INFORMATION CIRCULAR 20-F

Geology of the Greenwood Quadrangle Arkansas-Oklahoma

GEOLOGICAL SURVEY PROFESSIONAL PAPER 536-A

Prepared in cooperation with the Arkansas Geological Commission

U.S. DEPARTMENT OF THE INTERIOR

Haley and Hendricks—GEOLOGY OF THE GREENWOOD QUADRANGLE, ARKANSAS-OKLAHOMA—Geological Survey Professional Paper 536-A

Geology of the Greenwood Quadrangle Arkansas-Oklahoma

By BOYD R. HALEY *and* THOMAS A. HENDRICKS

GEOLOGY OF THE ARKANSAS VALLEY COAL FIELD

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By Boyd R. Haley and Thomas A. Hendricks

ABSTRACT

The Greenwood quadrangle is in west-central Arkansas and east-central Oklahoma, between lats 35°00′ and 35°15′ N. and longs 94°15′ and 94°30′ W. It comprises an area of about 184 square miles in Sebastian County, Ark., and about 60 square miles in Le-Flore County, Okla.

Sedimentary rocks of Middle Pennsylvanian age and unconsolidated sediments of Quaternary age are exposed at the surface, and sedimentary rocks of Late Cambrain to Middle Pennsylvanian age have been penetrated by wells drilled in or near the quadrangle.

The rocks in the quadrangle have been folded into eastward-trending synclines and anticlines and broken by normal and reverse faults. Displacement along one of the normal faults is probably 1,100 feet, and displacement along the reverse faults is estimated to aggregate more than 12,800 feet. Structural relief as measured on the base of the Hartshorne Sandstone is more than 10,800 feet.

The Atoka, McAlester, and Savanna Formations contain coal beds. The Lower Hartshorne coal bed near the base of the McAlester Formation is the thickest, the most widespread, and the most important economically. The Upper Hartshorne coal bed, the only other economically important coal bed, is present only in the southern part of the quadrangle.

Commercial quantities of natural gas have been produced from the lower part of the McAlester Formation, the Hartshorne Sandstone, the Atoka Formation, the Morrow Series, the Penters Chert, and the St. Clair Limestone.

Building stone has been obtained from the Atoka, Hartshorne, and McAlester Formations. Road metal has been obtained from these formations, the Savanna Formation, and the gravelly part of alluvial deposits.

INTRODUCTION

This report on the geology of the Greenwood quadrangle is one of a series of reports being prepared by the U.S. Geological Survey in cooperation with the Arkansas Geological Commission. Its purpose is to (1) provide a geologic map of the quadrangle on a modern topographic base; (2) show the extent and thickness of all coal beds; (3) present estimates of coal reserve; (4) provide geologic data and interpretations pertinent to the location of natural gas and petroleum; (5) provide information about building stone, gravel, sand, and clay; and (6) provide data on the nature and relations of the rock formations exposed at the surface and present in the subsurface.

This report is also published, under separate cover, as Arkansas Geological Commission Information Circular 20–F.

The Greenwood quadrangle is between lats 35°00′ and 35°15′ N. and longs 94°15′ and 94°30′ W. It covers an area of approximately 184 square miles in Sebastian County, Ark., and about 60 square miles in Le Flore County, Okla. (See fig. 1.)

Generalized geologic reports pertaining in part to the Greenwood quadrangle were made by Croneis (1930) and Haley (1960) for the Arkansas part, and by Drake (1897), Taff and Adams (1900), Taff (1905), Snider (1914), and Smith (1914) for the Oklahoma part.

Detailed geologic reports pertaining in part to the Greenwood quadrangle were made by Collier (1907) and Hendricks and Parks (1937, 1950) for the Arkansas part, and by Hendricks (1939) and Knechtel (1949) for the Oklahoma part.

The stratigraphic nomenclature and boundaries established by Hendricks and Parks (1950) for the Pennsylvanian rocks in the Fort Smith district, Arkansas, are used in this report with modifications. Merewether and Haley (1961) adopted Miser's (1954) terminology of McAlester, Savanna, and Boggy Formations, and Oakes' (1953) classification of the Krebs Group, which includes the Hartshorne Sandstone and the McAlester, Savanna, and Boggy Formations. Haley (1961) moved the contact between the Savanna Formation and the overlying Boggy Formation stratigraphically upward from that selected by most earlier workers, thereby conforming to Miser's (1954) interpretation. The pre-Pennsylvanian nomenclature used in this report conforms to that used in Arkansas. Table 1 compares the nomenclature used in the area of this report with that used in nearby areas.

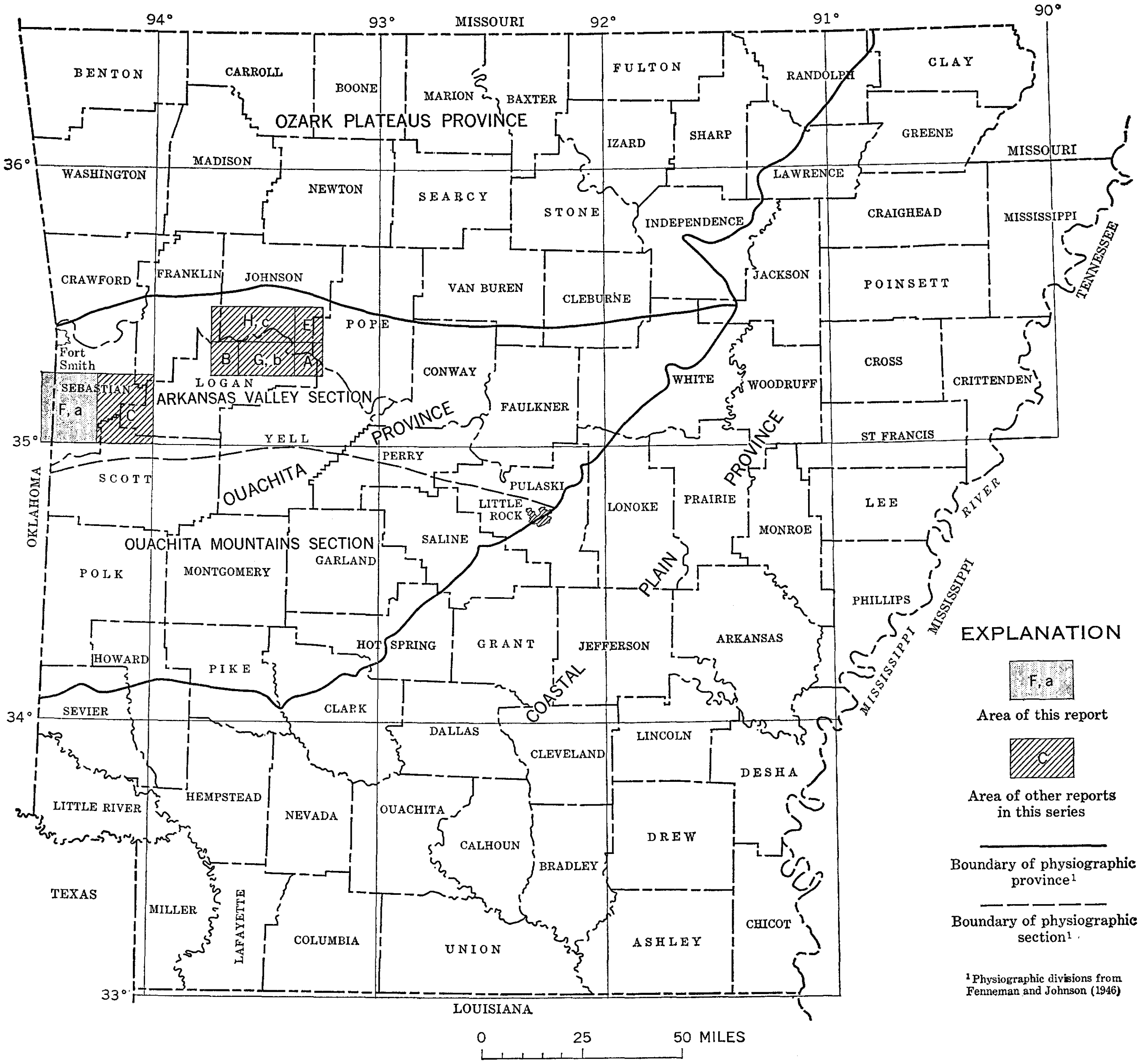

FIGURE 1.—Location of report area (F, a) andareas of other published chapters of Arkansas Geological Commission Information Circular 20 or of U.S. Geological Survey Professional Paper 536: A, Delaware quadrangle (Merewether and Haley, 1961); B, Paris quadrangle (Haley, 1961); C, Barber quadrangle (Haley, 1966); E, Knoxville quadrangle (Merewether, 1967); G and b, Scranton and New Blaine quadrangles (Haley, 1968); and H and c, Coal Hill, Hartman, and Clarksville quadrangles (Merewether and Haley, 1968).

STRATIGRAPHY

Rocks of Cambrian to Middle Pennsylvanian and of Quaternary age are exposed or have been penetrated by wells drilled in or near the quadrangle. The areal extent of some of these rocks is shown on plate 1, and the lithology of these rocks, except for those of quaternary age, is shown graphically on plate 2. All but two of the stratigraphic sections shown on plate 2 are described in detail. These two sections are the Shell Oil Co. Western Coal and Mining Co. 1 (well 2, pl. 2), which was described by Haley and Frezon (1965), and the Nichols Exploration Corp. Gann 1 (well 12, pl. 2), which has been described by Haley (1966).

CAMBRIAN SYSTEM

Rocks of the Cambrian System were penetrated in the Shell Oil Co. Western Coal and Mining Co. 1 (well 2). Haley and Frezon (1965) were uncertain whether these rocks correlate with Cambrian rocks exposed to the north in Missouri or to the southwest in Oklahoma. They stated that "the lower 20 feet of this well penetrated rocks possibly equivalent to the upper part of the Derby-Doerun" in Missouri "and the Butterly Dolomite" in Oklahoma. "If this is so, there may be several hundred feet of sedimentary rocks between the total depth of this well and the Precambrian basement."

The above well penetrated 416 feet (depth of 10,508–10,924 ft) of very light to medium-gray granular to coarsely crystalline dolomite containing fine to coarse quartz sand and white to medium-light-gray opaque chert. Thin beds of sandstone are in the intervals 10,508–10,558 feet and 10,883–10,905 feet. The rock in the interval 10,905–10,924 feet consists of a dark-gray dolomitic silt-size quartz matrix containing very fine to medium quartz sand, very fine angular to subrounded crystals of feldspar, and abundant coarse crystals of light- to dark-gray and pink dolomite.

ORDOVICIAN SYSTEM

VAN BUREN FORMATION AND GASCONADE DOLOMITE UNDIFFERENTIATED

The Van Buren Formation and Gasconade Dolomite undifferentiated is 483 feet thick where penetrated by the Shell Oil Co. Western Coal and Mining Co. (well 2). The basal part of this unit is the Gunter Sandstone Member of the Van Buren Formation. The Gunter consists of 143 feet of fine to very coarse grained quartz sandstone. Thin beds of very light to medium-light-gray granular to medium-crystalline dolomite are in the lower 50 feet of the Gunter. The remainder of the Van Buren and Gasconade unit is very light to dark-gray granular to coarsely crystalline dolomite with scattered fine to coarse quartz sand and abundant white to light-gray or pink chert. Much of the white chert contains fine to medium dolomite rhombs. A few thin beds of dark-gray shale are in the upper 15 feet of the unit.

ROUBIDOUX FORMATION

The Roubidoux Formation is 230 feet thick where penetrated by well 2. It consists of very light to medium-light-gray granular to coarsely crystalline dolomite containing abundant fine to coarse quartz sand and white to medium-gray, olive-gray, or pink sandy and oolitic chert. Some chert is very light gray (milky) and some is medium gray (smoky). White chert containing very coarse crystals of dolomite is in the lower 75 feet of the formation.

JEFFERSON CITY DOLOMITE

The Jefferson City Dolomite is 465 feet thick where penetrated by well 2. It is predominantly light- to medium-dark-gray granular to medium-crystalline dolomite containing fine to coarse quartz sand and white, gray, or pink chert. Thin beds of dark-gray or grayish-black chert are scattered throughout the formation.

COTTER DOLOMITE

The Cotter Dolomite is 365 feet thick where penetrated by well 2. It is light- to dark-gray granular to finely crystalline dolomite containing light-gray or pink chert and some fine to coarse quartz sand. In the lower 60 feet of the formation some of the chert is oolitic and contains fine to medium quartz sand. A thin bed of greenish-gray pyritic shale is at the top of the formation.

POWELL DOLOMITE

The Powell Dolomite is 227 feet thick where penetrated by well 2. It is a light- to dark-gray granular dolomite containing widely scattered pyrite, some grayish-black chert, and some olive-gray translucent chert.

EVERTON FORMATION

The Everton Formation is 503 feet thick where penetrated by well 2 and probably at least 114 feet thick where penetrated by the Midwest Oil Corp. Floyd Morris 1 (well 9). The formation consists of medium- to dark-gray granular to finely crystalline dolomite containing fine to medium quartz sand and white to very light gray fine- to coarse-grained sandstone. Some dark-gray shale is in the upper and lower parts of the formation, and some medium-dark-gray and olive-gray dense to very finely crystalline limestone is in the middle of the formation.

ST. PETER SANDSTONE

The St. Peter Sandstone is 72 feet thick in well 2 and 81 feet thick, as estimated from the electrical log, in well 9. The formation is white to very light gray subrounded fine- to coarse-grained sandstone.

JOACHIM DOLOMITE

The Joachim Dolomite is 95 feet thick in well 2 and is estimated to be 83 feet thick in well 9; 141 feet of the formation was penetrated by Mobil Oil Co. W. K. Veazey 1 (well 18). The formation is mostly medium- to dark-gray granular to very finely crystalline dolomite containing fine to coarse quartz sand. Some beds of white to light-gray fine- to medium -grained sandstone are present. The upper 45 feet of the formation in the Veazey well (well 18) is light- to dark-gray very finely crystalline dolomite that is free of sand.

TABLE 1.—*Stratigraphic nomenclature in or near the Greenwood quadrangle*

This report				Generalized northeast and east-central Oklahoma				East-central Oklahoma (Hendricks, 1939)			East-central Oklahoma (Knechtel, 1949)			West-central Arkansas (Hendricks and Parks, 1950)		
PENNSYLVANIAN	Des Moines Series	Krebs Group	Boggy Formation	PENNSYLVANIAN	Des Moines Series	Krebs Group	Boggy Formation	CARBONIFEROUS	Pennsylvanian Series	Boggy Shale	PENNSYLVANIAN	Des Moines Series	Boggy Formation	CARBONIFEROUS	Pennsylvanian Series	Boggy Shale
			Savanna Formation				Savanna Formation			Savanna Sandstone			Savanna Formation			Savanna Sandstone
			McAlester Formation				McAlester Formation			McAlester Shale			McAlester Formation			McAlester Shale
			Hartshorne Sandstone				Hartshorne Sandstone: Upper, Lower			Hartshorne Sandstone: Upper, Lower			Hartshorne Sandstone: Upper, Lower			Hartshorne Sandstone
	Atoka Series		Atoka Formation (Zone W, Zone P)		Atoka Series		Atoka Formation			Atoka Formation			Atoka Formation			Atoka Formation
	Morrow Series		Bloyd Formation: Kessler(?) Limestone Member		Morrow Series		Bloyd Formation: Kessler Limestone Member; Brentwood Limestone Member									
			Hale Formation: Prairie Grove Member; Cane Hill Member				Hale Formation: Prairie Grove Member; Cane Hill Member									
MISSISSIPPIAN	Lower and Upper		Pitkin Limestone	MISSISSIPPIAN	Chester age		Pitkin Limestone									
			Pre-Pitkin post-Chattanooga formations				Fayetteville Shale									
							Hindsville Limestone									
					Meramec age		Moorefield Formation									
					Osage age		Boone Formation									
	Kinderhook age		Chattanooga Shale		Kinderhook age		Chattanooga Shale									
?				?												
DEVONIAN				DEVONIAN	Upper											
	Lower or Middle		Penters Chert		Middle		Sallisaw Formation									
			(hatched)		? Lower		Frisco Limestone									

SILURIAN ?		St. Clair Limestone and undifferentiated rocks	SILURIAN		St. Clair Limestone and undifferentiated rocks
ORDOVICIAN	Upper	Cason Shale	ORDOVICIAN	Upper	Sylvan Shale
		Fernvale Limestone			Fernvale Limestone
	Middle	Plattin Limestone			Fite Limestone
		Joachim Dolomite			
		St. Peter Sandstone			McLish Formation
		Everton Formation			Tyner Formation Burgen Sandstone
	Lower	Powell Dolomite		Lower Ordovician	Powell Dolomite
		Cotter Dolomite			Cotter Dolomite
		Jefferson City Dolomite			
		Roubidoux Formation			
		Gasconade Dolomite and Van Buren Formation undifferentiated			
		Gunter Sandstone Member			
CAMBRIAN	Upper	Dolomite			

PLATTIN LIMESTONE

The Plattin Limestone is 48 feet thick in well 2, 130 feet thick in well 9, and 125 feet thick in well 18. It is predominantly medium- to dark-gray dense to granular limestone containing abundant fine to coarse crystals of dolomite and calcite. Some beds of medium-light-gray and olive-gray very finely crystalline limy dolomite are in the lower part of the formation.

FERNVALE LIMESTONE

The Fernvale Limestone is 45 feet thick in well 2, 47 feet thick in well 9, and 48 feet thick in well 18. It is light- to medium-gray granular to coarsely crystalline limestone. Crystals of dolomite and pink calcite are rare to common.

CASON SHALE

The Cason Shale is 15 feet thick in well 2, 25 feet thick in well 9, and 22 feet thick in well 18. The formation is greenish-gray and dark-gray dolomitic shale that contains finely crystalline pyrite in some parts.

SILURIAN AND DEVONIAN SYSTEMS, ST. CLAIR LIMESTONE AND UNDIFFERENTIATED ROCKS

The St. Clair Limestone of this report is the St. Clair equivalent of Haley and Frezon (1965). It is 115 feet thick in well 2, 145 feet thick in well 9, and 52 feet thick in well 18. It grades from very light gray granular limy dolomite in well 2 through interbedded very light to medium-gray granular to very finely crystalline limy dolomite and light-gray granular to medium-crystalline dolomitic limestone in well 9 to medium-gray granular to finely crystalline dolomitic limestone in well 18. In wells 2 and 9 the St. Clair is overlain by the Penters Chert of Devonian age, and the Penters is overlain by the Chattanooga Shale of Devonian and Mississippian age. In well 18 the St. Clair is overlain by Chattanooga. In this well, about 100 feet of St. Clair and all of the Penters is missing because of normal faulting or, more probably, because of pre-Chattanooga post-Penters erosion.

The rocks identified as St. Clair Limestone in this report are in the interval of the Brassfield, St. Clair, and Lafferty Limestones of northwestern Arkansas, the Frisco and St. Clair Limestones of northeastern Oklahoma, and the Chimneyhill, Henryhouse, Haragan, and Bois d'Arc Limestones of south-central Oklahoma. These formations could not be identified with certainty in wells 2, 9, and 18.

DEVONIAN SYSTEM, PENTERS CHERT

The Penters Chert is 39 feet thick in well 2, about 25 feet thick in well 9, and absent in well 18. It is predominantly very light gray translucent chert or very light to medium-gray opaque chert with a few thin beds of very light to medium-gray granular limestone. The chert is limy, dolmitic, and pyritic. The formation is missing in well 18 because of normal faulting or pre-Chattanooga post-Penters erosion.

DEVONIAN AND MISSISSIPPIAN SYSTEMS, CHATTANOOGA SHALE

The Chattanooga Shale is 38 feet thick in well 2, 91 feet thick in well 9, and 35 feet thick in well 18. It is pyritic dark-gray to grayish-black shale.

MISSISSIPPIAN SYSTEM

POST-CHATTANOOGA PRE-PITKIN FORMATIONS

Rock units, or their equivalents, in this interval elsewhere in the Arkansas Valley and Ozark Mountains are, in ascending order, the Boone Formation, the Moorefield Formation, the Ruddell Shale, the Batesville Sandstone, and the Fayetteville Shale. This sequence of rocks is 368 feet thick in well 2, 257 feet thick in well 9, and 410 feet thick in well 18. The rocks consist of dark-gray granular to very finely crystalline silty limestone and dark-gray to grayish-black nonsilty to very silty nonlimy to very limy shale in wells 2 and 9, and of dark-gray shale, some of which is silty, some medium-gray limy siltstone, some dark-gray to grayish-black shale, and some medium- to dark-gray argillaceous granular silty limestone in well 18. The Boone Formation, which consists of limestone and chert north of the Greenwood quadrangle, cannot be recognized in wells 2, 9, and 18, but rocks equivalent to the Boone may be in these wells. The Ruddell Shale cannot be identified in wells 2, 9, and 18, but it or its equivalent may be present. In areas where the Batesville Sandstone is missing or unidentifiable, as it is in this quadrangle, the Moorefield Formation is distinguished lithologically from the Fayetteville Shale by the presence of silt in the shale and limestone of the Moorefield. Haley and Frezon (1965) used this criterion to separate the two formations, and their division is on plate 2 (well 2). If only the Moorefield contains silt, there is no Fayetteville in well 9, and only 35 feet of shale could be Fayetteville in well 18. A thin or missing Fayetteville can be explained by nondeposition, by postdepositional erosion, or by a facies change from typical Fayetteville nonsilty shale and limestone to nontypical Fayetteville, typical Moorefield silty shale, silty limestone, and siltstone. The authors believe that rocks equivalent to the Fayetteville are in well 9 but cannot be differentiated from the underlying rocks of the Moorefield. It seems reasonable to believe that the Fayetteville and equivalent rocks are more than 73 feet thick in well 2 and more than 35 feet thick in well 18. (See pl. 2.)

PITKIN LIMESTONE

The Pitkin Limestone is 172 feet thick in well 2, 130 feet thick in well 9, and 124 feet thick in well 18. It is predominantly medium- to dark-gray dense to very finely crystalline limestone that contains abundant medium- to dark-gray oolites and, in places, very fine sand. Thin beds of dark-gray to grayish-black shale are present.

PENNSYLVANIAN SYSTEM

MORROW SERIES

The Morrow Series includes the Hale Formation and the overlying Bloyd Formation. These rocks are 438 feet thick in well 2 and 555 feet thick in well 9. Only the lowermost 97 feet of these rocks are in well 18; about 500 feet of the overlying rocks are missing because of a normal fault. (See pl. 4.) Haley and Frezon (1965) divided the Morrow Series into formations and members. Their division of the Morrow in well 2 is shown on plate 2. The Morrow rocks penetrated by well 9 cannot be divided with certainty and are shown on plates 2 and 4 as Bloyd and Hale. The rocks in the Morrow Series are predominantly dark-gray to grayish-black shale and medium-gray dense to finely crystalline limestone. Some light- to medium-gray very fine to medium-grained sandstone and medium-gray siltstone are in the lower part.

ATOKA SERIES, ATOKA FORMATION

The Atoka Formation composes the Atoka Series in Arkansas and Oklahoma. It is 6,390 feet thick in well 2, about 7,943 feet thick in well 9, and 10,600 feet thick in well 18. The lower 600 feet of the Atoka is missing from well 18 because of a normal fault that was active during early and middle Atoka deposition. The Atoka ranges in thickness from about 5,500 feet in the northwestern part of the quadrangle (fig. 2) to about 14,750 feet in the southeastern part. The Atoka thickens southward; the middle and lower parts thicken more than the upper part. The fault plane cut by well 18 does not reach the surface in the Greenwood quadrangle. The amount of movement (about 1,100 ft) along this fault plane is thought to be compensated by an equal amount of concurrent thickening within the Atoka on the south side of the fault. However, if the fault formed in the late early or middle Atoka time, the upthrown side may have been eroded before the deposition of younger Atoka beds. Most, if not all, of this thickening could have occurred in the middle part of the formation. The Atoka Formation is mostly dark-gray to grayish-black shale that is slightly silty or silty in part, with lesser amounts of light- to medium-gray siltstone and light- to medium-gray slightly silty to silty very to fine to fine-grained sandstone that contains medium to coarse quartz sand in some places. Two beds of bentonitic shale are near the base of the formation in well 2, and one bed is in well 9.

Haley (1966) reported that parts of the Atoka Formation have lithologic characteristics that tend to set them apart. He designated the lower one "zone P" and the upper one "zone W." Zone P is near the middle of the formation and is distinctive because (1) the sandstone in it is coarser grained than most of the rest of the sandstone in the Atoka, (2) coarse-sand-size to granule-size quartz is common, and (3) some of the sandstone is limy and fossiliferous. Zone P is partly exposed on the north side of Backbone anticline at the spillway of Wofford Lake (pl. 1) and has been completely penetrated by wells 2, 9, and 18 and partly penetrated by well 12. (See pl. 2.) Zone W is in the upper one-third of the Atoka and is distinctive because it is a zone more than 400 feet thick that is mostly sandstone and siltstone with a small amount of shale. Zone W crops out along Washburn anticline in the east-central part of the Greenwood quadrangle and along Backbone anticline in the northern part of the quadrangle (pl. 1); it has been penetrated by wells, 2, 9, 12, 13, and 18 (pl. 2).

DES MOINES SERIES, KREBS GROUP

Hartshorne Sandstone.—The Hartshorne Sandstone unconformably overlies the Atoka Formation. The contact is well exposed in the roadcut near Hackett and in a roadcut south of Huntington along U.S. Highway 71 near the center of NE¼SW¼ sec. 25, T. 5 N., R. 31 W. The Hartshorne Sandstone ranges in thickness from 10 to 210 feet in the Greenwood quadrangle. It is predominantly very light to medium-gray very fine to fine-grained sandstone that is slightly silty or silty in part. Thick beds of shale and and siltstone in the formation crop out along the south side of the Backbone anticline. (See pl. 1.) The sandstone is in beds of the channel type throughout much of the Greenwood quadrangle. The channel-type sandstone is well exposed in the roadcut along Arkansas State Highway 45 near the NW cor. NE¼NE¼ sec. 21, T. 6 N., R. 32 W., and in the quarry near the center of NE¼SW¼ sec. 35, T. 7 N., R. 31 W. At the quarry about 2 feet of one channel is filled with angular fragments of dark-gray shale as large as 3 by 15 by 20 inches and ironstone concretions as large as 3 by 6 by 10 inches.

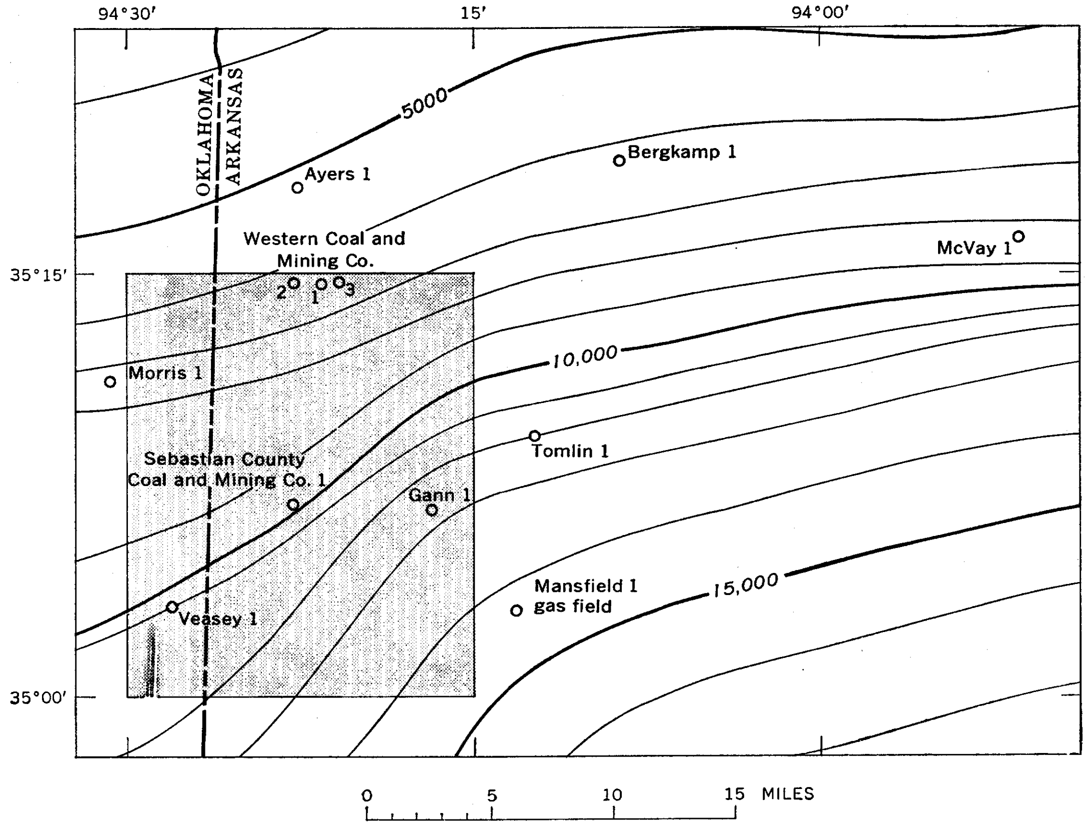

FIGURE 2.—Thickness of Atoka Formation in the Greenwood quadrangle (shaded) and vicinity, Arkansas and Oklahoma. Interval is 1,000 feet. Thickness lines from Haley (1961, fig. 6; 1966, fig. 3) with modifications based on subsequent information.

McAlester Formation.—The McAlester Formation conformably overlies the Hartshorne Sandstone. It is 1,458 feet thick in the Veazey well (No. 18). Hendricks (1939) estimated thicknesses of 1,850 feet at one location (pl. 33) and 2,000+ feet at another location (fig. 15) on the basis of scattered surface measurements across many concealed intervals. The McAlester Formation is dark-gray to grayish-black shale with minor amounts of medium-gray siltstone and light- to medium-gray very silty very fine grained sandstone to light-gray very fine grained sandstone. The McAlester has at least four coal beds; the most economically important and widespread is the Lower Hartshorne coal bed near the base of the formation. Excellent sediment-flow features are exposed in NW¼NW¼ sec. 2, T. 4 N., R. 32 W. The McAlester Formation of this report contains rocks considered by Hendricks and Parks (1937) to be equivalent of the upper part of the Hartshorne Sandstone in Oklahoma. These rocks are the shale below the Hartshorne coal, the Hartshorne coal, the shale above the coal, and the lenticular sandstone above the shale. These rocks cannot be mapped northeast of sec. 24, T. 6 N., R. 31 W. (pl. 1), so Hendricks and Parks and the authors of this report used the top of the first sandstone below the Lower Hartshorne coal bed as the base of the McAlester.

Savanna Formation.—The Savanna Formation overlies the McAlester with a locally unconformable contact. However, at places the contact is gradational and the McAlester and Savanna intertongue. The Savanna Formation is 1,300 feet thick in the Greenwood quadrangle. It is medium- to dark-gray shale with smaller amounts of light- to medium-gray siltstone and light- to medium-gray very silty very fine grained sandstone. Sediment-flow features are common in the sandstone.

Boggy Formation.—The Boggy Formation overlies the Savanna conformably. It is represented by 25 feet of very light gray very fine to medium-grained friable quartzose sandstone on Sugarloaf Mountain. Hendricks (1939, p. 272) reported as much as 4,000 feet of Boggy in nearby areas, but Miser (1954) revised the base of the Boggy and included beds in the Savanna that Hendricks placed in the Boggy.

QUATERNARY SYSTEM

TERRACE DEPOSITS

Alluvial material deposited by the Arkansas River forms one terrace in the northwest corner of the Greenwood quadrangle, and alluvial material deposited by local streams forms one or two terraces everywhere in the quadrangle. Terrace deposits along the Arkansas River consist of clay, silt, and sand, some of which is of local origin; pebbles and cobbles of shale and sandstone of local origin; and pebbles of quartz and chert of distant origin. The terrace deposits formed by local streams consist of clay, silt, and sand, and pebbles, cobbles, and boulders of shale, siltstone, and sandstone of local origin. Reworked material from the river terrace is in some of the stream terraces. The river-terrace gravel and the uppermost stream-terrace gravel are thought to be equivalent to the Gerty Sand of Pleistocene age.

ALLUVIUM

Alluvium has been deposited along most of the streams in the Greenwood quadrangle. It consists of clay, silt, and sand, pebbles of shale, siltstone, and sandstone, and, in some places, cobbles and boulders of shale, siltstone, and sandstone. Some of the alluvium contains reworked material from the river terrace.

STRUCTURE

The Greenwood quadrangle is in the Arkansas Valley section of the Ouachita province (fig. 1). The rocks in the quadrangle have been folded into east-trending anticlines and synclines. Two anticlines have been broken by reverse faulting and one syncline has been broken in one place by normal faulting. (See pls. 1, 3.) Structural relief on the base of the Hartshorne Sandstone is more than 10,800 feet as measured from the trough of the Cavanal syncline to the projected crest of the Backbone anticline. (See pls. 3, 4.)

The closure of the anticlines is thought to diminish with depth partly because of the southward-thickening of the Atoka Formation and partly because folds in near-surface rocks are represented by reverse faults at depth that cut the bedding of the rocks at an angle that decreases downward until the movement becomes bedding-plane slippage.

The south limb of the Central syncline extends across the northern part of the quadrangle; the Jenny Lind syncline extends across the extreme northeast corner of the quadrangle; the Greenwood syncline extends across the north-central part of the quadrangle; the Cavanal syncline extends across the south-central part of the quadrangle; and a part of the north limb of the Poteau Mountain syncline extends across the southeast corner of the quadrangle.

The faulted Backbone anticline extends across the northern part of the quadrangle; the Washburn anticline extends westward into the northeastern part of the quarangle; the Midland anticline extends eastward nearly across the quadrangle; and the Hartford anticline extends across the southeast corner of the quadrangle. The Backbone anticline has been broken by reverse faulting throughout most of its extent in the Greenwood quadrangle. The Washburn anticline has been broken by reverse faulting in the extreme eastern part of the quadrangle. The south limbs of the unfaulted Midland and Hartford anticlines are steeper than the north limbs, whereas the north limbs of the Backbone and Washburn anticlines are steeper than the south limbs.

The normal faults at the surface in the west-central part of the quadrangle (pls. 1, 3) have displacements of less than 40 feet. One of the faults dips 46° S. where exposed in sec. 28, T. 8 N., R. 27 E., but it dips an estimated 60° S. in sec. 5, T. 5 N., R. 32 W. A normal fault with a displacement of about 1,100 feet is at a depth of 12,815 feet in the Veazey well (well 18). This fault does not extend to the surface, and how much of the Atoka, or younger formations, is cut by this fault is unknown. The strike and the direction and amount of dip of the fault plane are unknown, but elsewhere in Arkansas, normal faults of this magnitude generally strike east and dip southward at angles of 50°–60°. (See section B–B′, pl. 4.) Three normal faults were discovered by coal miners in the northeastern part of the quadrangle. The direction of dip of the fault plane was recorded for two of these faults, and a dip of 63° N. was recorded for the fault in sec. 31, T. 7 N., R. 32 W. The amount of displacement along these faults is unknown but probably is less than 15 feet.

The reverse faults in and near the Greenwood quadrangle are in zones that may contain as many as 12 reverse faults and be as much as 2 miles wide. (See pl. 1, see also Haley, 1966, pl. 1.) Movement along the reverse faults probably represents a relief of the pressure that caused the folding of the Backbone and Washburn anticlines.

A small segment of one fault in the Washburn fault zone is in sec. 24, T. 6 N., R. 31 W. The movement along the Washburn fault zone decreases from 5,000+ feet as measured on zone P in T. 6 N., R. 27 W. (Haley, 1966, p. 11), to zero on the west end of the fault in the Greenwood quadrangle.

The Backbone fault zone, which extends nearly across the northern part of the Greenwood quadrangle, consists of two to five faults and is 300–4,000 feet wide. The fault planes of the major faults in the Backbone zone probably dip southward from angles near vertical at the surface to less than 15° in the subsurface. Fault planes of the major faults are not exposed in the quadrangle; however, they can be accurately mapped, and a dip of 75° can be estimated for the fault in NW¼ sec. 2, T. 6 N., R. 31 W. The major fault planes have angular relationships to the strata; these range from parallel to nearly 90° in the oversheet and from parallel to nearly 180° in the undersheet, where the strata are overturned. The amount of movement along any one fault is unknown, but the combined amount of movement along all the faults, as estimated on the projected base of the Hartshorne Sandstone, exceeds 12,800 feet near the Arkansas-Oklahoma boundary. The apparent amount of movement along these fault planes and along the fault zone decreases to zero at that place in the subsurface where the fault planes become parallel to bedding planes of the encompassing rocks. Slickensided shale, siltstone, and sandstone, found along many of the major faults, are well exposed in the quarry in NE¼SE¼ sec. 4, T. 6 N., R. 32 W.

The subsidiary reverse faults in the quadrangle have smaller magnitude and less steeply dipping fault planes. Fault planes of some of these faults are exposed in the following places: In a roadcut on Arkansas State Highway 45 in the center of NE¼SW¼ sec. 4, T. 6 N., R. 32 W., where the dip is 55° S. and the amount of displacement is probably less than 10 feet; near the center of NW¼SW¼ sec. 4, T. 6 N., R. 32 W., where the dip is 10° S. and the amount of displacement could be as much as 800 feet; and near the center of NE¼NE¼NW¼ sec. 2, T. 6 N., R. 32 W., where the dip is 35° S. and the amount of displacement could be as much as 1,600 feet.

A north-dipping reverse fault is exposed in the roadcut of U.S. Highway 71 in SE¼SE¼SE¼ sec. 31, T. 7 N., R. 31 W., where the dip of the fault plane ranges from 5°–15°. The amount of southward movement along this fault is unknown but is probably small.

ECONOMIC GEOLOGY

COAL

The Atoka, McAlester, and Savanna Formations contain coal beds. The Lower Hartshorne coal bed has been mined rather extensively in the area, and the Upper Hartshorne and the Stigler coal beds have been mined locally. The extent, thickness, and mined area of the Lower Hartshorne coal bed are shown on plate 3. The outcrops of all other coal beds are shown on plate 3, and the thickness measurements for these coal beds are listed in table 2.

TABLE 2.—*Selected coal thickness measurements in the Greenwood quadrangle*

[All measurements made in the Upper Hartshorne coal bed in the McAlester Formation, except as noted]

Approximate location	Depth of coal (feet)	Thickness of coal (inches)
Arkansas		
T. 6 N., R. 31 W.		
Center NE¼SE¼ sec. 36 [1]	Outcrop	4
T. 6 N., R. 32 W.		
NW cor. sec. 4 [2]	58	2
T. 5 N., R. 31 W.		
SW cor. NE¼NE¼ sec. 7	13	12
NE cor. SE¼NW¼NW¼ sec. 28	59	14
NW cor. SW¼SW¼NW¼ sec. 28	64	16
SW cor. SE¼SE¼NW¼ sec. 28	78	15
SE cor. NW¼NW¼SW¼ sec. 28	108	8
SE cor. NW¼SW¼ sec. 28	140	24
SE cor. NE¼NE¼NE¼SW¼ sec. 28	67	18
SW cor. SW¼ sec. 28	166	4
SE cor. SW¼NW¼SE¼SW¼ sec. 28	138	24
Center NW¼SE¼SW¼ sec. 28	102	15
SW cor. SE¼SE¼SW¼ sec. 28	81	8
SE cor. NW¼SE¼ sec. 28	37	18
SW cor. SE¼NE¼SE¼ sec. 28	23	22
SW cor. SE¼SE¼SE¼ sec. 31	64	10
Center NE¼NE¼NE¼NE¼ sec. 32	230	24
NW cor. NE¼NW¼NE¼NE¼ sec. 32	238	24
Center NW¼NE¼SW¼ sec. 32	192	24
Center SE¼NE¼SW¼SE¼ sec. 32	80	10
NE cor. NW¼NE¼ sec. 33	50	30
SE cor. NW¼NE¼ sec. 33	12	24
SW cor. NW¼SW¼NE¼ sec. 33	33	7
Center NE¼NE¼NW¼ sec. 33	128	18
NW cor. SW¼SW¼NW¼ sec. 33	174	9
NW cor. NW¼SE¼NW¼ sec. 33	88	24
SW cor. NE¼NE¼SE¼ sec. 33	33	7
T. 5 N., R. 32 W.		
NW cor. SW¼SE¼ sec. 11	186	31
Center SE¼SE¼ sec. 11	148	52
Center SW¼SW¼ sec. 12	138	66
Center NE¼NE¼ sec. 14	111	54
Center NW¼NE¼ sec. 14	132	70
Center SW¼NE¼ sec. 14	126	33
Center SW¼NW¼ sec. 14	192	39
Center SE¼SE¼NE¼ sec. 21 [2]	343	24
Do	700	18
NW cor. SW¼SW¼SE¼NE¼ sec. 28 [3]	79	6
Do.[2]	187	6
Do.[2]	200	18
Do.[2]	819	4
Do.[3]	845	12
Do.[2]	1,200	12
Do	1,505	11
SW cor. SE¼SW¼NE¼ sec. 29 [4]	Outcrop	4
T. 4 N., R. 32 W.		
900 ft from north line, 2,300 ft from west line sec. 2 [3]	24	9
1,950 ft from south line, 400 ft from west line sec. 5 [3]	408	12
Do.[2]	780	12
Do	1,182	5
2,650 ft from north line, 1,700 ft from west line sec. 6 [5]	Outcrop	4
SE cor. SW¼SW¼NE¼ sec. 7 [3]	241	4
Do.[2]	626	3
Do	1,058	9
NE cor. SE¼SE¼NW¼ sec. 8 [2]	303	2
Do	727	8
Center sec. 9	44	18
SW cor. NW¼NW¼SE¼SE¼ sec. 9	26	4
SW cor. SW¼NW¼SE¼SE¼ sec. 9	45	6
Center NW¼SW¼SE¼SE¼ sec. 9	38	6
Center SW¼SW¼SE¼SE¼ sec. 9	34	8
NE cor. SE¼NE¼NW¼ sec. 16	31	15
Center NW¼NE¼SW¼ sec. 16	231	18
NW cor. SW¼NE¼SW¼ sec. 16	256	26
NW cor. SW¼SW¼ sec. 16	280	30
NW cor. SW¼SW¼SW¼ sec. 19	307	8
Center NW¼SW¼SW¼ sec. 19	275	32
Center NW¼NE¼ sec. 23	231	5
Do.[2]	252	3

See footnotes at end of table.

TABLE 2.—*Selected coal thickness measurements in the Greenwood quadrangle*—Continued

Approximate location	Depth of coal (feet)	Thickness of coal (inches)
Oklahoma		
T. 7 N., R. 27 E.		
SW cor. sec. 5 [4]	Outcrop	16
Center SE¼NE¼NW¼ sec. 29 [4]	Outcrop	16
SW cor. SW¼SE¼NE¼SW¼ sec. 29. [4]	Outcrop	16

[1] Unnamed coal bed in Atoka Formation.
[2] Unnamed coal bed in McAlester Formation.
[3] McAlester (?) coal bed in McAlester Formation.
[4] Stigler coal bed in McAlester Formation.
[5] Charleston (?) coal bed in Savanna Formation.

All coal in the Greenwood quadrangle is classified as low-volatile bituminous (Haley, 1960, pl. 62; Trumbull, 1957, pl. 17) on the basis of the percentage of dry mineral-matter-free fixed carbon in the coal, in accordance with the specifications of the American Society for Testing and Materials (1939).

The estimated reserves of coal listed in tables 3 and 5 are tabulated in categories of amount of overburden, thickness of coal, and abundance of reliable thickness data in accordance with the standards and procedures adopted by the U.S. Geological Survey (Averitt, 1961, p. 14–26). The original, remaining, and recoverable reserves of coal listed in table 4 are also categories conformable to those of Averitt.

Trumbull (1967, p. 341–345, and pl. 17) described the rank, thickness, thickness of overburden, amount of reliable thickness data, and mined areas of the Lower Hartshorne coal bed in the Oklahoma part of the Greenwood quadrangle, but the amount of coal estimated to be in this area cannot be determined from his report. The coal-bearing part of this area is about one-half as large as the coal-bearing part of the quadrangle in Arkansas, and the coal has about the same average thickness; therefore, it seems reasonable to believe that this area contained as much as 140 million short tons of coal prior to mining.

Coal beds in the Atoka Formation

An Atoka coal bed crops out in the Greenwood quadrangle along the county road in NE¼SE¼ sec. 36, T. 6 N., R. 31 W. This coal bed, near the top of zone W, is known to extend eastward from the quadrangle for more than 45 miles. A coal bed was penetrated by the Gann well (well 12) at a depth of 438 feet. This coal bed was not found at the surface in the Greenwood quadrangle; however, it was found in the quadrangle to the east (Haley, 1966, pl. 1).

Coal beds in the McAlester Formation

Four McAlester coal beds are known in the Greenwood quadrangle. They are, in ascending order, the Lower Hartshorne coal bed, near the base; the Upper Hartshorne coal bed, 60–90 feet above the Lower Hartshorne coal bed; the McAlester coal bed, near the middle of the formation; and the Stigler coal bed, near the top of the formation.

The Lower Hartshorne coal bed is the thickest, most widespread, and most important economically in the Greenwood quadrangle. It lies near the base of the McAlester Formation, and in some areas the "bed" is actually a zone of 1–7 beds. The thickness of the coal, the amount of overburden, the mined areas, and the outcrop of the Hartshorne coal bed are shown on plate 3. The estimated reserves of coal in the Lower Hartshorne coal bed in the Arkansas part of the quadrangle after mining are listed in table 3, and the estimated original reserves, the estimated amount of coal mined and lost in mining, and the estimated recoverable reserves of coal in the Lower Hartshorne coal bed in the same area are listed in table 4.

TABLE 3.—*Estimated remaining reserves of coal in the Lower Hartshorne coal bed in the Arkansas part of the Greenwood quadrangle*

[In millions of short tons]

Overburden (feet)	Thickness of coal (inches)			
	14–28	28–42	>42	Total
Measured and indicated reserves				
0–1,000	3.638	50.275	48.645	102.558
1,000–2,000		2.487	6.338	8.825
2,000–3,000				
Total	3.638	52.762	54.983	111.383
Inferred reserves				
0–1,000	4.763	45.560	11.368	61.691
1,000–2,000	.243	24.092	13.561	37.896
2,000–3,000		6.017	1.751	7.768
Total	5.006	75.669	26.680	107.355
Total reserves				
0–1,000	8.401	95.835	60.013	164.249
1,000–2,000	.243	26.579	19.899	46.721
2,000–3,000		6.017	1.751	7.768
Total	8.644	128.431	81.663	218.738

TABLE 4.—*Estimated original, remaining, and recoverable reserves of coal in the Arkansas part of the Greenwood quadrangle*

[In millions of short tons]

Coal bed	Original reserves	Amount of coal mined and lost in mining	Remaining reserves	Recoverable reserves
Lower Hartshorne	315.552	96.814	218.738	109.369
Upper Hartshorne	28.004		28.004	14.002
Total	343.556	96.814	246.742	123.371

The Upper Hartshorne coal bed, 60–90 feet above the Lower Hartshorne coal bed, is present only in the southern part of the quadrangle. The outcrop of the coal bed is shown on plates 1 and 3, and coal-bed thicknesses are listed in table 2. The estimated original reserves of Upper Hartshorne coal in the Arkansas part of the quadrangle listed in table 5 are modifications of those reported by Haley (1960, table 1, p. 806). The estimated amount of coal mined and lost in mining, the remaining reserves, and the recoverable reserves in the Upper Hartshorne coal bed in the same area are listed in table 4.

The McAlester coal bed, near the middle of the McAlester Formation, is present only in the southwestern part of the quadrangle. The outcrop of the coal bed is shown on plates 1 and 3, and the measured thicknesses are recorded in table 2. The reserves of coal in the McAlester coal bed were not estimated because the coal is thought to be less than 14 inches thick throughout its extent in the quadrangle.

The Stigler coal bed, near the top of the McAlester Formation, is known only in the southwestern part of the quadrangle. The outcrop of the coal bed is shown on plates 1 and 3, and the measured thicknesses are tabulated in table 2. Reserves of coal in the Stigler coal bed were not estimated.

TABLE 5.—*Estimated original reserves of coal in the Upper Hartshorne coal bed in the Arkansas part of the Greenwood quadrangle*

[In millions of short tons. Modified from Haley (1960, table 1, p. 806)]

Overburden (feet)	Thickness of coal (inches)			
	14–28	28–42	>42	Total
Measured and indicated reserves				
0–1,000	11.417	0.188		11.605
1,000–2,000				
2,000–3,000				
Total	11.417	.188		11.605
Inferred reserves				
0–1,000	15.983			15.983
1,000–2,000	.416			.416
2,000–3,000				
Total	16.399			16.399
Total reserves				
0–1,000	27.400	0.188		27.588
1,000–2,000	.416			.416
2,000–3,000				
Total	27.816	.188		28.004

Coal beds in the Savanna Formation

One coal bed is known in the Savanna Formation in the Greenwood quadrangle, but it seems likely that others exist. The one known coal bed is 4 inches thick and is exposed near the base of the Savanna Formation in sec. 6, T. 4 N., R. 32 W. (pl. 1). This coal bed could be equivalent to the Charleston coal bed which is at this stratigraphic position elsewhere in Arkansas.

OIL AND GAS

Oil has not been discovered in the Greenwood quadrangle; however, streaks and blebs of solid carbonaceous material (dead oil) are present in the upper part of the St. Clair Limestone in well 9. The first producing gas well in Arkansas was drilled 1½ miles east of the quadrangle on the Hartford anticline in 1902. This well, the Choctaw Oil and Gas Co. Duncan 2, is the discovery well for the Mansfield gas field. The discovery wells for three other gas fields in the Greenwood quadrangle are the Shell Oil Co. Western Coal and Mining Co. (well 2) in the Bonanza field (pl. 3), the Le Flore County Gas and Electric Co. Hill 1 drilled west of the report area in the Poteau-Gilmore field, and an unknown well in the Rock Island field. These wells and others drilled in or near the Greenwood quadrangle are described in table 6.

Gas in the Greenwood quadrangle has been produced from the St. Clair Limestone, the Penters Chert, the Morrow Series, the Atoka Formation, the Hartshorne Sandstone, and the lower part of the McAlester Formation. Gas in the Mansfield gas field has been produced from standstone units mostly in zone W (Haley, 1966, p. 20). Gas in the Bonanza gas field has been produced from the St. Clair Limestone, Penters Chert, lower part of the Morrow Series, and middle part of the Atoka Formation. The gas from the Poteau-Gilmore gas field comes from the Hartshorne Sandstone and from the lowermost sandstone in the McAlester Formation. Gas in the Rock Island gas field is from the upper one-third of the Atoka Formation.

Gas is found in many of the Morrow, Atoka, Hartshorne, and lower McAlester sandstone beds. The extent and volume of gas in these rocks is dependent upon structure and lithologic changes. The importance of lithologic entrapment is exemplified by wells 10, 11, 12, 14 (table 6), all of which produce or have shows of gas from rock units that crop out updip from the wells.

BUILDING STONE

Slabs and blocks of weathered sandstone from the Atoka Formation have been used on the exterior of many of the buildings in the area. Building stone has been quarried from the Hartshorne Sandstone in secs. 9 and 10, T. 8 N., R. 27 E.; sec. 20, T. 6 N., R. 32 W.; and sec. 35, T. 7 N., R. 31 W.; and from a sandstone in the McAlester Formation in sec. 4, T. 7 N., R. 27 E. Most of the Hartshorne Sandstone used in building is taken from long foreset beds of remarkably uniform thickness. It is a popular building stone because of its uni-

TABLE 6.—*Description of selected wells drilled in or near the Greenwood quadrangle as of January 1, 1964*

Well No. (pls. 1-4)	Company name	Lease name	Location (EL, east line; NL, north line; SL, south line; WL, west line)	Total depth (ft)	Reported elevation (ft)	Electrical log	Stratigraphic zone of production	Depth of production (ft)	Reported production (cu ft per day)	Completion date	Remarks
1	Shell Oil Co.	Western Coal and Mining Co. 3.	339 ft north and 363 ft west of center sec. 31, T. 7 N., R. 31 W.	8,030	484	Yes	Prairie Grove Member	7,075–7,085	3,820,000	June 1963	
							St. Clair Limestone	7,880–7,890	1,880,000		
2	do	Western Coal and Mining Co. 1.	620 ft south and 450 ft west of center sec. 36, T. 7 N., R. 32 W.	10,924	505	do	Middle part, Atoka Formation.	2,985	50,000	Apr. 1962	Discovery well of Bonanza Field. First commercial production in Arkansas from rocks older than Devonian. Rock samples examined and logged by B. R. Haley to 7,400 ft and by S. E. Frezon from 7,400 to 10,924 ft. Described by Haley and Frezon (1965).
							St. Clair Limestone	7,936–7,958	9,400,000		
							Powell Dolomite	8,802–8,812	100,000		
							do	8,924–8,930	70,000		
							Roubidoux Formation	9,857–9,975	Show of gas.		
3	do	E. Hamilton A-1	895 ft south and 330 ft west of center sec. 12, T. 6 N., R. 31 W.								Being drilled.
4	do	Western Coal and Mining Co. 2.	400 ft north and 500 ft east of center sec. 35, T. 7 N,. R. 32 W.	8,057	[1] 518	Yes	Middle part, Atoka Formation.	4,618–4,638	700,000	Nov. 1962	
							Prairie Grove Member	7,-113–7,120	275,000		
							Penters Chert and St. Clair Limestone.	7-740, 7,874	21,000,000		
							St. Clair Limestone	7,946–7,958	2,500,000		
5	do	Young 1-2	1,980 ft from SL and 1,980 ft from WL N W¼ sec. 2, T. 6 N., R. 32 W.	8,150	582	do	do	7,901–8,045	5,600,000	June 1962	
6	do	Acee Milk Co. 1-3	1,320 ft south and 1,980 ft west of NE cor. sec. 3, T. 6 N., R. 32 W.	8,182	548	do	Prairie Grove Member	7,230–7,290	3,800,000	Nov. 1963	
							Penters Chert	7,890–7,940	2,900,000		
7	Le Flore County Gas and Electric Co.	Tompas-Backbone 1.	Center SW¼S W¼ sec. 31, T. 9 N., R. 27 E.	4,845	[2] 670		Atoka Formation		Gas [3]	1944	
8	do	McClure 1	Center NE¼S W¼N W¼ sec. 7, T. 8 N., R. 27 E.	2,771	[2] 485	No			Dry	1923	
9	Midwest Oil Corp.	F. Morris 1	3,300 ft from SL and 2,840 ft from WL sec. 12, T. 7 N., R. 26 E.	9,216	[1] 476	Yes	Zone P, Atoka Formation	5,205–5,262	2,000,000	1961	Discovery well of deeper gas in Rock Island gas field. Well is 3,860 ft west of Greenwood quadrangle. Rock samples examined and logged by S. E. Frezon.
10	Le Flore County Gas and Electric Co.	Littman 26	Center NE¼N W¼N W¼ sec. 18, T. 8 N., R. 27 E.	2,615	[2] 470	No	Upper part, Atoka Formation.		Gas [3]	1922	400 ft west of Greenwood quadrangle.
11	do	Littman 25	Center S W¼N W¼N W¼ sec. 18, T. 8 N., R. 27 E.	1,607	[2] 470	do	do		Gas [3]	1922	700 ft west of Greenwood quadrangle.
12	J. W. Nichols Exploration Co.	Gann 1	Center NE¼S W¼ sec. 15, T. 5 N., R. 31 W.	6,005	565	Yes	do		Dry	Sept. 1957	Gas escaping around casing in March 1958 (Haley, 1966, table 3). Rock samples examined and logged by B. R. Haley. Described by Haley (1966).
13	Wheeler and Ryan	Sebastian County Coal and Mining Co. 1.	2,210 ft from SL and 2,146 ft from WL of sec. 14, T. 5 N., R. 32 W.	6,016	563	do			Dry	April 1962	Rock samples examined and logged by R. B. Haley.
14	Atheletic Mining and Smelting Co.	do	Center NE¼NE¼S W¼ sec. 14, T. 5 N., R. 32 W.	4,335	[2] 560	No	Zone W, Atoka Formation	3,380	Show of gas		
15	Le Flore County Gas and Electric Co.	F. L. Holton 29	Center S W¼NE¼S W¼ sec. 34, T. 8 N., R. 27 E.	1,505	[2] 630	do			Gas [3]	1923	
16	do	Mooneyahm 22	Center SE¼N W¼N W¼ sec. 32, T. 8 N., R. 27 E.	2,487	[2] 690	do			Gas [3]	1921	
17	do	Kilgore-Cedars 5	Center N W¼SE¼NE¼ sec. 9, T. 7 N., R. 27 E.	3,250	[2] 600	do			Gas [3]	1929	

See footnotes at end of table.

TABLE 6.—*Description of selected wells drilled in or near the Greenwood quadrangle as of January 1, 1964*—Continued

Well No. (pls. 1-4)	Company name	Lease name	Location (EL, east line; NL, north line; SL, south line; WL, west line)	Total depth (ft)	Reported elevation (ft)	Electrical log	Stratigraphic zone of production	Depth of production (ft)	Reported production (cu ft per day)	Completion date	Remarks
18	Mobil Oil Co	W. K. Veazey 1	3,630 ft from SL and 840 ft from WL sec. 28, T. 7 N., R. 27 E.	13,871	[1] 1,152	Yes	Zone W, Atoka Formation	5,494–5,510	25,000	1962	Rock samples examined and logged by B. R. Haley to 13,400 ft and by S. E. Frezon from 13,400 to 13,871 ft.
19	Le Flore County Gas and Electric Co.	Garrett 55	Center SE¼NE¼NW¼ sec. 30, T. 7 N., R. 27 E.	1,478	[2] 650	No			Gas [3]	1925	
20	do	Garrett 76	Center SE¼NW¼NW¼ sec. 30, T. 7 N., R. 27 E.	1,539	[2] 635	do			Gas [3]	1927	300 ft west of Greenwood quadrangle.
21	do	Slocum 78	Center SE¼SW¼NW¼ sec. 30, T. 7 N., R. 27 E.	1,596	[2] 620	do			Gas [3]	1927	Do.
22	do	Hall 56	Center SE¼SW¼NE¼ sec. 30, T. 7 N., R. 27 E.	2,134	[2] 655	do			Gas [3]	1925	
23	Central Coal and Coke Co.	Hartford 1	4,200 ft from NL and 1,300 ft from EL sec. 21, T. 4 N., R. 32 W.	4,270	[2] 670	do		2,210	Show of gas	1914	2,900 ft south of Greenwood quadrangle.
								3,587	do		
								4,035	do		
24		Tucker 1	2,000 ft from NL and 1,450 ft from WL sec. 36, T. 5 N., R. 31 W.	1,804	[2] 610	do	Upper part, AtokaFormation.	786–799	do	1945	
25	Mansfield Gas Co	12	4,000 ft from NL and 3,500 ft from WL sec. 2, T. 4 N., R. 31 W.	2,071	[2] 680	do	do	1,240	950,500	1922	
							Zone W, Atoka Formation	1,645	1,391,000		
							do	1,740	250,000		
							do	2,047	2,040,000		
26	do	9	4,300 ft from NL and 2,600 ft from WL sec. 2, T. 4 N., R. 31 W.	2,016	[2] 690	do	Upper part, Atoka Formation.	1,425	150,000	1923	
							Zone W, Atoka Formation	1,743	1,500,000		
							do	2,005	1,750,000		
27	do	10	5,050 ft from NL and 2,600 ft from WL sec. 2, T. 4 N., R. 31 W.	2,265	[2] 740	do	Upper part, Atoka Formation.	1,180	Gas [3]	1914	
							Zone W, Atoka Formation	2,200	Gas [3]		

[1] Elevation of derrick floor. [2] Elevation estimated. [3] Quantity unknown.

form thickness, pleasing light color and lamination, and resistance to weathering. Shale has been quarried as a clay source for brick from the Atoka Formation in the center of sec. 36, T. 5 N., R. 31 W.

ROAD METAL

Shale or interbedded shale and siltstone has been quarried for road metal from the Atoka and McAlester Formations, and sandstone has been quarried for road metal from the Hartshorne Sandstone. Gravel from the river terraces and clinker from burned coal-mine dumps have also been used as road metal.

GRAVEL, SAND, AND CLAY

The river terraces, some of the stream terraces, and most of the alluvium contain well-sorted gravel. Sand is present in much of the alluvium. A zone of weathered shale at least 6 feet thick is present underneath the stream terrace along Arkansas State Highway 45 in the SW¼NW¼ sec. 11, T. 4 N., R. 32 W. This weathered shale is similar to that used as a source of clay for brick elsewhere in Arkansas. Deposits of nonsandy or nonsilty clay are rare in the alluvium or terrace deposits.

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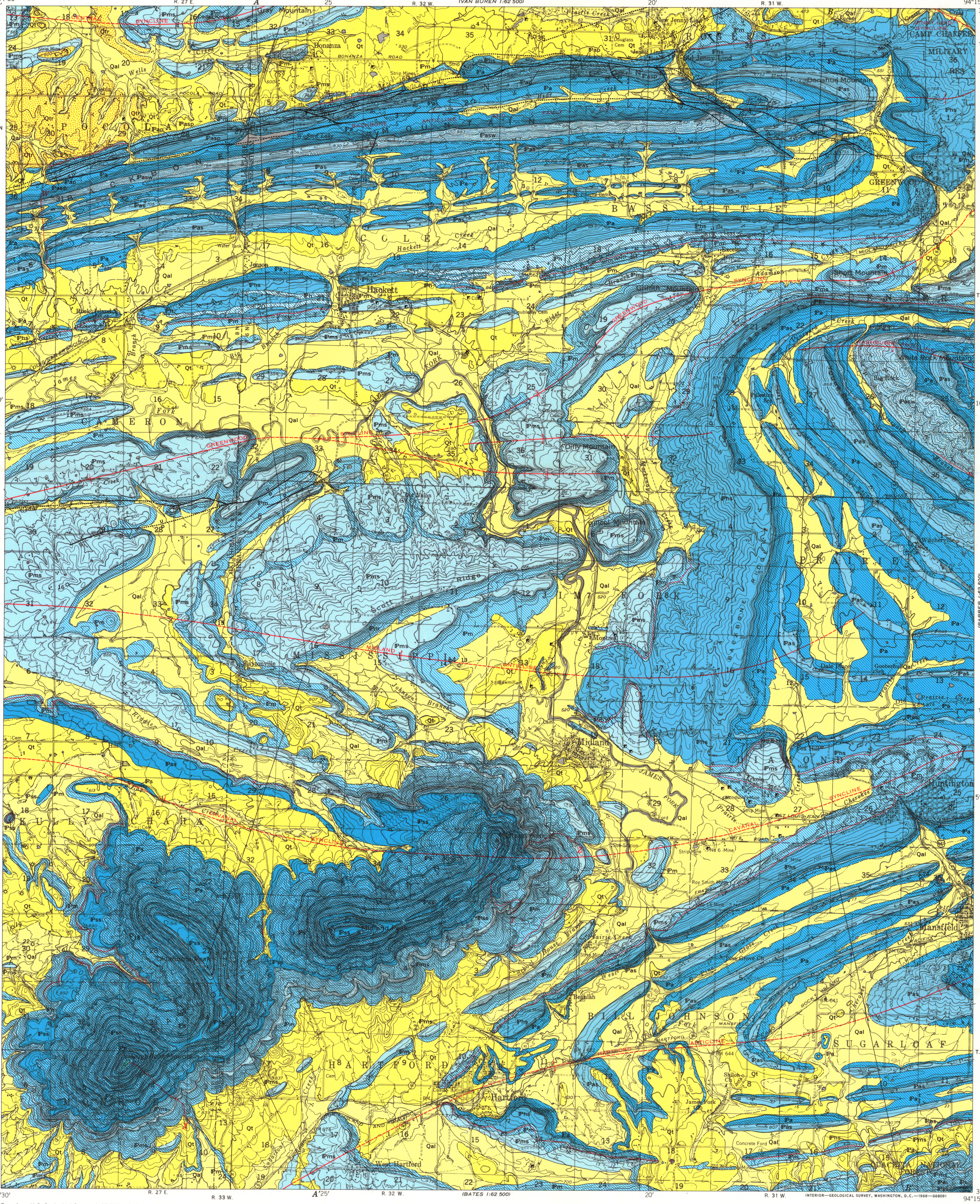
ARKANSAS GEOLOGICAL COMMISSION



Base from U.S. Geological Survey, 1:62,500, 1947

Geology by Boyd R. Haley and Thomas A. Hendricks, 1934 and 1960

GEOLOGIC MAP OF GREENWOOD QUADRANGLE, SEBASTIAN COUNTY, ARKANSAS AND LE FLORE COUNTY, OKLAHOMA

SCALE 1:48 000

1 ½ 0 1 2 3 MILES

1 .5 0 1 2 3 KILOMETERS

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

TRUE NORTH — MAGNETIC NORTH 7½°
APPROXIMATE MEAN DECLINATION, 1968

EXPLANATION

QUATERNARY

Recent

Qal

Alluvium
Deposits along stream channels. In some places includes parts of the lowermost terrace

Pleistocene

Qt
Qtr

Terrace deposits
Alluvial deposits on two terrace levels
Qt, *stream terrace deposits*
Qtr, *river terrace deposits*

UNCONFORMITY

CARBONIFEROUS — PENNSYLVANIAN

Des Moines — Krebs Group

IPb

Boggy Formation
Only the basal sandstone is present in the mapped area

IPs
IPss

Savanna Formation
Alternating units of predominant shale or predominant sandstone
IPs, *shale, siltstone, and thin beds of silty sandstone*
IPss, *sandstone, silty, sandstone, or interbedded sandstone, siltstone, and shale*

IPm
IPms

McAlester Formation
Alternating units of predominant shale or predominant sandstone
IPm, *shale, siltstone, and thin beds of sandstone or silty sandstone*
IPms, *sandstone, silty sandstone, or interbedded sandstone, siltstone, and shale*

IPh
IPhs

Hartshorne Sandstone
Alternating units of predominant shale or predominant sandstone
IPh, *shale, siltstone, and thin beds of sandstone or silty sandstone*
IPhs, *sandstone, silty sandstone, or interbedded sandstone, siltstone, and shale*

Atoka

IPa
IPas
IPasw
IPap
IPasp

Atoka Formation
Alternating units of predominant shale or predominant sandstone
IPa, *shale, siltstone, and thin beds of sandstone or silty sandstone*
IPas, *sandstone, silty sandstone, or interbedded sandstone, siltstone, and shale*
IPasw, *sandstone, silty sandstone, or interbedded sandstone, siltstone, and shale; zone W*
IPap, *shale, siltstone, and thin beds of sandstone or silty sandstone; zone P*
IPasp, *sandstone, silty sandstone, or interbedded sandstone, siltstone, and shale; zone P*

Contact
Dashed where approximately located

46 U D

Fault, showing dip
Dotted where concealed. U, *upthrown side;* D, *downthrown side*

35 T

Reverse fault, showing dip
Dotted where concealed. T, *designates upper plate*

Anticline Syncline
Folds
Showing trace of axial plane. Dashed where inferred

10 85

Inclined Overturned Vertical Horizontal
Strike and dip of beds
Symbols in areas of alluvial deposits were measured on bedrock exposures too small to be shown on this map

Coal bed
Dashed where approximately located

x
Exposure of coal bed

Surface opening to coal bed

Mine shaft

Quarry

B —— B′
Structural section shown on plate 4

—— X
Stratigraphic section shown on plate 2

27
Gas producing

12
Show of gas

13
No show of gas

3
Being drilled as of January 1, 1964

Wells
Number designates well listed in table in text

[1]And Undifferentiated rocks

STRATIGRAPHIC SECTIONS IN GREENWOOD QUADRANGLE, SEBASTIAN COUNTY ARKANSAS, AND LE FLORE COUNTY, OKLAHOMA

313-705 O - 68 (In pocket) No. 2

UNITED STATES DEPARTMENT OF THE INTERIOR
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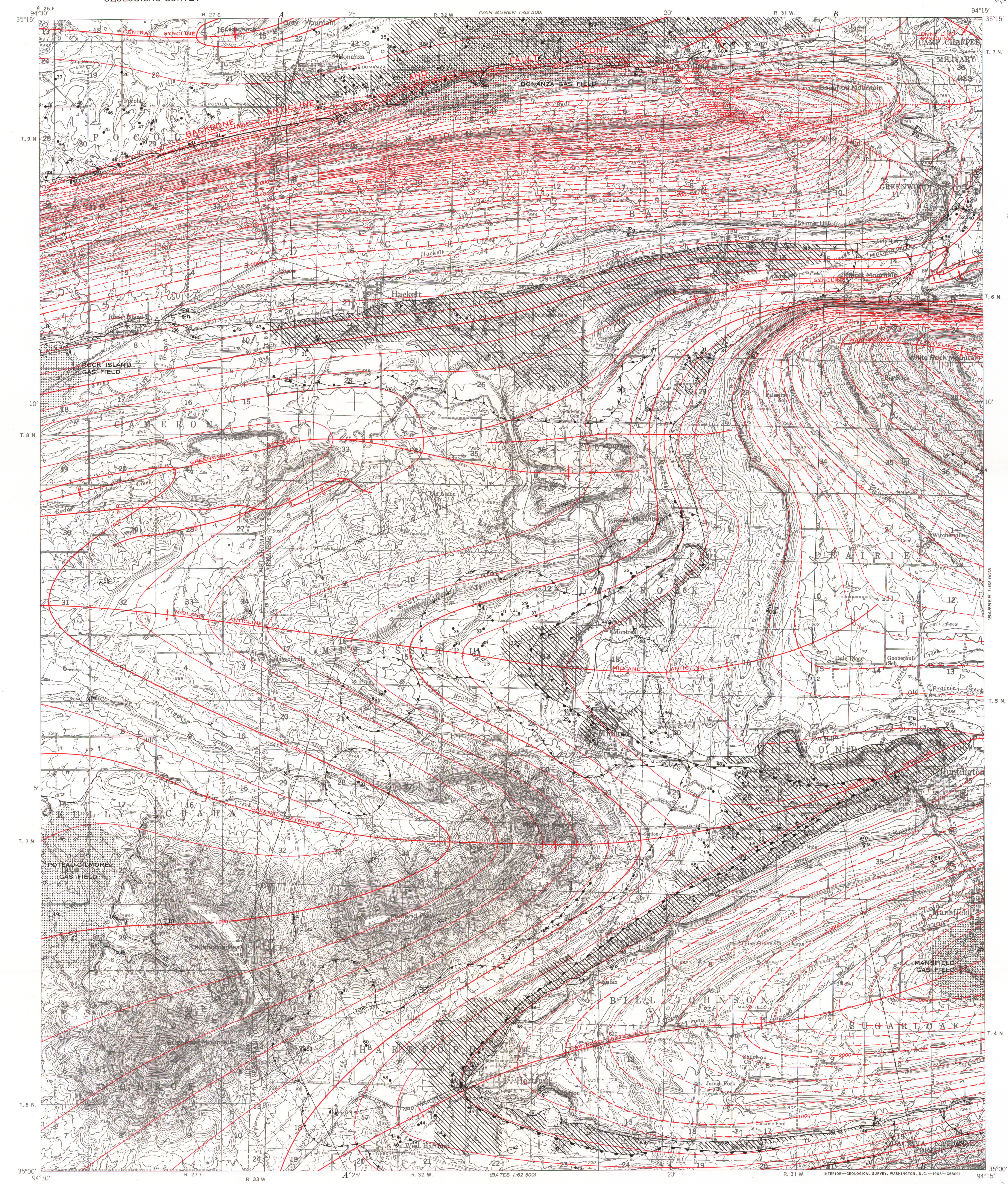
PROFESSIONAL PAPER 536-A
PLATE 3



EXPLANATION

Symbols in red indicate data on contoured horizon

3000

Structure contours
Drawn on base of Hartshorne Sandstone. Dashed where datum is eroded. Contour interval 200 feet

Anticline — Syncline
Folds
Showing trace of axial plane

U / D
Fault
U, *upthrown side;* D, *downthrown side*

Reverse fault
T, *designates upper plate*

Reverse fault bounding Lower Hartshorne coal bed

Ph / Pa
Surface trace of contact between Hartshorne Sandstone (Ph) and Atoka Sandstone (Pa)

A ——— A′
Structural section shown on plate 4

Unnamed coal bed in Savanna Formation

Stigler coal bed

McAlester coal bed

Upper Hartshorne coal bed

Lower Hartshorne coal bed

Unnamed coal bed in Atoka Formation

X 44
Exposure of coal
Number is thickness of coal, in inches

32
Surface opening on coal bed
Number is thickness of coal, in inches

Mine shaft

Quarry

43
Drill hole or mine locality in Lower Hartshorne coal bed
Number is thickness of coal, in inches

Mined area in Lower Hartshorne coal bed

42
Lower Hartshorne coal bed thickness line in Arkansas
Number is thickness of coal, in inches

1000
Lower Hartshorne coal bed overburden thickness line
Number is thickness of overburden, in feet

Boundary between measured and indicated reserves and inferred reserves of coal
Square on side of area of measured and indicated reserves of coal

2
Gas producing

12
Show of gas

13
No show of gas

3
Being drilled as of January 1, 1964
Wells
Number designates well listed in table in text

Gas field

Base from U.S. Geological Survey, 1:62,500, 1947

Geology by Boyd R. Haley and Thomas A. Hendricks, 1934 and 1960

STRUCTURE CONTOUR, COAL BED, AND GAS FIELD MAP OF GREENWOOD QUADRANGLE SEBASTIAN COUNTY, ARKANSAS, AND LE FLORE COUNTY, OKLAHOMA

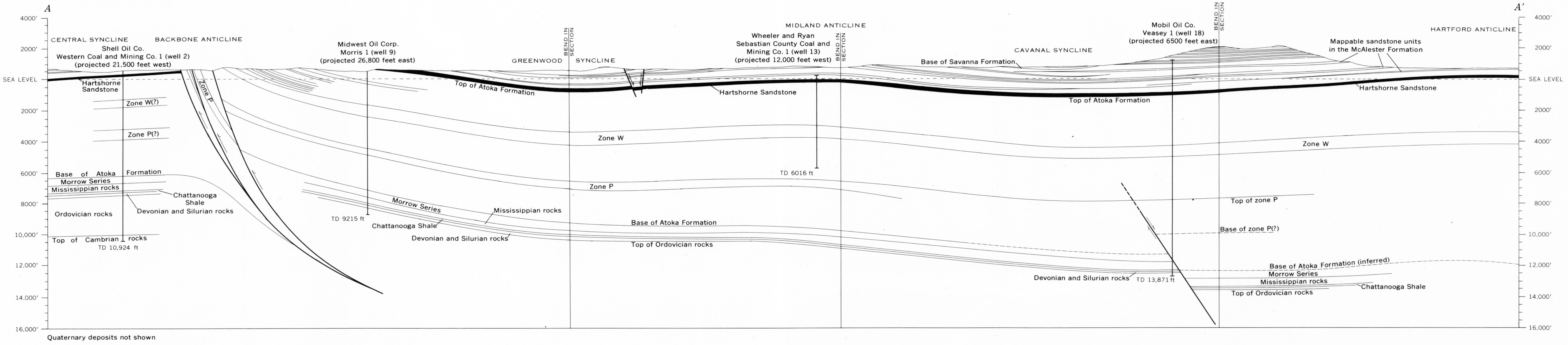
TRUE NORTH — MAGNETIC NORTH — 7½°
APPROXIMATE MEAN DECLINATION, 1968

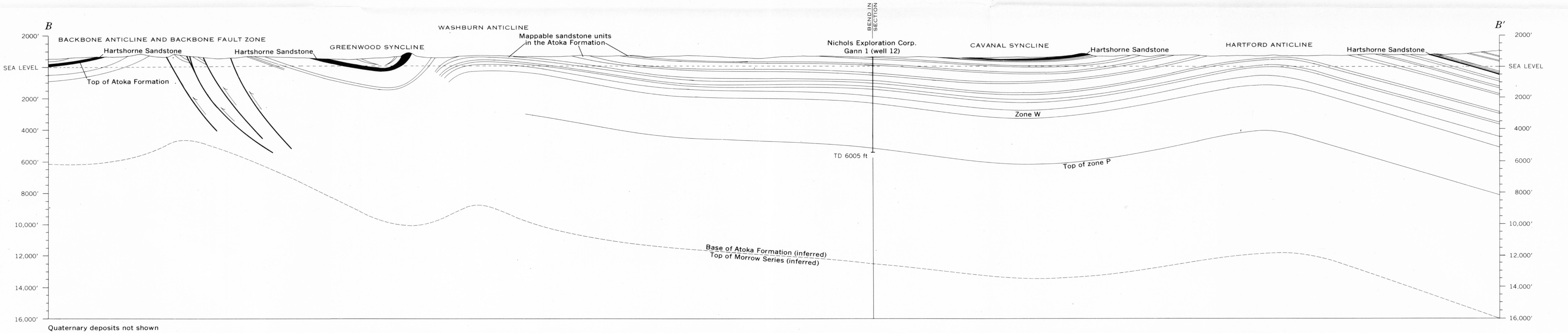
SCALE 1:48 000

1 ½ 0 1 2 3 MILES

1 .5 0 1 2 3 KILOMETERS

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL





STRUCTURAL SECTIONS IN GREENWOOD QUADRANGLE, SEBASTIAN COUNTY, ARKANSAS, AND LE FLORE COUNTY, OKLAHOMA

SCALE 1:48 000

1 ½ 0 1 2 3 MILES

1 .5 0 1 2 3 KILOMETERS

DATUM IS MEAN SEA LEVEL

313-705 O - 68 (In pocket) No. 4