.0
	Coal	0.3
	Shale: brown, sandy	6.0
	Sandstone: brown, cross-bedded; some channeling at base; jointed	6.0
	Shale: brown, silty; not measured	

108

Sec. 29, T. 12 N., R. 17 E. Measured along a southward-flowing stream in NW¼, by W. F. Coleman.

		Thickness (feet)
	BOGGY FORMATION	
5?	Sandstone: brown, hard	0.3
	Shale: brown	0.2
	Sandstone: brown, hard, medium-grained, thin-bedded	2.0
	Sandstone: brown, thin-bedded, shaly, cross-bedded, ripple-marked; contains scattered ironstone concretions and fossil plant impressions	5.0
	Siltstone: gray, thin-bedded; contains carbonized fossil plant debris; may be slightly calcareous	1.8
	Shale: gray, blocky	7.2
	Shale: mostly covered; not measured	

109

Secs. 1, 11, 12, 14, T. 12 N., R. 18 E. Measured from SW¼ SW¼ sec. 1, south by west to the base of the Boggy Formation, by W. F. Coleman.

		Thickness (feet)
	BOGGY FORMATION	
b	Sandstone: massive; not measured	
	SAVANNA FORMATION	
	Shale: mostly covered	200.0
	MCALESTER FORMATION	
	Shale: mostly covered; approximately	30.0
k?	Sandstone: about	6.0
	Shale: mostly covered but brown where exposed; approximately	100.0
cl	Sandstone: brown, thin-bedded, soft	6.0
	Shale: mostly covered but brown where exposed	25.7
w	Sandstone: not measured	

110

Secs. 3, 10, T. 12 N., R. 18 E. Measured from top of Warner Sandstone in Dirty Creek, NE¼ SE¼ SE¼ sec. 3, southwestward to the base of the Bluejacket Sandstone in sec. 10, by W. F. Coleman.

		Thickness (feet)
	BOGGY FORMATION	
b	Sandstone: massive; not measured	
	Shale: mostly covered	200.0
sp?	Limestone: gray, fossiliferous; weathers red	0.5
	MCALESTER FORMATION	
	Shale: brown	128.0
	Sandstone: silty, soft	2.0
	Shale: gray, fissile to blocky; contains dark-gray clay ironstone concretionary beds with calcite in fractures	28.0
	Coal: Stigler; same associated pyrite	0.9
	Shale: gray, blocky; contains carbonized plant remains	0.5
	Shale: light-gray, blocky, soft	1.0
cl	Sandstone: brown, fine- to medium-grained, thin-bedded, cross-bedded, ripple-marked	5.7
	Shale: mostly covered; approximately	25.0
w	Sandstone: not measured	

111

Sec. 4, T. 12 N., R. 18 E. Measured along the east line of NE¼ SE¼, by W. F. Coleman.

		Thickness (feet)
	BOGGY FORMATION	
b	Sandstone: massive; not measured	
	SAVANNA FORMATION	
	Shale: mostly covered but where exposed is black and brown, fissile and blocky	132.0
	Coal: Rowe; not found in place; probably	0.5
	Covered: probably shale	20.0
sc	Limestone: gray, fossiliferous; weathers red; not found in place	0.4
	Covered: probably shale	9.0
	Shale: gray, fossiliferous	2.0
	Shale: mostly covered	39.0
sp	Limestone: gray, hard, fossiliferous; lower 2 inches set off by a shale break	0.75
	MCALESTER FORMATION	
	Covered: probably shale	3.0
	Siltstone: brown, sandy, thin-bedded, soft	4.0
	Shale: mostly covered but brown where exposed; not measured	

112

Secs. 9, 10, T. 12 N., R. 18 E. Composite of sections measured along stream and on south slope of Pine Valley, by W. F. Coleman.

		THICKNESS (FEET)
	SAVANNA FORMATION	
	Shale: brown and black, fissile to blocky	144.0
	Shale: black, fossiliferous	0.33
d	Limestone: gray; weathers reddish gray	0.33
	Shale: black, extremely carbonaceous	0.1
	Coal: Rowe	0.5
	Clay: brown to light-gray	1.0
	Shale: brown	1.15
	Shale and siltstone: brown	20.0
sc	Limestone: brown, fossiliferous, shaly	0.3
	Limestone: gray, massive, hard; weathers red	0.6
	Shale: gray, extremely fossiliferous	1.0
	Shale: gray, fissile to blocky	32.0
	Siltstone: brown, thin-bedded; with shale partings	6.0
	Shale: gray, nonfossiliferous	0.45
	Shale: black, nonfossiliferous	0.17
sp?	Shale: silty, fossiliferous	0.49
	Shale: light-gray, silty	0.5
	Siltstone: gray	0.17
	Shale: brown silty	1.25
	Shale: gray, blocky to fissile	2.0
	Shale: brown	1.1
	Sandstone: gray to brown, fine-grained; contains carbonized plant remains	0.9
	Siltstone: brown, thin-bedded	3.5
	Shale: gray, blocky to fissile; contains some concretionary beds	10.0

113

Sec. 10, T. 12 N., R. 18 E. Measured on the north slope of Pine Valley, by W. F. Coleman.

		THICKNESS (FEET)
	BOGGY FORMATION	
b	Sandstone: not measured	
	SAVANNA FORMATION	
	Shale: brown; mostly covered; grades to silt at top	72.0
	Shale: dark-gray; contains some concretionary beds	53.6
	Shale: gray, fossiliferous	1.0
d	Limestone: gray, fossiliferous; weathers red; upper part dense; middle soft and shaly; lower part dense	1.4
	Shale: dark-gray, fissile	12.0
	Shale: dark-gray; fossiliferous, some zones extremely so, laterally some grade into limestone lenses	9.0
	Shale: mostly covered	50.0
	Sandstone: fine-grained; numerous plant fossils; markings in some surfaces suggest worm trails; top indistinct	5.0
sp	Limestone: gray, fossiliferous	0.6
	MCALESTER FORMATION	
k?	Shale: brown, silty; may contain fossiliferous sandstone; probably represents Keota Sandstone	19.0
	Siltstone: shaly; upper part brown; lower part gray	3.1
	Limestone: gray, hard, dense, fossiliferous; red on weathered surfaces	0.4
	Limestone: gray, fossiliferous, shaly	0.3
	Clay: brown	0.1
	Coal	0.1
	Shale: lower part brown; middle gray; upper yellow brown	11.0
	Sandstone: brown, noncalcareous, silty; platy at top	2.1
	Shale: brown; partly covered; contains at least one calcareous concretionary bed	3.0
	Siltstone: brown, finely wavy and ripple-marked	1.0
	Shale: covered	11.0
	Siltstone: brown, irregularly bedded; contains fucoids	2.0
	Shale: dark-gray, fissile	32.0
	Limestone: gray; ranges in thickness from 2 inches to 8 inches within 30 feet; about	0.8
	Shale: mostly covered; not measured	

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Sec. 14, T. 12 N., R. 18 E. Measured in NE¼ SE¼, by W. F. Coleman.

		THICKNESS (FEET)
	BOGGY FORMATION	
b	Sandstone: brown, fine- to medium-grained, thin-bedded, cross-bedded, ripple-marked; contains thin shale partings; top eroded; not measured	
	SAVANNA FORMATION	
	Siltstone: brown; thin-bedded lower part shaly	26.0
	Shale: brown where exposed; mostly covered	36.0
	Shale: black, fissile; contains black to dark-gray clay ironstone concretions	62.0
d	Limestone: gray, fossiliferous; weathers brown	0.3
	Shale and clay: gray	1.0
	Coal: Rowe	1.4
	Clay: light-gray	0.1
	Shale: brown; contains clay ironstone concretionary beds some of which may be fossiliferous	28.0
sc	Limestone: gray, fossiliferous; weathers red	0.5
	Shale: gray, fissile to blocky	16.0
	Shale: gray, extremely fossiliferous	6.0
	Shale: brown to gray, fissile to blocky	13.0
	Covered: probably shale; not measured	

115

Sec. 25, T. 12 N., R. 18 E. Measured on south side of a small lake, by W. F. Coleman.

	Thickness (feet)
Boggy Formation	
b Sandstone: gray, hard to soft, extremely cross-bedded; weathers tan to brown; top eroded	31.0
Savanna Formation	
Shale: dark-gray, blocky to fissile, hard; weathers brown; contains silt zones, some of which are calcareous; more silty in upper part	35.0

116

Sec. 31, T. 12 N., R. 18 E. Measured at the southwest corner of LeaVel strip mine (probably near the center of the section), by W. F. Coleman.

	Thickness (feet)
Boggy Formation	
Siltstone: dark-gray, shaly, calcareous	4.0
Shale: black, fissile to blocky, calcareous; contains some fossils, brown calcareous concretions and nodules; thin calcareous silt layers and a thin calcite layer of secondary origin	12.0
Siltstone: gray, dense, calcareous; said to be hard to drill	0.9
Shale: black to brown	0.8
Pyritic zone: black shale and pyrite nodules	0.3
Coal: Secor	1.3
Shale: chocolate-brown, shiny; grades laterally to silt	0.1
Shale: black, fissile	0.05
Coal: Secor	1.07
Underlain by hard, black, pyritic shale	

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Sec. 31, T. 12 N., R. 18 E. Measured in coal pit 0.5 mile east of measured section 116, probably near E¼ cor., by W. F. Coleman.

	Thickness (feet)
Boggy Formation	
Shale and silts as in measured section 116	
Coal: Secor	1.25
Shale: black silty, noncalcareous; contains pyrite and many impressions of plants	1.7
Coal: Secor	1.07
Floor of pit flooded; water flowing from top of lower coal tasted of iron and sulfur and rapidly stained the coal	

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(**Boldface** number indicates main reference)