Merewether and Haley—COAL HILL, HARTMAN, AND CLARKSVILLE QUADRANGLES, ARKANSAS—Geological Survey Professional Paper 536-C

Geology of the Coal Hill Hartman, and Clarksville Quadrangles, Johnson County and Vicinity, Arkansas

GEOLOGICAL SURVEY PROFESSIONAL PAPER 536-C

Prepared in cooperation with the Arkansas Geological Commission

Geology of the Coal Hill Hartman, and Clarksville Quadrangles, Johnson County and Vicinity, Arkansas

By E. A. MEREWETHER *and* BOYD R. HALEY

GEOLOGY OF THE ARKANSAS VALLEY COAL FIELD

GEOLOGICAL SURVEY PROFESSIONAL PAPER 536-C

Prepared in cooperation with the
Arkansas Geological Commission

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1969

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

GEOLOGY OF THE COAL HILL, HARTMAN, AND CLARKSVILLE QUADRANGLES, JOHNSON COUNTY AND VICINITY, ARKANSAS

By E. A. Merewether and Boyd R. Haley

ABSTRACT

The Coal Hill, Hartman, and Clarksville quadrangles enclose an area of approximately 182 square miles in Johnson, Logan, and Franklin Counties in northwestern Arkansas.

Sedimentary rocks penetrated by wells drilled for gas in the area range in age from Middle Ordovician to Middle Pennsylvanian. Rocks of the Atoka and Des Moines Series of Pennsylvanian age and terrace deposits and alluvium of Pleistocene and Recent age crop out in the area. The exposed rocks consist mainly of dark-gray shale, light- to medium-gray siltstone and sandstone, and a few beds of coal.

The sedimentary rocks are folded into gently dipping generally east-west-trending anticlines and synclines and are broken by normal faults striking generally east-west. The structural relief, measured on the base of the Hartshorne Sandstone, is about 1,600 feet.

Natural gas, coal, building stone, road metal, gravel, sand, and clay are of commercial importance in the area. The reported potential production of gas (Oct. 1, 1964) is about 331 million cubic feet per day. The Lower Hartshorne coal bed in the McAlester Formation of the Des Moines Series, which is the only coal bed of economic interest, has approximately 348 million short tons of remaining reserves. Building stone has been quarried from beds of sandstone in the Savanna Formation of the Des Moines Series and can probably be obtained from beds of sandstone in the other exposed formations. Sources of road metal are abundant and include outcropping sandstone, terrace deposits, and alluvium. Gravel and sand are available in the terrace deposits and alluvium, and clay can be most readily obtained from beds of shale.

INTRODUCTION

This report is one of a series being prepared by the U.S. Geological Survey in cooperation with the Arkansas Geological Commission. The purpose of these reports is to describe the geology and provide information pertinent to the exploitation of mineral resources.

This report is also distributed as Arkansas Geological Commission Information Circular 20–H.

The Coal Hill quadrangle is in Franklin, Johnson, and Logan Counties, Ark., and the Hartman and Clarksville quadrangles are in Johnson and Logan Counties. The three quadrangles are contiguous and are bounded by lats 35°22′30″ N., and 35°30′00″ N., and longs 93°22′30″ W. and 93°45′00″ W. The westernmost and easternmost of the quadrangles are Coal Hill and Clarksville, respectively. The three quadrangles include an area of approximately 182 square miles (fig. 1).

Clarksville, county seat of Johnson County and the largest town in the area, has a population of about 4,000. Other towns in the area and their approximate populations are Coal Hill, 700; Lamar, 500; Hartman, 300; and Denning, 200. These communities lie along either U.S. Highway 64 or the Missouri-Pacific Railroad, both of which cross the three quadrangles. County and private roads provide access to most of the area. The Arkansas River also crosses the three quadrangles, and part of Dardanelle Reservoir, which was formed by a dam across the Arkansas River to the east, is in the Clarksville quadrangle.

The elevation above sea level in the area ranges from about 310 feet, near the southeast corner along the Arkansas River, to about 910 feet, near the northwest corner, in secs. 34 and 35, T. 10 N., R. 26 W., and sec. 3, T. 9 N., R. 26 W.

The diverse land forms of the area, both erosional and depositional, have resulted from the erosion of the folded and faulted sedimentary rocks. Mesas, buttes, questas, resequent fault-line scarps, anticlinal ridges, and synclinal valleys are the most common erosional forms, and terraces are the prevalent depositional form. The drainage patterns are mainly dendritic. The smaller streams are usually either resequent or longitudinal subsequent; the larger streams, Horsehead and Spadra Creeks, may be in part superposed. The Arkansas River is probably mainly resequent.

Reports by Collier (1907), Croneis (1930), and Haley (1960) contain general descriptions of the geology in the Coal Hill, Hartman, and Clarksville quadrangles. This report was also influenced by the work of Hendricks and Read (1934), Hendricks, Dane, and Knechtel

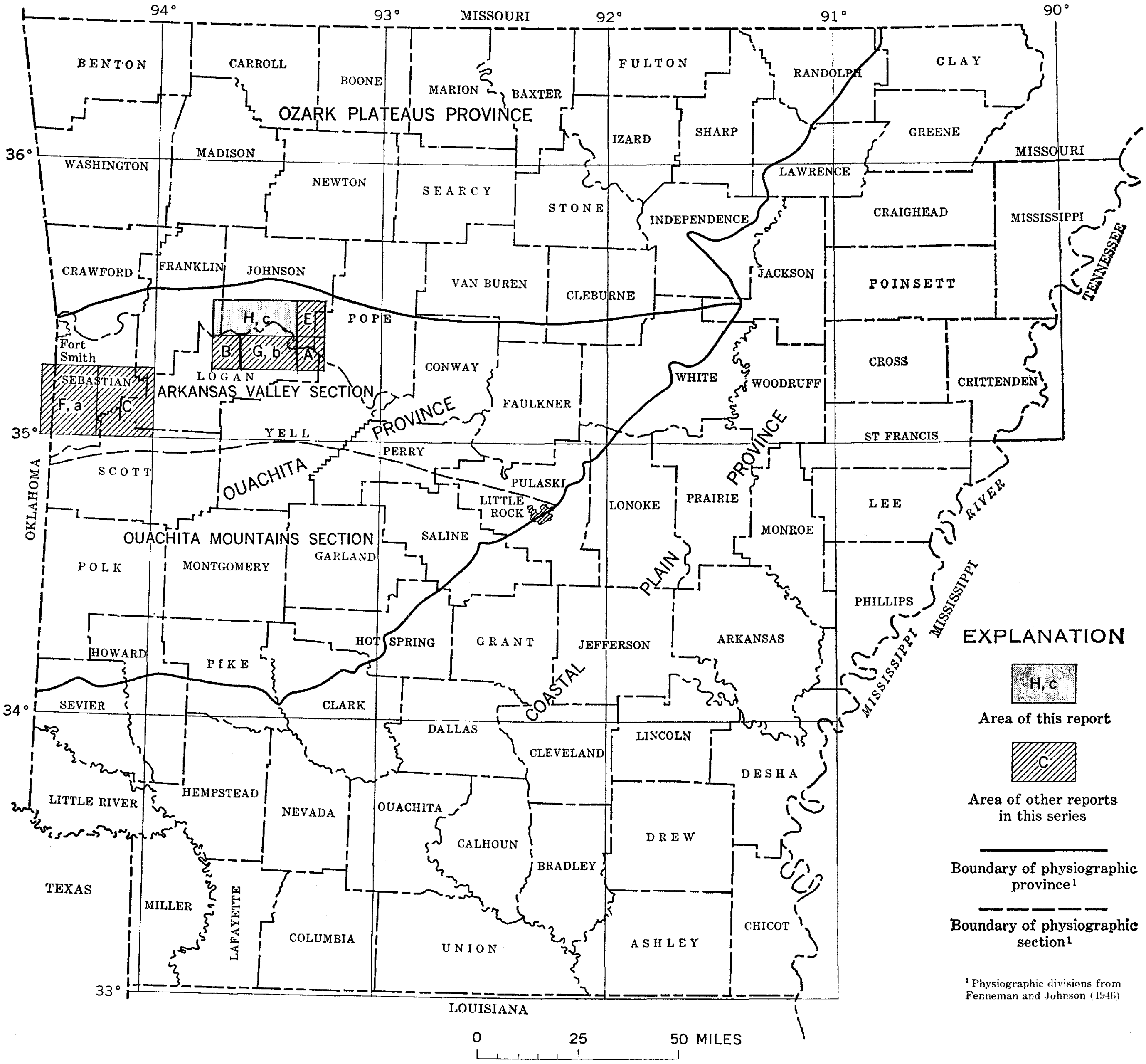


FIGURE 1.—Location of report area (H, c) and areas of previously published chapters of Arkansas Geological Commission Information Circular 20 or of U.S. Geological Survey Professional Paper 536: A, Delaware quadrangle (Merewether and Haley, 1961); B, Paris quadrangle (Haley, 1961); C, Barber quadrangle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

(1936), and Hendricks and Parks (1950), which pertained to areas near the Arkansas-Oklahoma State line. The stratigraphic boundaries and nomenclature used in this report for rocks of Middle Pennsylvanian age are those of the U.S. Geological Survey and were used by Merewether and Haley (1961) and Haley (1961). The stratigraphic terminology for rocks of Early Pennsylvanian and pre-Pennsylvanian age is derived from that used by the U.S. Geological Survey for rocks exposed in the Ozark Mountains of northern Arkansas. These rocks were traced in the subsurface southward to the area of this report by Maher and Lantz (1953) and Frezon and Glick (1959). The stratigraphic classification used in this report and the classification of the exposed rocks in the Arkansas Valley and Ozark Mountains are compared in table 1.

TABLE 1.—*Selected stratigraphic units in or near the Coal Hill, Hartman, and Clarksville quadrangles*

System		Series	Group	This report: Formation	This report: Member, zone, or bed	Arkansas Valley and Ozark Mountains: Formation	Arkansas Valley and Ozark Mountains: Member
CARBONIFEROUS	PENNSYLVANIAN	Des Moines	Krebs	Savanna Formation		Savanna Formation	
				McAlester Formation	Lower Hartshorne coal bed	McAlester Formation	
				Hartshorne Sandstone		Hartshorne Sandstone	
		Atoka		Atoka Formation	Zone C	Atoka Formation	
					Zone S		
							Greenland Sandstone Member
		Morrow		Bloyd Formation and		Bloyd Formation	Trace Creek Shale Member
							Kessler Limestone Member
							Dye Shale Member
							Woolsey Member
							Brentwood Limestone Member
				Hale Formation	Prairie Grove Member	Hale Formation	Prairie Grove Member
					Cane Hill Member		Cane Hill Member
	MISSISSIPPIAN	Upper		Rocks of Mississippian age		Pitkin Limestone	
						Fayetteville Shale	
						Batesville Sandstone	
						Ruddell Shale	
						Moorefield Formation	
		?					
		Lower				Boone Formation	
				Chattanooga Shale		Chattanooga Shale	
DEVONIAN				Penters Chert		Penters Chert	
SILURIAN				St. Clair Limestone		St. Clair Limestone	
ORDOVICIAN		Upper		Cason Shale		Cason Shale	
				Fernvale Limestone		Fernvale Limestone	
		Middle		Kimmswick Limestone and Plattin Limestone		Kimmswick Limestone	
						Plattin Limestone	
				St. Peter Sandstone and Everton Formation		St. Peter Sandstone	
						Everton Formation	

Norman F. Williams, State Geologist, Arkansas Geological Commission, provided samples of drill cuttings from 16 of the wells drilled for gas in the three quadrangles. The Fort Smith Gas Co. provided samples of drill cuttings from one well in the area. Gulf Oil Corp. and Phillips Petroleum Co. loaned copies of the electric logs of several wells to the authors. The Gulf Oil Corp. also loaned samples of drill cuttings and presented copies of electric logs from exploratory shallow holes drilled in the quadrangles. Mr. Kenneth King of Clarksville, Ark., loaned a compilation of old coal mine maps. To these individuals and organizations the authors express their sincere appreciation.

The geology of the parts of the Coal Hill, Hartman, and Clarksville quadrangles that are south of the north boundary of the alluvium of the Arkansas River was mapped and interpreted for this report by Boyd R. Haley. The remaining northern part of the report area was mapped and interpreted by E. A. Merewether. The contributions to this report by other personnel of the U.S. Geological Survey are noted where appropiate.

STRATIGRAPHY

Sedimentary rocks of the Pennsylvanian System and unconsolidated sediments of the Quaternary System crop out in the Coal Hill, Hartman, and Clarksville quadrangles, Arkansas (pl. 1). Sedimentary rocks of the Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian Systems have been penetrated by wells drilled for gas in the three quadrangles. Most of these rocks are represented graphically on plate 2.

The sediments of Quaternary age are stream and river terrace deposits of Pleistocene age (Hendricks and Parks, 1950, p. 78) and stream and river alluvium of Recent age.

Rocks in the subsurface were studied by examining the drill cuttings and electric logs of selected holes drilled in these quadrangles. A description of all wells drilled for gas in the mapped area is presented in table 2. Electric logs, sample logs, and composite interpretive logs from 44 of the 51 wells drilled for gas in the area were available for use in interpreting the subsurface geology. Most of the stratigraphic units penetrated by the wells can be correlated within a gas field, but correlations between gas fields are generally more difficult because only a few distinctive units can be traced throughout the area.

The Gulf Oil Corp. drilled 138 shallow holes in the mapped area (table 3) while exploring the Arkansas Valley for natural gas. The logs of these holes were used intensively by the authors in interpreting the stratigraphy and structure of the rocks beneath the alluvium of the Arkansas River. The logs of the shallow holes are mainly composite interpretive logs. Electric logs only were available for 10 of the holes and sample logs only were available for five of the holes. All electric logs were made with the same equipment and procedures. The composite interpretive logs and the electric logs can be correlated, generally, throughout the area of this report.

ORDOVICIAN SYSTEM

EVERTON FORMATION AND ST. PETER SANDSTONE UNDIVIDED

Dolomite, sandstone, and shale, probably correlative with the upper part of the Everton Formation and the overlying St. Peter Sandstone of the Ozark Mountains, were penetrated by the Humble Oil and Refining Co. H. L. Hembree Unit 1 (well 16) in sec. 25, T. 9 N., R. 26 W. The combined thickness of these units in well 16 is 214 feet. The rocks in the lower half of this interval consist of about 50 percent medium- to dark-gray slightly sandy to argillaceous dense to very finely crystalline dolomite. Interbedded with the dolomite is dark-gray dolomitic shale and light- to medium-gray dolomitic very fine to fine-grained sandstone containing scattered medium sand grains. The rocks in the upper half of the Everton and St. Peter consist of about two-thirds light- to medium-gray very fine to medium-grained dolomitic sandstone containing scattered medium to coarse sand grains. Interbedded with the sandstone is medium-dark- to dark-gray dolomite some of which is very finely to finely sandy.

PLATTIN LIMESTONE AND KIMMSWICK LIMESTONE UNDIVIDED

A unit of limestone with a few thin beds of shale, penetrated by well 16, probably represents the Plattin and Kimmswick Limestones of the Ozark Mountains. This unit is 110 feet thick and is about 90 percent limestone. In the lower part the limestone is medium gray and dense, and in the middle and upper parts it is light to dark gray, dense to finely crystalline, argillaceous, and finely sandy and contains medium-gray to black chert. The limestone in the middle part is dolomitic. The shale ranges in color from medium light gray with a waxy luster to dark gray.

FERNVALE LIMESTONE

Limestone probably representing the Fernvale Limestone of the Ozarks was penetrated by well 16. It is light gray, slightly dolomitic, and dense and contains scattered chert and a small amount of pyrite. This unit is 30 feet thick.

CASON SHALE

A siltstone unit in well 16 is probably the Cason Shale of the Ozark Mountains. The siltstone is about 3 feet thick, light greenish gray, and very limy.

TABLE 2.—*Description of wells in the Coal Hill, Hartman, and Clarksville quadrangles as of October 1, 1964*

Well No. (pls. 1-4)	Company name	Lease name	Location (NL, north line; WL, west line; EL, east line; SL, south line)	Total depth (ft)	Reported elevation (ft)	Electrical log [2]	Stratigraphic zone of production	Depth of production (ft)	Reported production (cu ft per day)	Completion date	Remarks
1	Humble Oil and Refining Co.	Mo-Pac Unit 1	700 ft south and west of center sec. 26, T. 10 N., R. 26 W.	4,315	630	Yes			Dry	Nov. 1961	Rock samples examined and logged by E. A. Merewether.
2	Stephens Production Co.	J. A. Greenwood 1	760 ft from NL and 660 ft from WL of NE¼ sec. 31, T. 10 N., R. 25 W.	3,852	[1] 575	Yes			Dry	June 1964	
3	Arkansas Western Gas Co.	M. Skod 1	S½SE¼SW¼ sec. 31, T. 10 N., R. 25 W.	4,937	480	Yes	Lower part of Atoka Formation.	3,790–3,795	5,500,000	May 1963	
								3,900–3,928	6,500,000		
4	do	D. B. Castleberry Estate 1.	1,030 ft south and 180 ft west of center sec. 32, T. 10 N., R. 25 W.	4,594	478	Yes	do	3,544–3,562	6,000,000	July 1964	
5	do	R. Floyd 1	660 ft from NL and 1,150 ft from WL of SE¼ sec. 33, T. 10 N., R. 25 W.	4,576	448	Yes	Bloyd Formation and Prairie Grove Member (upper part).	3,831–3,837	4,500,000	May 1961	
							Bloyd Formation and Prairie Grove Member (middle part).	4,194–4,202	2,500,000		
6	Stephens, Inc.	P. Sunderman Unit 1.	80 ft from SL and 1,590 ft from WL of sec. 35, T. 10 N., R. 25 W.	5,244	418	Yes			Dry	April 1961	
7	Arkansas-Oklahoma Gas Co.	Tipton 1	1,320 ft south and 660 ft east of center sec. 29, T. 10 N., R. 24 W.	4,050	[1] 580	No			Dry	Unknown	Rock samples examined and logged by S. E. Frezon.
8	Phillips Petroleum Co.	South Clarksville 1	Center NW¼SW¼ sec. 27, T. 10 N., R. 24 W.	5,046	727	Yes			Dry	Aug. 1961	Rock samples examined and logged by E. A. Merewether.
9	Piney Oil and Gas Co.	W. Gray 1	SW¼SW¼ sec. 25, T. 10 N., R. 23 W.	3,001	[1] 520	No	Middle part of Atoka Formation.	2,283	Show of gas	Unknown	
10	J. M. Huber Corp.	Kramer 1	1,980 ft from SL and 1,856 ft from EL of sec. 3, T. 9 N., R. 26 W.	5,447	875	Yes	Basal sandstone of Atoka Formation.	4,976–5,002	25,800,000	July 1961	
							Bloyd Formation and Prairie Grove Member (middle part).	5,392–5,402	720,000		
11	Arkansas Western Gas Co.	Post 1	1,000 ft south and 100 ft west of center sec. 2, T. 9 N., R. 26 W.	5,448	865	Yes	Lower part of Atoka Formation.	4,433–4,443	1,250,000	Sept. 1961	
12	do	W. H. Timmerman 1	200 ft north and 100 ft west of center sec. 11, T. 9 N., R. 26 W.	5,268	760	Yes	do	4,101–4,103	250,000	Sept. 1960	
								4,256–4,268; 4,332–4,336; 4,340–4,344	11,000,000		
13	do	H. G. Sullivan 1	100 ft north and 200 ft east of center sec. 12, T. 9 N., R. 26 W.	5,365	714	Yes	Basal sandstone of Atoka Formation.	4,667–4,677	3,000,000	Sept. 1963	
14	Murphy Corp.	Altus Gas Unit 1	150 ft north and 1,000 ft west of center sec. 14, T. 9 N., R. 26 W.	5,269	559	Yes	Middle part of Atoka Formation.	2,570–2,578	1,800,000	July 1962	Rock samples examined and logged by E. A. Merewether.
							Lower part of Atoka Formation.	4,252–4,258; 4,363–4,365	3,000,000		
							Boyd Formation and Prairie Grove Member (upper part).	5,005–5,016	825,000		
15	Humble Oil and Refining Co.	Western Coal Co. 1	Center SW¼NE¼ sec. 23, T. 9 N., R. 26 W.	5,725	404	Yes	Lower part of Atoka Formation.	4,353–4,368	2,700,000	June 1964	
								4,492–4,502; 4,692–4,697	2,700,000		
16	do	H. L. Hembree Unit 1.	S½SW¼NE¼ sec. 25, T. 9 N., R. 26 W.	7,000	359	Yes	do	4,708–4,722; 5,178–5,186	1,500,000	Nov. 1961	Discovery well of Alix gas field. Rock samples examined and logged by E. A. Merewether.
17	Arkansas Western Gas Co.	G. Wootten 1	300 ft from SL and 200 ft from EL of NW¼ sec. 5, T. 9 N., R. 25 W.	5,304	580	Yes			Dry	Sept. 1958	
18	do	J. B. Hurst 1	260 ft from NL and 675 ft from EL of SW¼ sec. 4, T. 9 N., R. 25 W.	4,855	475	Yes	Lower part of Atoka Formation.	3,041–3,064	7,000,000	May 1958	Discovery well of Coal Hill gas field.
19	do	R. Bartlett 1	615 ft from NL and 350 ft from EL of NW¼ sec. 3, T. 9 N., R. 25 W.	4,763	425	Yes	do	3,576–3,601	23,000,000	Dec. 1959	
	Piney Oil and Gas Co.	J. N. Hill 1	Location in section unknown. Sec. 3, T. 9 N., R. 25 W.	2,800	Unknown	No			Dry	1922	
20	Humble Oil and Refining Co.	D. L. Evans 1	400 ft from SL and 200 ft from EL of SW¼ sec. 3, T. 9 N., R. 25 W.	4,800	[1] 690	Yes			Dry	April 1960	Rock samples examined and logged by E. A. Merewether.

See footnotes at end of table.

TABLE 2.—*Description of wells in the Coal Hill, Hartman, and Clarksville quadrangles as of October 1, 1964*—Continued

Well No. (pls. 1–4)	Company name	Lease name	Location (NL, north line; WL, west line; EL, east line; SL, south line)	Total depth (ft)	Reported elevation (ft)	Electrical log [2]	Stratigraphic zone of production	Depth of production (ft)	Reported production (cu ft per day)	Completion date	Remarks
21	River Valley Gas Co.	Western Coal and Mining Co. 1.	SW cor. NW¼SE¼SE¼ sec. 20, T. 9 N., R. 25 W.	2,240	445	No			Dry	Unknown	
22	Blackwell Oil and Gas Co.	Winn 1	Center SW¼SE¼ sec. 21, T. 9 N., R. 25 W.	5,597	[1] 500	No	Middle part of Atoka Formation.	1,975 3,240–3,243	Show of gas 500,000	Sept. 1929 ---	
23	River Valley Gas Co.	W. F. Collier 1	SE¼SE¼ sec. 21, T. 9 N., R. 25 W.	1,980	496	No	Upper part of Atoka Formation.	450–500	1,500,000	1930	
							Middle part of Atoka Formation.	1,960–1,974	Show of gas	---	
24	J. M. Huber Corp	Estep 1	330 ft from SL and 2,970 ft from WL of sec. 36, T. 9 N., R. 25 W.	6,721	345	Yes	Basal sandstone of Atoka Formation.	5,992–6,000 6,044–6,050	1,170,000	June 1962	
							Bloyd Formation and Prairie Grove Member (middle part).	6,585–6,658	7,600,000	---	
25	Stephens Production Co.	O. Rinke 1	300 ft from NL and 800 ft from WL of SE¼ sec. 6., T. 9 N., R. 24 W.	5,728	[1] 530	Yes	Basal sandstone of Atoka Formation.	5,188–5,206	2,500,000	April 1959	
26	do	B. Cater 1	850 ft north and 450 ft east of center sec. 7, T. 9 N., R. 24 W.	5,253	[1] 465	Yes	Lower part of Atoka Formation.	3,962–3,972	262,000	Dec. 1963	
27	do	B. Hardgrave 1	400 ft from NL and 500 ft from WL of SE¼ sec. 5, T. 9 N., R. 24 W.	5,148	[1] 540	Yes	Basal sandstone of Atoka Formation.	4,384–4,443	3,509,000	March 1958	Discovery well of Union City gas field.
							Bloyd Formation and Prairie Grove Member (upper part).	4,659–4,681	25,000,000	---	
28	do	B. E. Cobb 1	1,100 ft north and 150 ft west of center sec. 8, T. 9 N., R. 24 W.	5,751	[1] 430	Yes	Basal sandstone of Atoka Formation.	4,706–4,733	9,320,000	Dec. 1960	
29	do	Ozark Coal Co. 1	150 ft south and 700 ft west of center sec. 4, T. 9 N., R. 24 W.	4,807	[1] 520	Yes	Lower part of Atoka Formation.	4,385–4,405	1,500,000	Jan. 1960	
							Bloyd Formation and Prairie Grove Member (upper part).	4,690–4,706	50,000,000	---	
30	do	Patrick-McWilliams 1.	700 ft north and 650 ft west of center sec. 9, T. 9 N., R. 24 W.	5,719	[1] 400	Yes	do	4,637–4,641	252,000	Dec. 1963	
31	do	W. H. Hooten 1	400 ft south and 900 ft west of center sec. 3, T. 9 N., R. 24 W.	5,418	[1] 390	Yes			Dry	Jan. 1962	
32	Gulf Oil Corp	McAlester Fuel Co. 1.	Center NW¼SE¼ sec. 31, T. 9 N., R. 24 W.	6,952	347	Yes	Middle part of Atoka Formation.	3,006 4,472	2,000,000 2,600,000	Aug. 1961	Rock samples examined and logged by B. R. Haley.
33	J. M. Huber Corp	Hunt 1	50 ft from NL and 2,640 ft from WL of NW cor. sec. 32, T. 9 N., R. 24 W.	7,740	348	Yes			Dry	1961	
	Hugo-Spadra Oil and Gas Co.	Parks 1	Location in section unknown. Sec. 3, T. 9 N., R. 23 W.	2,250	Unknown	No			Dry	Unknown	
34	Gulf Oil Corp	Excelsior Coal 1	100 ft south and 900 ft east of center sec. 17, T. 9 N., R. 23 W.	6,105	398	Yes	Lower part of Atoka Formation.	5,282–5,284 5,306–5,308	9,900,000	Feb. 1964	Rock samples examined and logged by E. A. Merewether.
35	Stephens Inc	A. C. Brown 1	800 ft south and 400 ft west of center sec. 16, T. 9 N., R. 23 W.	6,305	[1] 385	Yes	do	4,622–4,628 4,634–4,640	100,000	July 1963	
								5,343–5,514	9,500,000	---	
36	Gulf Oil Corp	Vola 1	20 ft south and 535 ft west of center sec. 15, T. 9 N., R. 23 W.	5,940	585	Yes	do	5,380–5,388 5,437–5,439	1,780,000	Sept. 1964	
								5,514–5,544	29,500,000	---	
37	Western Natural Gas Co.	C. H. Bryant 1	4,200 ft from NL and 3,800 ft from WL of sec. 19, T. 9 N., R. 23 W.	5,970	375	Yes	do	4,850–5,000	176,000	April 1954	Discovery well of Spadra gas field. Rock samples examined and logged by E. E. Glick.
38	Gulf Oil Corp	Excelsior 1	1,973 ft from NL and 3,232 ft from WL of sec. 30, T. 9 N., R. 23 W.	6,382	337	Yes	Bloyd Formation and Prairie Grove Member (upper part).	6,337–6,380	Show of gas	Oct. 1961	Rock samples examined and logged by E. A. Merewether.
39	do	ARECI C-1	646 ft from NL and 2,508 ft from EL of sec. 29, T. 9 N., R. 23 W.	6,354	[1] 334	Yes	Basal sandstone of Atoka Formation	5,950–5,956	4,000,000	Jan. 1961	Do.
							Bloyd Formation and Prairie Grove Member (upper part).	6,260–6,280	11,700,000		
40	do	Arkansas Real Estate Co., Inc. B-1.	4,850 ft from SL and 1,230 ft from WL of sec. 28, T. 9 N., R. 23 W.	6,501	[1] 379	Yes	Lower part of Atoka Formation. Basal sandstone of Atoka Formation. Bloyd Formation and Prairie Grove Member (upper part).	5,177 5,328–5,336 6,078–6,102 6,262–6,292	15,000,000–20,000,000	May 1961	Do.

41	do.	Spadra Bottoms 1	NE¼SW¼ sec. 22, T. 9 N., R. 23 W.	6,792	333	Yes	Lower part of Atoka Formation.	5,623-5,647	2,424,000	Oct. 1960	Do.
42	do.	Ragon 1	Center SE¼SW¼ sec. 28, T. 9 N., R. 23 W.	6,901	349	Yes	Bloyd Formation and Prairie Grove Member (upper part).	6,258-6,280	606,000	Feb. 1956	Depleted and abandoned Oct. 1964. Rock samples examined and logged by B. R. Haley.
43	do.	Arkansas Real Estate Co., Inc. 1.	165 ft south and 35 ft east of center E½NE¼NW¼ sec. 32, T. 9 N., R. 23 W.	6,555	537	Yes	Middle part of Atoka Formation.	3,491-3,530	1,100,000	May 1958	Rock samples examined and logged by E. E. Glick.
								4,268-4,306	2,941,000		
							Lower part of Atoka Formation.	5,574-5,579	3,228,000		
44	Wheeler and Ryan	Arkansas Minerals Corp. 1.	700 ft from SL and 2,970 ft from EL of sec. 32, T. 9 N., R. 23 W.	7,272	424	Yes	Upper part of Atoka Formation.	3,215-3,232	Show of gas	Nov. 1962	
45	Arkansas Louisiana Gas Co.	Hunt-Hembree 2	2,400 ft north and 2,500 ft west of SE cor. sec. 11, T. 8 N., R. 26 W.	7,302	357	Yes	Middle part of Atoka Formation.	4,282-4,305	625,000	July 1964	
							Lower part of Atoka Formation.	5,509-5,522	4,600,000		
46	J. M. Huber Corp.	King 1	4,752 ft from SL and 2,140 ft from EL of sec. 12, T. 8 N., R. 25 W.	7,699	462	Yes	do.	5,546 6,074	50,000-75,000	July 1963	Rock samples examined and logged by B. R. Haley.
							Bloyd Formation and Prairie Grove Member (upper part).	7,384	Show of gas		
47	do.	Kimes 1	290 ft from NL and 1,250 ft from WL of sec. 6, T. 8 N., R. 24 W.	7,005	340	Yes	do.	6,416-6,448	349,000	May 1963	
								6,672-6,755 6,778-6,804	15,200,000		
48	do.	Mabry 1	330 ft from SL and 3,490 ft from EL of sec. 6, T. 8 N., R. 24 W.	7,920	496	Yes	Basal sandstone of Atoka Formation.	6,745-6,774	5,300,000	Dec. 1960	Discovery well of Scranton gas field.
							Bloyd Formation and Prairie Grove Member (upper part). Bloyd Formation and Prairie Grove Member (middle part).	7,013-7,052 7,215-7,300 7,328-7,373	1,360,000		Rock samples examined and logged by B. R. Haley.
49	Reinhart and Donovan	M. J. Reinhart 1	Center NW¼NE¼ sec. 11, T. 8 N., R. 24 W.	4,821	[1] 355	Unknown			Dry	March 1947	

[1] Estimated from plate 1.
[2] Electrical logs include radioactivity logs.

TABLE 3.—*Description of shallow holes drilled by the Gulf Oil Corp. in the Coal Hill, Hartman, and Clarksville quadrangles*

Hole number: Company designations.
Location: NL, north line; WL, west line; SL, south line; EL, east line.
Bottom of hole: Stratigraphic position above, A, or below, B, top of Hartshorne Sandstone.
Remarks: Samples examined and logged by individuals named. Lithologic and electrical logs available unless otherwise noted.

Hole No. (pls. 1, 3)	Location	Reported ground elevation (ft)	Depth of hole (ft)	Bottom of hole (ft)	Remarks
2	W½SW¼SE¼ sec. 8, T. 9 N., R. 23 W.	390	600	279 B	S. E. Frezon.
3	NW¼SE¼SE¼ sec. 9, T. 9 N., R. 23 W.	520	600	6 B	No lithologic log.
4	NE¼NW¼SE¼ sec. 17, T. 9 N., R. 23 W.	384	190	6 B	Do.
5	NE¼NE¼SW¼SE¼ sec. 16, T. 9 N., R. 23 W.	331	136	6 B	Do.
6	SW¼SW¼SW¼ sec. 15, T. 9 N., R. 23 W.	337	142	4 B	Do.
7	SE¼NE¼SE¼NW¼ sec. 22, T. 9 N., R. 23 W.	319	205	1 B	B. R. Haley.
8, 9	SE¼NE¼NE¼NW¼ sec. 22, T. 9 N., R. 23 W.	335	218	1 B	B. R. Haley; no electrical log.
10	NE¼SE¼SW¼SE¼ sec. 17, T. 9 N., R. 23 W.	349	60	4 B	B. R. Haley.
11	SW¼NE¼NE¼NE¼ sec. 19, T. 9 N., R. 23 W.	370	42	Unknown A	B. R. Haley; no electrical log.
12	NE¼SE¼SE¼NE¼ sec. 19, T. 9 N., R. 23 W.	330	283	323 B	B. R. Haley.
13	NE¼NE¼NW¼SW¼ sec. 18, T. 9 N., R. 23 W.	355	197	15 A	Do.
14	NW¼SW¼SW¼SW¼ sec. 18, T. 9 N., R. 23 W.	334	120	4 A	Do.
16	3,060 ft from NL, 4,330 ft from WL sec. 19, T. 9 N., R. 23 W.	332	265	1 B	No lithologic log.
17	4,180 ft from NL, 5,550 ft from WL sec. 19, T. 9 N., R. 23 W.	322	241	429 A	Do.
18	5,260 ft from NL, 4,100 ft from WL sec. 19, T. 9 N., R. 23 W.	340	405	243 A	Do.
19	NE¼NE¼NE¼NE¼ sec. 23, T. 9 N., R. 24 W.	363	385	253 B	Do.
21	SE¼NW¼SW¼ sec. 24, T. 9 N., R. 24 W.	370	335	331 B	B. R. Haley.
22	SE¼SW¼NW¼ sec. 19, T. 9 N., R. 23 W.	330	324	342 B	No lithologic log.
23	5,075 ft from NL, 1,525 ft from WL sec. 19, T. 9 N., R. 23 W.	337	745	8 B	S. E. Frezon.
24	7,050 ft from NL, 2,950 ft from WL sec. 19, T. 9 N., R. 23 W.	332	285	348 A	B. R. Haley.
25	60 ft north of hole 22 SE¼SW¼NW¼ sec. 19, T. 9 N., R. 23 W.	332	187	204 B	E. A. Merewether.
26	2,871 ft from NL, 1,765 ft from EL sec. 35, T. 9 N., R. 23 W.	334	479	11 B	B. R. Haley.
27	4,550 ft from NL, 1,200 ft from EL sec. 35, T. 9 N., R. 23 W.	325	295	126 A	Do.
28	1,875 ft from SL, 3,125 ft from WL sec. 2, T. 8 N., R. 23 W.	324	215	329 A	Do.
29	3,950 ft from NL, 2,800 ft from EL sec. 35, T. 9 N., R. 23 W.	344	154	337 A	Do.
30	2,450 ft from SL, 25 ft from WL sec. 23, T. 9 N., R. 23 W.	337	265	1 B	B. R. Haley; 440-ft fault at depth of 242 ft.
31	50 ft from SL, 900 ft from WL sec. 23, T. 9 N., R. 23 W.	334	345	355 A	B. R. Haley.
32	1,500 ft from NL, 1,150 ft from WL sec. 26, T. 9 N., R. 23 W.	337	98	44 B	Do.
33	5,100 ft from SL, 3,290 ft from WL sec. 33, T. 9 N., R. 23 W.	333	421	2 B	Do.
34	2,975 ft from SL, 2,400 ft from WL sec. 33, T. 9 N., R. 23 W.	355	109	302 A	Do.
35	650 ft from SL, 1,900 ft from WL sec. 33, T. 9 N., R. 23 W.	387	290	352 A	Do.
36	950 ft from SL, 100 ft from WL sec. 31, T. 9 N., R. 23 W.	345	200	388 A	Do.
37	25 ft from SL, 25 ft from EL sec. 36, T. 9 N., R. 24 W.	354	590	2 B	S. E. Frezon.
38	900 ft from NL, 25 ft from EL sec. 1, T. 8 N., R. 24 W.	346	260	352 A	B. R. Haley.
39	1,050 ft from SL, 1,100 ft from WL sec. 32, T. 9 N., R. 23 W.	416	170	373 A	S. E. Frezon.
40	2,225 ft from NL, 80 ft from EL sec. 6, T. 8 N., R. 23 W.	378	365	299 A	B. R. Haley.
41	1,350 ft from SL, 300 ft from EL sec. 34, T. 9 N., R. 24 W.	325	395	298 A	B. R. Haley; 64-ft fault at depth of 248 ft.
42	3,700 ft from SL, 2,650 ft from EL sec. 34, T. 9 N., R. 24 W.	326	545	178 A	S. E. Frezon.
43	0 ft from SL, 1,950 ft from EL sec. 33, T. 9 N., R. 24 W.	338	400	308 A	B. R. Haley; 54-ft fault at depth of 293 ft.
44	1,050 ft from SL, 1,100 ft from EL sec. 6, T. 8 N., R. 24 W.	348	325	295 A	B. R. Haley and S. E. Frezon.

TABLE 3.—*Description of shallow holes drilled by the Gulf Oil Corp. in the Coal Hill, Hartman, and Clarksville quadrangles*—Continued

Hole No. (pls. 1, 3)	Location	Reported ground elevation (ft)	Depth of hole (ft)	Bottom of hole (ft)	Remarks
45	900 ft from NL, 4,400 ft from EL sec. 12, T. 8 N., R. 25 W.	387	320	313 A	B. R. Haley and S. E. Frezon.
46	4,650 ft from SL, 50 ft from WL sec. 11, T. 8 N., R. 25 W.	337	570	11 B	S. E. Frezon.
47	50 ft from NL, 50 ft from EL sec. 8, T. 8 N., R. 25 W.	352	210	234 A	B. R. Haley.
48	1,925 ft from SL, 150 ft from WL sec. 3, T. 8 N., R. 25 W.	339	255	298 A	B. R. Haley and S. E. Frezon.
50	850 ft from NL, 0 ft from EL sec. 9, T. 8 N., R. 25 W.	343	200	318 A	Do.
52	475 ft from NL, 4,150 ft from EL sec. 8, T. 8 N., R. 25 W.	343	328	99 A	B. R. Haley.
53	2,525 ft from NL, 4,025 ft from EL sec. 8, T. 8 N., R. 25 W.	358	210	240 A	Do.
55	1,150 ft from NL, 10 ft from EL sec. 8, T. 8 N., R. 25 W.	347	255	199 A	Do.
58	1,250 ft from NL, 3,950 ft from EL sec. 8, T. 8 N., R. 25 W.	348	185	239 A	Do.
82	3,400 ft from NL, 100 ft from EL sec. 3, T. 8 N., R. 26 W.	358	345	77 A	Do.
85	525 ft from SL, 50 ft from WL sec. 35, T. 9 N., R. 26 W.	362	258	2 B	W. L. Adkison.
86	500 ft from NL, 1,300 ft from EL sec. 2, T. 8 N., R. 26 W.	352	218	3 B	Do.
87	3,000 ft from NL, 50 ft from WL sec. 1, T. 8 N., R. 26 W.	360	275	234 A	B. R. Haley.
88	125 ft from NL, 2,550 ft from WL sec. 1, T. 8 N., R. 26 W.	356	173	2 B	W. L. Adkison.
89	1,775 ft from NL, 20 ft from WL sec. 1, T. 8 N., R. 26 W.	357	240	298 A	Do.
90	2,900 ft from NL, 1,250 ft from EL sec. 1, T. 8 N., R. 26 W.	368	230	281 A	B. R. Haley.
91	2,010 ft from SL, 125 ft from WL sec. 35, T. 9 N., R. 26 W.	388	262	1 B	Do.
92	1,700 ft from NL, 20 ft from WL sec. 1, T. 8 N., R. 26 W.	355	241	1 B	W. L. Adkison; 292-ft fault at depth of 180 ft.
93	1,825 ft from NL, 20 ft from WL sec. 1, T. 8 N., R. 26 W.	358	266	297 A	B. R. Haley.
94	2,880 ft from NL, 25 ft from EL sec. 3, T. 8 N., R. 26 W.	360	230	215 A	Do.
95	2,275 ft from NL, 25 ft from EL sec. 3, T. 8 N., R. 26 W.	368	286	43 B	W. L. Adkison; 175-ft fault at depth of 119 ft.
96	2,225 ft from NL, 25 ft from EL sec. 3, T. 8 N., R. 26 W.	368	242	At the top	B. R. Haley; 175-ft fault at depth of 122 ft.
97	300 ft from SL, 100 ft from EL sec. 31, T. 9 N., R. 25 W.	360	153	4 B	B. R. Haley.
98	2,150 ft from NL, 1,550 ft from WL sec. 6, T. 8 N., R. 25 W.	363	557	3 B	Do.
99	250 ft from NL, 75 ft from EL sec. 35, T. 9 N., R. 26 W.	353	221	5 B	W. L. Adkison.
100	2,550 ft from SL, 2,700 ft from WL sec. 36, T. 9 N., R. 26 W.	356	210	12 B	Do.
101	150 ft from NL, 1,300 ft from EL sec. 36, T. 9 N., R. 26 W.	354	134	1 B	Do.
103	150 ft from SL, 100 ft from WL sec. 31, T. 9 N., R. 25 W.	353	161	9 B	B. R. Haley.
104	2,275 ft from NL, 20 ft from WL sec. 36, T. 9 N., R. 26 W.	355	228	5 B	Do.
105	2,800 ft from NL, 450 ft from EL sec. 26, T. 9 N., R. 26 W.	363	55	2 B	B. R. Haley; no electrical log.
106	2,440 ft from NL, 2,640 ft from WL sec. 35, T. 9 N., R. 26 W.	359	263	2 B	B. R. Haley.
107	1,550 ft from SL, 430 ft from EL sec. 26, T. 9 N., R. 26 W.	355	104	5 A	B. R. Haley; no electrical log.
111	300 ft from SL, 630 ft from WL sec. 26, T. 9 N., R. 26 W.	380	189	1 B	W. L. Adkison.
112	675 ft from SL, 5 ft from WL sec. 25, T. 9 N., R. 26 W.	353	168	2 A	B. R. Haley; no electrical log.
123	20 ft from NL, 790 ft from WL sec. 32, T. 9 N., R. 25 W.	355	70	25 B	B. R. Haley.
124	2,550 ft from NL, 800 ft from WL sec. 32, T. 9 N., R. 25 W.	356	138	12 A	Do.
125	2,220 ft from NL, 3,475 ft from WL sec. 32, T. 9 N., R. 25 W.	352	167	7 A	Do.

TABLE 3.—*Description of shallow holes drilled by the Gulf Oil Corp. in the Coal Hill, Hartman, and Clarksville quadrangles*—Continued

Hole No. (pls. 1, 3)	Location	Reported ground elevation (ft)	Depth of hole (ft)	Bottom of hole (ft)	Remarks
126	2,275 ft from SL, 2,650 ft from EL, sec. 31, T. 9 N., R. 25 W.	354	156	8 B	B. R. Haley.
127	1,500 ft from NL, 1,350 ft from EL, sec. 28, T. 9 N., R. 25 W.	354	63	4 B	Do.
128	30 ft from NL, 30 ft from EL, sec. 34, T. 9 N., R. 25 W.	354	293	17 B	Do.
129	2,650 ft from NL, 20 ft from EL, sec. 34, T. 9 N., R. 25 W.	352	675	13 B	Do.
130	2,600 ft from NL, 2,050 ft from EL, sec. 34, T. 9 N., R. 25 W.	353	687	-------------	B. R. Haley; starts in McAlester Formation and ends in Atoka Formation; Hartshorne Sandstone faulted out; 290-ft fault at depth of 442 ft.
131	50 ft from NL, 2,650 ft from EL, sec. 34, T. 9 N., R. 25 W.	352	235	13 B	B. R. Haley.
132	50 ft from SL, 50 ft from WL, sec. 27, T. 9 N., R. 25 W.	350	245	29 B	Do.
133	2,500 ft from SL, 1,250 ft from WL, sec. 27, T. 9 N., R. 25 W.	351	128	10 B	Do.
134	300 ft from SL, 70 ft from EL, sec. 26, T. 9 N., R. 25 W.	352	380	--------------	B. R. Haley; starts in McAlester Formation and ends in Atoka Formation; Hartshorne Sandstone faulted out; 258-ft fault at depth of 332 ft.
135	2,650 ft from NL, 2,700 ft from WL, sec. 35, T. 9 N., R. 25 W.	348	365	295 A	B. R. Haley.
136	5,250 ft from NL, 2,300 ft from EL, sec. 35, T. 9 N., R. 25 W.	350	485	158 A	Do.
137	4,625 ft from SL, 1,460 ft from EL, sec. 27, T. 9 N., R. 25 W.	350	160	22 B	Do.
138	20 ft from SL, 2,625 ft from WL, sec. 23, T. 9 N., R. 25 W.	348	254	5 B	Do.
139	2,620 ft from NL, 20 ft from EL, sec. 35, T. 9 N., R. 25 W.	348	375	296 A	Do.
140	2,600 ft from SL, 2,230 ft from EL, sec. 26, T. 9 N., R. 25 W.	349	320	9 B	Do.
141	2,455 ft from NL, 2,690 ft from EL, sec. 25, T. 9 N., R. 25 W.	348	335	118 A	Do.
142	50 ft from SL, 125 ft from WL, sec. 24, T. 9 N., R. 25 W.	347	340	6 B	Do.
143	2,500 ft from NL, 25 ft from EL, sec. 25, T. 9 N., R. 25 W.	348	335	202 A	Do.
144	2,700 ft from NL, 2,800 ft from WL, sec. 30, T. 9 N., R. 24 W.	347	335	256 A	Do.
145	20 ft from NL, 75 ft from EL, sec. 25, T. 9 N., R. 25 W.	351	435	2 A	E. A. Merewether.
146	20 ft from SL, 50 ft from EL, sec. 25, T. 9 N., R. 25 W.	352	485	267 A	Do.
147	20 ft from SL, 3,030 ft from WL, sec. 30, T. 9 N., R. 24 W.	342	440	363 A	Do.
148	2,675 ft from SL, 2,430 ft from WL, sec. 31, T. 9 N., R. 24 W.	357	395	299 A	Do.
149	2,740 ft from SL, 1,490 ft from EL, sec. 36, T. 9 N., R. 25 W.	350	320	357 A	B. R. Haley.
150	1,730 ft from NL, 2,535 ft from EL, sec. 1, T. 8 N., R. 25 W.	345	595	23 B	Do.
151	10 ft from SL, 125 ft from EL, sec. 36, T. 9 N., R. 25 W.	355	320	238 A	Do.
152	2,550 ft from NL, 10 ft from EL, sec. 31, T. 9 N., R. 24 W.	356	530	253 A	Do.
153	500 ft from SL, 3,950 ft from WL, sec. 31, T. 9 N., R. 24 W.	340	272	353 A	Do.
154	3,680 ft from NL, 1,715 ft from EL, sec. 31, T. 9 N., R. 24 W.	360	725	13 B	Do.
155	175 ft from SL, 2,800 ft from WL, sec. 30, T. 9 N., R. 24 W.	349	440	343 A	Do.
156	2,620 ft from NL, 1,595 ft from WL, sec. 19, T. 9 N., R. 23 W.	331	330	356 B	Do.
157	2,993 ft from NL, 1,595 ft from WL, sec. 19, T. 9 N., R. 23 W.	329	238	4 B	Do.
158	2,818 ft from NL, 1,595 ft from WL, sec. 19, T. 9 N., R. 23 W.	330	315	--------------	B. R. Haley; starts in McAlester Formation and ends in Atoka Formation; Hartshorne Sandstone faulted out; 242-ft fault at depth of 212 ft.

TABLE 3.—*Description of shallow holes drilled by the Gulf Oil Corp. in the Coal Hill, Hartman, and Clarksville quadrangles*—Continued

Hole No. (pls. 1, 3)	Location	Reported ground elevation (ft)	Depth of hole (ft)	Bottom of hole (ft)	Remarks
159	2,758 ft from NL, 1,595 ft from WL, sec. 19, T. 9 N., R. 23 W.	331	260	--------------	B. R. Haley; starts in McAlester Formation and ends in Atoka Formation; Hartshorne Sandstone faulted out; 244-ft fault at depth of 187 ft.
160	4,380 ft from NL, 1,595 ft from WL, sec. 19, T. 9 N., R. 23 W.	332	601	--------------	B. R. Haley; starts in lowermost Savanna Formation and ends in Atoka Formation; Hartshorne Sandstone faulted out; 433-ft fault at depth of 473 ft.
161	4,180 ft from NL, 1,595 ft from WL, sec. 19, T. 9 N., R. 23 W.	332	450	--------------	B. R. Haley; starts in lowermost Savanna Formation and ends in Atoka Formation; Hartshorne Sandstone faulted out; 475-ft fault at depth of 328 ft.
162	3,980 ft from NL, 1,595 ft from WL, sec. 19, T. 9 N., R. 23 W.	332	217	1 B	B. R. Haley; 388-ft fault at depth of 138 ft.
167	4,120 ft from NL, 2,710 ft from WL, sec. 36, T. 9 N., R. 25 W.	353	485	169 A	B. R. Haley.
168	968 ft south of NE cor. sec. 1, T. 8 N., R. 25 W.	355	320	225 A	Do.
169	230 ft from NL, 60 ft from WL, sec. 32, T. 9 N., R. 24 W.	346	290	515 A	E. A. Merewether.
170	390 ft from NL, 2,740 ft from WL, sec. 36, T. 9 N., R. 25 W.	349	254	390 A	B. R. Haley.
171	3,960 ft from NL, 90 ft from WL, sec. 28, T. 9 N., R. 24 W.	344	711	15 B	Do.
172	2,390 ft from NL, 60 ft from WL, sec. 33, T. 9 N., R. 24 W.	344	350	300 A	E. A. Merewether.
173	4,520 ft from NL, 2,600 ft from WL, sec. 28, T. 9 N., R. 24 W.	345	450	235 A	Do.
174	120 ft from SL, 150 ft from WL, sec. 28, T. 9 N., R. 24 W.	335	425	311 A	Do.
175	870 ft from NL, 200 ft from WL, sec. 33, T. 9 N., R. 24 W.	325	385	346 A	Do.
176	4,100 ft from NL, 100 ft from WL, sec. 28, T. 9 N., R. 24 W.	339	320	411 A	E. A. Merewether; 6-ft fault at depth of 216 ft; 29-ft fault at depth of 278 ft.
177	2,500 ft from NL, 2,710 ft from WL, sec. 32, T. 9 N., R. 24 W.	341	355	347 A	B. R. Haley.
178	470 ft from SL, 30 ft from EL, sec. 20, T. 9 N., R. 24 W.	434	401	259 A	Do.
179	2,950 ft from NL, 495 ft from WL, sec. 29, T. 9 N., R. 24 W.	353	405	262 A	Do.
180	3,520 ft from NL, 1,980 ft from EL, sec. 29, T. 9 N., R. 24 W.	347	275	384 A	B. R. Haley; 57-ft fault at depth of 96 ft.
181	15 ft from SL, 1,330 ft from WL, sec. 20, T. 9 N., R. 24 W.	399	350	16 A	B. R. Haley; 130-ft fault at depth of 224 ft.
182	790 ft from NL, 400 ft from EL, sec. 29, T. 9 N., R. 24 W.	534	410	366 A	E. A. Merewether.
183	1,060 ft from NL, 180 ft from WL, sec. 29, T. 9 N., R. 24 W.	418	230	373 A	Do.
184	4,005 ft fron NL, 390 ft from WL, sec. 29, T. 9 N., R. 24 W.	352	352	342 A	Do.
185	1,320 ft fron SL, 1,820 ft from WL, sec. 30, T. 9 N., R. 24 W.	347	386	269 A	Do.
186	870 ft from SL, 1,820 ft from WL, sec. 30, T. 9 N., R. 24 W.	349	390	281 A	E. A. Merewether; 10-ft fault at depth of 90 ft; 36-ft fault at depth of 138 ft.
187	420 ft from SL, 1,820 ft from WL, sec. 30, T. 9 N., R. 24 W.	347	730	4 B	E. A. Merewether; 30-ft fault at depth of 507 ft; 30-ft fault at depth of 544 ft.
188	645 ft from SL, 1,820 ft from WL, sec. 30, T. 9 N., R. 24 W.	348	430	302 A	E. A. Merewether; 21-ft fault at depth of 278 ft; 40-ft fault at depth of 314 ft.
189	1,560 ft from NL, 1,270 ft from WL, sec. 28, T. 9 N., R. 24 W.	477	315	456 A	E. A. Merewether.
190	50 ft from NL, 1,600 ft from WL, sec. 28, T. 9 N., R. 24 W.	652	455	476 A	No lithologic log.

SILURIAN SYSTEM, ST. CLAIR LIMESTONE

The St. Clair Limestone of the Ozark Mountains is probably represented in well 16 by a unit which consists mainly of limestone and is about 175 feet thick. The limestone in the lower part of the unit, about 53 feet thick, is light gray, dense, and slightly cherty. Some fragments have pinkish tint. The upper part of the unit, about 122 feet thick, consists of more than 99 percent limestone that is very light to medium gray, dense to very finely crystalline, and slightly cherty. The upper part also contains a few thin beds of dark-gray slightly silty shale. Some of the limestone included in the upper part of the St. Clair in this area may be part of the overlying Penters Chert. The thickness of the St. Clair Limestone in well 16, however, is similar to thickness of the St. Clair in wells near the area of this report.

DEVONIAN SYSTEM, PENTERS CHERT

The Penters Chert in well 16 consists of medium-light-gray to medium-dark-gray limy dolomitic chert and is about 23 feet thick. The upper part of the Penters is probably faulted out of the section in this well. A regional map of the thickness of the Penters Chert (Frezon and Glick, 1959, pl. 24) indicates that the complete thickness of the formation in this area is about 150 feet.

DEVONIAN AND MISSISSIPPIAN SYSTEMS, CHATTANOOGA SHALE

The Chattanooga Shale probably is beneath the surface of the area of this report, but it has not been penetrated by the wells drilled for gas. The Chattanooga and overlying rocks of Mississippian age were removed by faulting from the section in well 16. The thickness of the Chattanooga in the mapped area is probably 50–60 feet (Frezon and Glick, 1959, pl. 25). It is 66 feet in a well near the south boundary of the Coal Hill quadrangle (Haley, 1961, p. 4) and 28 feet in a well near the south boundary of the Hartman quadrangle (Haley, 1968). Where penetrated by wells near the area, the Chattanooga consists mainly of grayish-black pyritic shale.

MISSISSIPPIAN SYSTEM

The rocks of Mississippian age were not completely penetrated by the wells in the area of this report. On the basis of regional evidence, Frezon and Glick (1959, pl. 26) indicated that the total Mississippian section in this area is less than 600 feet thick. They suggested that these rocks in this area are transitional between dominantly limestone to the north and shale to the south, and that these rocks thicken both northward and southward. The formations of the Mississippian System assumed to be present in this area are, in ascending order, the upper part of the Chattanooga Shale, the Boone Formation, the Moorefield Formation, the Ruddell Shale, the Batesville Sandstone, the Fayetteville Shale, and the Pitkin Limestone. These formations, if present, are probably different from their counterparts in the Ozark Mountains.

Six wells were drilled into rocks of Mississippian age—the Phillips Petroleum Co. South Clarksville 1 (well 8), in sec. 27, T. 10 N., R. 24 W.; the J. M. Huber Corp. Mabry 1 (well 48), in sec. 6, T. 8 N., R. 24 W.; the Arkansas Western Gas Co. M. Skod 1 (well 3), in sec. 31, T. 10 N., R. 25 W.; the Arkansas Western Gas Co. R. Floyd 1 (well 5), in sec. 33, T. 10 N., R. 25 W.; the Stephens, Inc. P. Sunderman Unit 1 (well 6), in sec. 35, T. 10 N., R. 25 W.; and the Stephens Production Co. B. E. Cobb 1 (well 28), in sec. 8, T. 9 N., R. 24 W. These rocks were classified by use of composite interpretive logs for wells 8 and 48, and electric logs for wells 3, 5, 6, and 28.

In well 8 the section is about 42 feet thick and is 30 percent limestone and 70 percent shale. The limestone is light to dark gray, argillaceous, very finely to very coarsely crystalline, and fossiliferous (pelecypods and crinoids). The shale is dark gray, slightly silty, and limy in part. The section in well 48 is about 216 feet thick and is 12 percent limestone and 88 percent siltstone and shale. The limestone is medium gray, argillaceous, dense to granular, and fossiliferous (crinoids and bryozoa) in part. The siltstone is medium to dark gray, limy, and very finely micaceous in part. Most of the shale is dark gray to grayish black, and some of it is silty, limy, micaceous, and pyritic. The most complete section in the area, interpreted from the electric log of well 3, is 264 feet thick and probably includes, in descending order, a limestone unit about 214 feet thick and a shale unit about 50 feet thick. The rocks of Mississippian age penetrated by wells 5, 6, and 28 are 65, 123, and 70 feet thick, respectively.

The interbedded limestone, shale, and siltstone of Mississippian age represented on the logs of these wells are probably correlative with the Pitkin Limestone and the underlying Fayetteville Shale. The sections from wells 8, 48, 5, 6, and 28 may be equivalent to parts of the Pitkin Limestone. The rocks exposed in well 3 may include the Pitkin Limestone and part of the Fayetteville Shale. No wells in the area of this report penetrated all the rocks of Mississippian age believed to be present in the subsurface.

PENNSYLVANIAN SYSTEM

MORROW SERIES

Rocks of the Morrow Series do not crop out but have been at least partially penetrated by 37 of the 51 wells in the area. The Morrow, the oldest series in the Pennsylvanian System, is overlain by the Atoka Series, and in this area it consists of the Hale Formation and the overlying Bloyd Formation. The stratigraphic nomenclature of the Morrow Series in the Ozark Mountains and the Arkansas Valley is listed in table 1. The rocks of Morrow age in the area of this report are correlative with the Hale Formation and the Bloyd Formation but cannot be divided into these formations with certainty. The lithology of the upper part of the Hale Formation in this area differs enough from the lithology of the upper part of the Hale in the Ozark Mountains to preclude the selection of a common upper boundary. The Hale Formation is composed of two members, the Cane Hill and the overlying Prairie Grove, separated by an unconformity. The Cane Hill Member can be distinguished from the younger units of the Morrow Series and is described separately in this report. The Prairie Grove Member of the Hale Formation and the Bloyd Formation are described as a single unit.

The lower and upper boundaries of the Morrow Series are unconformities where exposed in the Ozark Mountains and may be unconformities in the Arkansas Valley. The selection of the lower and upper limits of the Morrow in this area is based, respectively, on the presence of limy rocks correlative with the Pitkin Limestone of Mississippian age and on the presence of clastic rocks and beds of bentonite typical of the lowest part of the Atoka Formation of Pennsylvanian age.

The Morrow Series in the mapped area is composed mainly of shale, sandstone, and siltstone, but it also includes limestone units. The thickness of the Morrow Series in this area, where measured, ranges from about 820 to about 955 feet. Regional studies (E. E. Glick, written commun., 1964) indicate that the thickness of the Morrow Series increases toward the south and southeast in the Arkansas Valley. The thicknesses of the Morrow Series in the area of this report generally correspond to those in the region as a whole.

The most complete stratigraphic sections of Morrow age are represented on the logs of the Arkansas Western Gas Co. R. Floyd 1 (well 5) and the Stephens, Inc. P. Sunderman Unit 1 (well 6), in the Coal Hill gas field (pl. 3), the Phillips Petroleum Corp. South Clarksville 1 (well 8), the Stephens Production Co. B. E. Cobb 1 (well 28), the J. M. Huber Corp. Mabry 1 (well 48), and the Gulf Oil Corp. Ragon 1 (well 42). The Morrow age rocks in wells 5 and 6 are about 850 and 820 feet thick, respectively, and the sections are complete. In well 8 the rocks of Morrow age are faulted, and about 100 feet of section is missing. The section remaining, about 725 feet thick, consists of approximately 43 percent shale, 32 percent siltstone, 15 percent sandstone, and 10 percent limestone. The rocks of Morrow age in well 28 are unfaulted and are about 868 feet thick. In the Mabry well (well 48) the section is about 855 feet thick, and about 100 feet was removed by faulting. The rocks are composed of about 49 percent shale, 11 percent siltstone, 29 percent sandstone, and 11 percent limestone. The Ragon well (well 42) probably failed to completely penetrate the rocks of Morrow age by 10–100 feet. There the section is not faulted, it is 801 feet thick, and it consists of about 24 percent shale, 7 percent siltstone, 67 percent sandstone, and 2 percent limestone.

The stratigraphic units of the Morrow Series in this area are not uniform in either thickness or lithology. In the Altus and Coal Hill gas fields several lithologic units within the Morrow are distinctive enough to be recognized on the electric logs of the closely spaced gas wells. However, these lithologic units cannot be identified with certainty in wells in other parts of the area of this report. The dissimilarity of the sections in the area probably results from facies changes and from channeling associated with unconformities at the top of and within the Morrow Series. The sandstone units in the Ragon well (well 42), distinctive in abundance and thickness, may grade laterally into other lithologies in other wells and represent a change in the environment of deposition, or they may be locally thicker equivalents of sandstones in other wells and represent a deeper part of a standstone-filled channel.

Cane Hill Member of Hale Formation

Rocks in the lower part of the Morrow Series, correlative with the Cane Hill Member of the Ozark Mountains, were penetrated by wells 5, 6, 8, 28, 42, and 48, but they are missing from well 16 because of faulting. The Cane Hill Member in these wells consists of shale, siltstone, sandstone, and limestone and ranges in thickness from about 275 to about 340 feet. The thickness of the Cane Hill is about 285 feet in well 5, about 275 feet in well 6, about 330 feet in well 28, and about 340 feet in well 48. In well 8 the Morrow Series is faulted, and in well 42 the base of the Cane Hill is below the bottom of the well.

The lithology of these rocks, where penetrated by wells 8, 42, and 48, is depicted on plate 2. The Cane Hill Member in well 48 is 70 percent dark-gray to grayish-black shale, 15 percent light- to medium-gray slightly limy siltstone, and 15 percent light-gray slightly limy very fine grained sandstone. The part of the Cane Hill in well 8 consists of medium-light gray to medium-dark-gray very finely sandy slightly limy siltstone, dark-gray slightly silty shale, and light- to dark-gray very finely sandy finely to very coarsely crystalline limestone. The Cane Hill in well 42 consists of medium- to dark-gray siltstone that is in part slightly limy, and dark-gray shale. The drill cuttings from wells 5, 6, and 28 were not examined.

Prairie Grove Member of Hale Formation and Bloyd Formation Undivided

The unit composed of the Prairie Grove Member of the Hale Formation and the Bloyd Formation is most complete in wells 5, 6, 8, 28, 42, and 48. In these wells the unit consists of sandstone, shale, siltstone, and limestone and ranges in thickness from about 538 to about 752 feet. The thickness is about 565 feet in well 5, about 545 feet in well 6, about 538 feet in well 28, and about 752 feet in well 42. In well 48 the unit is about 515 feet thick, but an additional 100 feet was removed by faulting. A fault prevented the determination of the thickness in well 8.

The Prairie Grove and Bloyd unit in the mapped area commonly consists of a thick basal sandstone overlain by interbedded shale, siltstone, sandstone, and limestone. The lithology of the Prairie Grove and Bloyd in wells 8, 42, and 48 is depicted on plate 2. Where penetrated by well 42 the unit is 21 percent dark-gray shale, commonly silty and micaceous; 5 percent medium-gray very finely sandy or argillaceous micaceous siltstone; 71 percent light-gray very fine to fine-grained sandstone that contains medium to coarse sand grains in part and is silty, limy, and quartzose in part; and 3 percent light- to medium-gray, dense to granular limestone that is very finely sandy in places. The percentage of sandstone in the unit in this well is probably unusually large. The part of the Prairie Grove and Bloyd unit in well 8 is composed of dark-gray silty shale; light-gray to medium-dark-gray siltstone that is limy in part and very finely sandy in part; light-gray to medium-dark-gray limy very fine to fine-grained sandstone that is silty in places; light-gray to medium-dark-gray limy, fine- to medium-grained sandstone containing scattered coarse and very coarse grains; and light-gray to medium-dark-gray slightly very finely to finely sandy, dense to very coarsely crystalline limestone. In well 48 the unit is generally composed of dark-gray very finely micaceous shale; light- to medium-gray very finely micaceous siltstone, argillaceous in part and slightly limy in part; very light to light-gray limy very fine to fine-grained sandstone; and light- to dark-gray sandy dense to granular limestone.

ATOKA SERIES, ATOKA FORMATION

The rocks of the Atoka Series in Arkansas constitute the Atoka Formation. The Atoka Formation is separated from the overlying Hartshorne Sandstone by a disconformity and from the underlying Bloyd Formation by an unconformity. The top of the Atoka Formation was traced into the area of this report by surface mapping from the adjacent Knoxville quadrangle to the east (Merewether, 1967). The base of the formation in the subsurface is generally the base of the first sandstone above rocks typical of the Morrow Series. Identification of the base is commonly aided by the presence of a distinctive thin bed of bentonite, generally less than 80 feet above the basal sandstone of the Atoka (Frezon and Schultz, 1961).

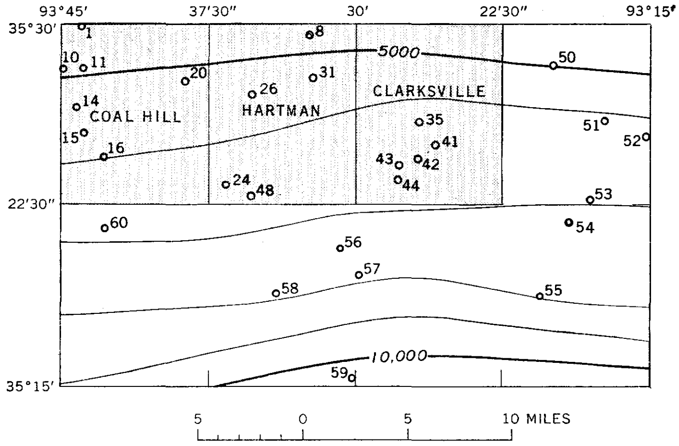
The Atoka Formation in the mapped area is composed mostly of shale, siltstone, and sandstone. It ranges in thickness from about 4,400 feet at the northwest corner of the area, to about 7,000 feet, at the southeast corner of the area.

Rocks of the Atoka Formation are exposed along the east and north boundaries and in the northwestern part of the area. Some of the Atoka was penetrated by all of the 51 wells in the area, and the base of the formation was probably reached in 37 of them. The wells most useful in studying the stratigraphy of the Atoka are the Humble Oil and Refining Co. Mo-Pac Unit 1 (well 1), Phillips Petroleum Co. South Clarksville 1 (well 8), Arkansas Western Gas Co. H. G. Sullivan 1 (well 13), Murphy Corp. Altus Gas Unit 1 (well 14), Humble Oil and Refining Co. H. L. Hembree Unit 1 (well 16), Humble Oil and Refining Co. D. L. Evans 1 (well 20), Stephens Production Co. W. H. Hooten 1 (well 31), wells 24, 32, 33, 46, 47, and 48 in the Scranton gas field, and wells 37 through 44 in the Spadra gas field. The importance of these wells to this report results from their location and depth and the type and completeness of their well logs.

The Atoka Formation is mainly shale, siltstone, and sandstone, but it includes a few thin beds of coal, limestone, and bentonite. Stratigraphic units within the Atoka generally are not consistent in either thickness or composition throughout this area. Representative variations in the lithology and thickness are depicted on plate 2. The shale is medium gray to grayish black and is commonly silty and micaceous. The siltstone is mostly light gray to dark gray, argillaceous to quartzose and sandy, and generally micaceous and well indurated. Most of the sandstone is very light gray to medium dark gray, very fine to fine grained, and silty; a small percentage is medium-grained and contains scattered coarse to very coarse grains. The sand grains are subangular to rounded; the medium and coarse grains are the most rounded. The sandstones are quartzose in part and argillaceous in part, and most are well indurated. Pyrite is a common accessory mineral in the Atoka, and iron-rich concretions and fossil plant fragments are scattered through the formation. A few beds of clastic rocks are slightly limy; calcium carbonate is most common in the coarse-grained sandstones. Limestone makes up less than 1 percent of the Atoka and occurs as thin and probably lenticular beds. The limestones are medium gray to medium dark gray, dense to coarsely crystalline, commonly slightly sandy, and slightly fossiliferous. In the area of this report the Atoka includes at least two thin beds of bentonite. The two beds are widespread, and each generally occurs near a correlative unit in the formation. The lower of the two ranges from about 80 to about 270 feet above the base of the Atoka, and the upper, from about 670 to about 1,050 feet above the base. The bentonite is mainly very light gray to greenish gray and soft and flaky and has a waxy or pearly luster; it commonly contains very fine dolomite crystals.

The thickness of the Atoka ranges from 4,493 feet in well 1, near the northwest corner of the area, to 6,605 feet in well 44, in the southeastern part of the area. The thickness of the Atoka Formation in the Coal Hill, Hartman, and Clarksville quadrangles and adjacent 7½-minute quadrangles to the east and south is summarized in figure 2. The formation, where penetrated by well 1 (pl. 1), is 48 percent shale, 32 percent siltstone, and 20 percent sandstone. In well 20 the Atoka is about 5,095 feet thick and is 41 percent shale, 42 percent siltstone, and 17 percent sandstone. In well 16 it is 5,995 feet thick and is 48 percent shale, 33 percent siltstone, and 19 percent sandstone. In well 48 the formation is probably about 6,540 feet thick, including 520 feet of section removed by faulting, and, excluding the missing section, is 54 percent shale, 27 percent siltstone, and 19 percent sandstone. In well 43 the Atoka is approximately 6,585 feet thick, including 790 feet of section removed by faulting, and, excluding the missing section, is 51 percent shale, 28 percent siltstone, and 21 percent sandstone.

In the report area the Atoka Formation can be divided, very generally, into three parts. The lower part, about 700–1,000 feet thick, extends from the base of the formation to the uppermost of the two common bentonite beds or, where the bentonite is missing, to an equivalent position on the log. The middle part of the Atoka, about 1,800–2,600 feet thick, extends from the upper bentonite bed to approximate depths of 1,470 feet in well 1, 2,017 feet in well 14, 2,762 feet in well 16, 3,210 feet below the Hartshorne in the Scranton gas field,



LIST OF SELECTED WELLS

1. Humble Oil and Refining Co. Mo-Pac Unit 1
8. Phillips Petroleum Co. South Clarksville 1
10. J. M. Huber Corp. Kramer 1
11. Arkansas Western Gas Co. Post 1
14. Murphy Corp. Altus Gas Unit 1
15. Humble Oil and Refining Co. Western Coal Co. 1
16. Humble Oil and Refining Co. H. L. Hembree Unit 1
20. Humble Oil and Refining Co. D. L. Evans 1
24. J. M. Huber Corp. Estep 1
26. Stephens Production Co. B. Cater 1
31. Stephens Production Co. W. H. Hooten 1
35. Stephens Inc. A. C. Brown 1
41. Gulf Oil Corp. Spadra Bottoms 1
42. Gulf Oil Corp. Ragon 1
43. Gulf Oil Corp. Arkansas Real Estate Co., Inc., 1
44. Wheeler and Ryan Arkansas Minerals Corp. 1
48. J. M. Huber Corp. Mabry 1
50. Arkansas-Oklahoma Gas Co. Wilkins 1
51. Gulf Oil Corp. J. J. Bauman 1
52. Gulf Oil Corp. Johnston Heirs 1
53. Gulf Oil Corp. W. H. Tackett 1
54. Steve Gose Whorton Unit 1
55. Gulf Oil Corp. J. W. Roberts 1
56. Humble Oil and Refining Co. Reinhart and Donovan Unit 1
57. Western Natural Gas Co. R. Gray 1
58. Gulf Oil Corp. A. W. McElroy 1
59. Sinclair Oil and Gas Co. Federal-Smith 1
60. Gulf Oil Corp. R. Hembree 1

FIGURE 2.—Thickness, in feet, of the Atoka Formation in the Coal Hill, Hartman, and Clarksville quadrangles and vicinity.

2,470 feet below the Hartshorne in the Union City gas field, and 2,900–3,100 feet below the Hartshorne in the Spadra gas field. The upper part, about 2,000–3,200 feet thick, extends from the top of the middle part to the base of the Hartshorne Sandstone. The lower and upper parts of the Atoka are similar; however, plant fossils and coal are common in the upper part but sparse in the lower part. The middle part generally consists of thick units of mainly sandstone and siltstone, and thin units of shale. The grain size of some of the sandstone and siltstone units decreases from the top to the bottom of the unit—ideally from sandstone near the top through silty sandstone, sandy siltstone, and siltstone, to shale at the bottom.

The part of the Atoka Formation that crops out in the area is about 400 feet thick. Shale, siltstone, and thin sandstone units in the upper part of the Atoka are well exposed on the steeper slopes beneath the Hartshorne Sandstone along roads in sec. 35, T. 10 N., R. 24 W., in sec. 3, T. 9 N., R. 25 W., and in sec. 1, T. 9 N., R. 26 W.

The best exposures of the thick sandstone in the Atoka are near the tops of the ridges in the SW¼ sec. 30, T. 10 N., R. 22 W., and in the NE¼ sec. 36, T. 10 N., R. 23 W. The exposed shale is generally dark gray but weathers grayish orange, is very finely micaceous, and is generally in beds less than 1 inch thick commonly in units as much as 35 feet thick. Most of the shale is in thick homogeneous units, but units of interbedded thin ripple-marked siltstone or sandstone and shale are common. The exposed siltstone is mainly medium to medium dark gray and weathers yellowish orange; it is argillaceous to slightly sandy, and micaceous. The siltstone is generally in beds about 1–6 inches thick, and it may be interlaminated with shale or it may be in units as much as 20 feet thick. Units of siltstone are medium to thin bedded and evenly to unevenly bedded and commonly display ripple marks on the bedding surfaces. The exposed sandstone is very light gray to medium gray, and where weathered it is yellowish gray, orange gray, reddish gray, and brownish gray. The sandstone is generally very fine to fine grained, silty, and micaceous, but the thickest units are commonly fine grained with scattered medium grains. Units composed predominantly of sandstone are as much as 70 feet thick. The sandstone is thin bedded to massive, is evenly to unevenly bedded, and may be lenticular. The sandstone in the thick beds tends to be coarser grained than that in the thin beds. Much of the unevenly bedded sandstone is foreset bedded, and the rest has ripple-marked surfaces. Some of the lower contacts of the sandstone beds are gradational but others are sharp. The sharp lower contact of many beds outlines channels and intersects the bedding of the underlying units.

Zone S, depicted on plate 2 in the middle of the Atoka, includes in most places a sandstone unit and an underlying shale unit. The two units are intergradational. The grain size of these rocks, in general, decreases from the top to the bottom of the zone. Zone S crops out in the Boston Mountains, a few miles to the north (Glick, Haley, and Merewether, unpub. data) but is not exposed in the area of this report. The zone has been penetrated by most of the wells in the area and is correlative throughout the area. The sandstone unit in zone S of this report is probably continuous with the sandstone unit of zone S in the Knoxville quadrangle (Merewether, 1967). Zone S of this report, in contrast with Zone S of the Knoxville quadrangle, includes the shale unit underlying the sandstone unit. The base of zone S was redefined in this area because the sandstone unit grades into the shale unit, and the base of the shale is a distinctive and widespread horizon. The sandstone in zone S is probably continuous with the Self sandstone of local usage, as used by the Fort Smith Geological Society Stratigraphic Committee (1960), but is not continuous with the Tackett sandstone of local usage of that committee as indicated by Merewether (1967). The Tackett sandstone, where penetrated by the Gulf Oil Corp. W. H. Tackett 1 well in the Knoxville quadrangle to the east, is about 700 feet above the Self sandstone.

The sandstone of zone C, exposed in the northeastern part of the area of this report (sec. 30, T. 10 N., R. 22 W., and secs. 25 and 36, T. 10 N., R. 23 W.), is a good example of the thick units of sandstone in the upper part of the Atoka. Zone C is easily recognized and is widespread in quadrangles east of the area (Merewether, 1967), but it cannot be identified with certainty on the surface westward across the report area. Some wells in the Spadra gas field, in the central part of the Clarksville quadrangle, have penetrated a thick sandstone unit correlative with zone C and, using electric logs, this interval can be traced westward in the subsurface to the Alix gas field. Between the Spadra and Scranton gas fields zone C changes from sandstone and siltstone with scattered thinner beds of shale to shale with scattered thinner beds of siltstone and a few subordinate beds of silty sandstone. Where exposed the sandstones in zone C are generally light gray to light brownish gray; they weather to shades of reddish or yellowish gray. They are generally very fine to fine grained but contain scattered medium grains where massive and are medium bedded to massive and regularly to irregularly bedded with foreset bedding. The zone is as much as 70 feet thick and includes thick beds in channels, the fossilized limbs or roots of plants, and several discontinuous stringers of coal within 3 feet of its base.

Invertebrate fossils were not found in the part of the Atoka Formation exposed in the area, but a few were found in samples of drill cuttings from several of the wells. The invertebrate fossils in the Atoka are pelecypods, gastropods, cephalopods, ostracodes, bryozoans, crinoids, and brachiopods. These fossils apparently are not restricted to any part of the Atoka or to any rock type, but the greatest number and variety are in shale. The fossils are slightly more common in two parts of the formation: the lower 1,000 feet of the Atoka Formation includes scattered fossils in about half of the wells, and a zone of dark-gray shale and limy siltstone and sandstone in the upper part of the formation contains fossils in slightly more than half of the wells. Fossils in this part of the Atoka were penetrated in well 8 at a depth of 1,415 feet, in well 16 at 1,760 feet, in well 20 at 1,426 and 1,470 feet, in well 48 between 2,945 and 3,100 feet, and in well 34, in the Spadra gas field, between 2,000 and 2,100 feet. Fossils were also found in several other wells in the Spadra gas field.

Plant fossils are also preserved in rocks of the Atoka Formation. Casts of limbs or roots were found in a sandstone in the SW¼ sec. 30, T. 10 N., R. 22 W., and smaller parts of fossil plants were found in drill cuttings. The fossils in the drill cuttings occur mostly in dark-gray shales in the upper half of the Atoka.

Coal, mostly in thin and probably lenticular beds, composes less than 1 percent of the Atoka and is largely confined to the upper part of the formation. Coal was found in a few samples from most wells, but none of the beds persist throughout the area. The most widespread coal is at a depth of 976 feet in well 8, 668 feet in well 14, 1,167 feet in well 16, 2,297 feet in well 48, 2,177 feet in well 46, and 1,267 feet in well 39, which is in the Spadra gas field. Coal was also penetrated in three other wells in the Spadra gas field. Coal in the Atoka Formation is exposed in three parts of the area. In the SW¼ sec. 30, T. 10 N., R. 22 W., in the northeastern part of the Clarksville quadrangle, stringers of coal crop out within a sandstone unit. Another coal, about 4 inches thick, is exposed in the NE¼ sec. 27, T. 10 N., R. 24 W., near the middle of the north border of the area. The thickest coal of the Atoka exposed in the area crops out at several places in and near secs. 3 and 4, T. 9 N., R. 25 W., and is 6–9 inches thick. The coal penetrated by well 20 at a depth of 387 feet may be the coal that crops out in the northwestern part of the area.

DES MOINES SERIES, KREBS GROUP

The Krebs Group consists of, from oldest to youngest, the Hartshorne Sandstone and the McAlester, Savanna, and Boggy Formations. The upper part of the Savanna Formation and all of the Boggy Formation do not occur in the area of this report, but the other units of the Krebs Group constitute most of the exposed rocks of Pennsylvanian age. The boundaries of these formations were mapped into this area from the Knoxville quadrangle to the east (Merewether, 1967) and the Paris, Scranton, and New Blaine quadrangles to the south (Haley, 1961, 1968). Many rocks of the Krebs Group and the upper part of the underlying Atoka Formation are so similar in this area that differentiation is difficult. The widespread Lower Hartshorne coal bed, near the base of the McAlester Formation, and the distinctive basal sandstone of the Savanna Formation are the most easily recognized units.

HARTSHORNE SANDSTONE

The boundary between the Hartshorne Sandstone and the underlying Atoka Formation is a disconformity. The contact of the Hartshorne with the overlying McAlester Formation is conformable. The determination of the upper boundary of the Hartshorne is facilitated by the presence of the Lower Hartshorne coal bed near the base of the McAlester Formation.

The Hartshorne in most parts of the mapped area is mainly very fine to fine-grained sandstone. Measured thicknesses of the formation in the area range from about 24 feet, in shallow hole 95 near the southwest corner of the Coal Hill quadrangle (sec. 3, T. 8 N., R. 26 W.), to about 85 feet, in well 46 near the southwest corner of the Hartman quadrangle (sec. 12, T. 8 N., R. 25 W.).

The Hartshorne Sandstone is well exposed at many places in the area of this report. Good outcrops occur along the rim of the large mesa in secs. 34 and 35, T. 10 N., R. 26 W., secs. 1, 2, 3, 10, 11, 12, T. 9 N., R. 26 W., and sec. 7, T. 9 N., R. 25 W., in the northwestern part of the area, along the rim of the large mesa northwest of the town of Hartman, in the vicinity of well 7 near the middle of the north boundary of the area, and along the crest of the ridge in secs. 26 and 35, T. 10 N., R. 23 W. The apparently great resistance of the Hartshorne Sandstone to erosion results in anticlinal ridges, as along the Union City anticline, and synclinal depressions, as along the Pond Creek Hills syncline, where the Hartshorne constitutes the surface in large areas. The Hartshorne has been penetrated by many of the wells and shallow holes in the three quadrangles and is one of the few beds that can be correlated between surface exposures and well logs with certainty. Drill cuttings from nine of the wells and nine of the shallow holes penetrating the Hartshorne were examined. The wells are numbers 1, 16, 32, 34, 37, 39, 43, 46, and 48. The shallow holes are numbers 2, 21, 95, 100, 123, 132, 137, and 150. The stratigraphic horizon used for the structure contour lines on plate 3 is the base of the Hartshorne Sandstone.

The Hartshorne Sandstone in most places consists of sandstone interlayered with scattered thin beds of shale, but in a few places it consists mainly of siltstone. The sandstone is generally very light gray to medium gray and, where weathered, is pinkish gray, pale reddish brown, light olive gray, and medium brownish gray. The sand is generally very fine to fine grained and is commonly mixed with silt. The sandstone in the Hartshorne is commonly micaceous and includes chert grains, pyrite, iron-rich and limy concretions, fossil plant impressions, and coal stringers in a few areas. The sandstone is generally well indurated and rarely slightly limy. The siltstone of the Hartshorne is mostly light to medium gray and micaceous and contains very fine sand; it is rarely medium to dark gray, argillaceous, and micaceous. In a few places it contains scattered plant fossils. The shale in the Hartshorne is dark gray, micaceous, and, in places, silty.

The Hartshorne is thin bedded to massive, regularly to irregularly bedded, and lenticular in places. Crossbedding, foreset bedding, and ripple marks are common. The base of the formation is generally sharp and, in many places, is irregular, outlining channels that intersect the bedding of the underlying units. The sandstone in the channels, at some localities, contains scattered shale pebbles and irregular stringers of shale. The lower surface of the lowest sandstone bed in the formation has current flow casts at several places.

MCLESTER FORMATION

The McAlester Formation conformably overlies the Hartshorne Sandstone and is overlain by the Savanna Formation. The McAlester and Savanna Formations are generally conformable but are separated locally by a disconformity.

The McAlester is mostly shale but includes sitlstone, sandstone, and coal. Measured thicknesses of the formation in the mapped area range from about 560 feet to about 670 feet.

The McAlester Formation is widely distributed at the surface through the central part of the area but is not generally well exposed. The part of the McAlester that crops out consists mainly of shale and thin beds of siltstone and sandstone, usually forms valleys and low ridges, and is commonly partly covered with alluvium and terrace deposits. Most of the formation crops out in scattered areas near Jamestown, south of Clarksville. The lower part of the McAlester is well exposed in the strip mines south of Coal Hill, east and northeast of Hartman, and west and northeast of Clarksville. Rocks of the McAlester were penetrated by several of the wells and many of the shallow holes in the area.

The McAlester Formation is composed mainly of shale, but contains smaller amounts of siltstone and sandstone and a few coal beds. The shale is medium gray to grayish black, but generally it is dark gray; it is commonly silty and micaceous and in many places contains scattered pyrite crystals and plant fossils. Invertebrate fossils are sparse. The siltstone is light gray to dark gray, but it is most commonly medium gray. Most of the siltstone is micaceous. It ranges in composition from argillaceous to very finely sandy, and some is slightly limy. In a few places it contains scattered phosphatic pellets and plant fossils. The siltstone is commonly well indurated. The sandstone of the McAlester is generally light to medium gray and weathers yellowish gray, grayish red, or brownish gray; it is very fine grained, silty, micaceous, and well indurated. It is argillaceous in part and limy in part and includes plant and invertebrate fossils in a few places. Coal, mainly in thin lenticular beds, is scattered through the McAlester Formation. The thickest and most widespread coal bed in the report area is the Lower Hartshorne coal, near the base of the formation.

The McAlester Formation in the southern part of the area, where complete sections have been penetrated, ranges in thickness from about 560 to about 670 feet. The thickness of the McAlester apparently increases irregularly toward the southwest in part of this area. In well 43, in the southern part of the Clarksville quadrangle, the formation is 560 feet thick and is nearly 91 percent shale, 7 percent silstone, 2 percent sandstone, and less than 0.5 percent coal. The McAlester in shallow hole 23, about 1½ miles northwest of well 43, is 606 feet thick and is nearly 92 percent shale, 5 percent siltstone, 3 percent sandstone, and less than 0.5 percent coal. The McAlester, where penetrated by shallow hole 171 in sec. 28, T. 9 N., R. 24 W., is 617 feet thick and is nearly 87 percent shale, 12 percent siltstone, less than 0.5 percent sandstone, and about 1 percent coal. The formation in the south-central part of the area where penetrated by well 48 is 633 feet thick and is nearly 82 percent shale, 6 percent siltstone, 12 percent sandstone, and less than 0.5 percent coal.

The shale of the McAlester is in beds as much as one-fourth-inch thick and in units as much as 300 feet thick. The shale may be in units a few feet thick and interbedded with siltstone. The siltstone is in beds as much as 6 inches thick and in units as much as 55 feet thick. In the units of interbedded siltstone and shale, the beds of siltstone are as much as 6 inches thick. The siltstone is generally irregularly bedded and is partly crossbedded and partly ripple marked. The sandstone of the McAlester Formation is in beds as much as 4 feet thick, in units as much as 25 feet thick, and is generally irregularly bedded. Crossbedding, foreset bedding, ripple-marked bedding surfaces, and sediment-flow and slump features occur in these sandstones. The lower contact of the sandstone units is generally sharp and in a few places outlines channels. The lower surface of sandstone units rarely has current flow casts. The sandstone units of the McAlester are not consistent in either lithology or thickness in this area but grade laterally into siltstones or are lenticular. A few beds of underclay, as much as 5 inches thick, crop out in sec. 15, T. 9 N., R. 23 W. The underclay is very light to medium gray and underlies coal and carbonaceous shale.

Invertebrate fossils are not abundant in the McAlester but have been found in drill cuttings and outcrops. Dark-gray shale apparently is the most fossiliferous rock type, and it contains crinoids, brachiopods, pelecypods, and ostracodes. Some of the siltstone contains casts of borings created by bottom-dwelling organisms. Invertebrate fossils occur sparsely in sandstone of the McAlester; however, in sec. 9, T. 9 N., R. 24 W., a weathered iron-rich sandstone contains crinoids, brachiopods, horn corals, pelecypods, gastropods, and trilobites. Mackenzie Gordon, Jr., of the U.S. Geological Survey, examined these fossils and identified the following forms: *Lophophyllidium* sp., zaphrentoid coral, crinoid columnals, *Derbyia*? sp., *Beecheria*? sp., *Hustedia mormoni* (Marcou), *Composita subtilita* (Hall)? *Aviculopecten* sp., *Limipecten*? sp., pelecypod indet., *Naticopsis* sp., *Platyceras* sp., gastropod indet., and *Ditomopyge* sp. Another fossiliferous sandstone, possibly correlative with the first described, crops out in the northern part of the Clarksville quadrangle, in the N½ SE¼NW¼ sec. 34, T. 10 N., R. 23 W. A pelecypod obtained from a coal mine near Spadra, in sec. 24, T. 9 N., R. 24 W., was identified as *Pleurophorus subcostatus*? by G. H. Girty of the U.S. Geological Survey (Collier, 1907, p. 31). This fossil was probably collected from shale or siltstone in the lower part of the McAlester Formation.

Poorly preserved or incomplete plant fossils are scattered through much of the shale, siltstone, and sandstone of the McAlester. Abundant well-preserved plant fossils, mainly leaves and parts of ferns, are common in the lowest part of the formation, above and between the two benches of the Lower Hartshorne coal bed. These fossils are generally well exposed in the waste piles of strip mines and occur in the shale and siltstone that overlie or separate the Hartshorne coals. One of the best fossil localities is the strip mine in the SE¼ sec. 35, T. 10 N., R. 24 W. Rocks of the McAlester rarely contain the larger parts of fossil trees, but the cast of a log was found in a strip mine in the S½ sec. 3, T. 9 N., R. 24 W.

The Lower Hartshorne coal of the McAlester Formation is the thickest and most widespread coal bed in the area of this report. However, it has been removed by erosion from the approximate north half of the Coal Hill quadrangle, from a large part of the north half of the Hartman quadrangle, and from areas in the northeast and southeast quarters of the Clarksville quadrangle. The Lower Hartshorne coal is 2½–19 feet above the top of the Hartshorne Sandstone and is separated into two benches, commonly of about the same thickness, by a parting of shale or siltstone. The total thickness of the two benches of coal ranges from less than 14 inches, along the south boundary of the Coal Hill quadrangle, to 64 inches, near the south boundary of the Hartman quadrangle in sec. 5, T. 8 N., R. 24 W. The total thickness of the two benches in the extensively mined areas (pl. 3) is about 32–63 inches. The thickness of the parting, which ranges from about 1 inch to about 20 feet but is less than 12 inches in much of the coal-bearing area, apparently changes rapidly and without uniformity in either rate or direction of thickening, at least in the approximate south half of the report area. In the north half of the report area the parting is generally thicker; it is 20 feet thick near the north boundary of the Hartman and Clarksville quadrangles. Where the parting is several feet thick, the upper bench of coal in some places has not been mined and in other places it has been discarded. The coal thickness lines on plate 3 represent only the lower bench where the upper bench has not been utilized. Other coal beds in the McAlester Formation do not exceed 8 inches in thickness, where exposed, and are probably discontinuous in the mapped area.

Two samples of shale from the lower part of the McAlester Formation were analyzed for clay minerals, carbon, and selected trace elements (table 4) as part of an investigation of depositional environments.

TABLE 4.—*Clay-mineral, carbon, and selected trace-element contents of shale from the McAlester Formation, Hartman quadrangle*

[All figures in percent, except as noted. Clay-mineral content determined by X-ray diffraction; analysts, H. C. Starkey and T. Manzanares. Carbon content determined using induction furnace and a gasometric procedure; analyst, I. C. Frost. Trace-element content determined by quantitative spectrographic analyses; analyst, Nancy Conklin. Samples collected in northwestern part of a strip mine in SW¼SW¼ sec. 32, T. 10 N., R. 24 W.]

Sample	4	5
Clay-mineral content (approximate)		
Quartz	33	42
Mica [1]	24	29
Kaolinite	29	19
Chlorite	11	8
Mixed layered mica-vermiculite [2]	2	--------
Vermiculite (aluminum interlayered) [3]	1	--------
Mixed layered chlorite-mica		1
Mixed layered montmorillonite-mica		1
Carbon content		
Organic carbon	2	0.6
Mineral carbon	.03	<.01
Total carbon	2.03	.62
Trace-element content		
B	0.010	0.0095
Cr	.019	.015
Ga	.0028	.0024
Ni	.0064	.0039
Li	.0089	.0091
Rb	.014	.016

[1] Mica is muscovite plus illite.
[2] Trioctahedral vermiculite.
[3] Nearer to being dioctahedral vermiculite.

4. Dark-gray shale from first 6 in. of rock overlying the Lower Hartshorne coal bed; contains fossil plant fragments 0.1–2.5 in. long.
5. Medium-gray shale from exposure about 12 in. below the Lower Hartshorne coal bed; contains abundant fossil plant fragments.

SAVANNA FORMATION

The Savanna Formation overlies and, in general, is conformable with the McAlester Formation. However, the two formations are separated by a local disconformity where the basal unit of the Savanna fills channels in the underlying rocks of the McAlester. In mapping, where the lowest sandstone bed of the Savanna lenses out, the base of the nearest overlying bed of sandstone is selected as the base of the formation. This interfingering of the two formations is probably common.

The lower part of the Savanna Formation has been penetrated by wells and shallow holes, and it crops out in the southern and eastern parts of the mapped area. The upper part of the Savanna and the overlying Boggy Formation have been removed by erosion. The best exposures of the rocks of the Savanna are on Tick Hill, south of the community of Montana, on Regan Mountain, in the southeastern part of the area, and on the ridges and buttes east of Clarksville and Jamestown.

The greatest measured thickness of the Savanna Formation in the mapped area is 333 feet, in shallow hole 190 on Tick Hill in sec. 28, T. 9 N., R. 24 W. In other parts of the mapped area the Savanna is probably less than 250 feet thick. Where the Savanna is overlain by the Boggy Formation, near the west boundary of the Paris quadrangle to the southwest, it is about 2,200 feet thick (Haley, 1961, p. 8).

The Savanna Formation, where most complete, consists mainly of shale, but it also contains siltstone, sandstone, several thin beds of coal, and very sparse limestone and nonbedded claystone. Most of the sandstone and siltstone units are not lithologically uniform and do not persist throughout the area.

The shale is medium gray to grayish black, but generally it is dark gray. It is commonly silty and micaceous and sparsely coaly to carbonaceous; in many places it contains pyrite, limy and iron-rich concretions, and plant fossils. The shale is in beds as much as one-fourth inch thick and in units as much as 81 feet thick; it comprises both uninterrupted thick units and thin units interbedded with siltstone and sandstone.

The siltstone in the Savanna Formation is mostly medium gray and micaceous, but it ranges from medium light gray to dark gray, and it is, in part, argillaceous, very finely sandy, and slightly limy. The siltstone is in beds as much as several inches thick and in units as much as 51 feet thick. It is generally thin bedded and commonly irregularly bedded; in a few places it is crossbedded.

The sandstone in the Savanna Formation is generally light to medium gray and weathers brownish gray and pinkish gray; it is very fine to fine grained, silty, and micaceous, and in places it contains medium sand grains and is slightly limy. The sandstone is commonly well indurated, and locally it contains plant fossils, shale pebbles, fine grains of chert, and grains of glauconite. The sandstone is thin bedded to massive and is in units as much as 90 feet thick. It is regularly to irregularly bedded and is, in part, crossbedded, foreset bedded, convolute bedded, and ripple marked. Slump structures are sparse. The lower boundaries of the sandstone units are commonly sharp and uneven, and they outline channels in several places. These sandstone units locally contain shale pebbles and stringers of coal and shale, and at a few exposures current-flow casts are on the lower bedding surface.

Coal, which probably composes less than 1 percent of the Savanna, occurs in many parts of the stratigraphic section. The coal beds are as much as 10 inches thick, and most of them probably lens out within a few miles, but a few may extend throughout the approximate east half of the area.

The basal unit of the Savanna is the most distinctive part of the formation in this area, and it has several characteristics in common with the Hartshorne Sandstone. It is well exposed near the crest of Big Danger Hill in secs. 15 and 16, T. 9 N., R. 23 W., at the west end of the ridge in SE¼ sec. 26, T. 9 N., R. 23 W., and was penetrated by many of the wells and shallow holes in the three quadrangles. The unit consists of interbedded sandstone, siltstone, and shale; the beds are not laterally uniform in lithology and thickness. The lithology of the basal unit ranges from mostly shale, in shallow holes 182 and 188, to mostly fine- to medium-grained sandstone, on Big Danger Hill. The thickness of the unit ranges from about 15 to about 90 feet. Few characteristics of the basal unit persist throughout the report area; however, a coal bed or a bed containing abundant plant fossils is commonly present a few feet above the top of the basal unit, and in several places the lower part of the unit contains invertebrate fossils and glauconite. One widespread though not universal characteristic of the unit is the sharp lower contact. Where exposed, mainly in the eastern one-third of the area, the base of the unit is an irregular surface, with current flow casts in a few places, and it outlines channels in the underlying rocks. A lense of conglomerate filling the lower part of one of these channels (SE¼ sec. 26, T. 9 N., R. 23 W.) is about 15 feet wide and as much as 1 foot thick. The conglomerate consists of pebbles of well-indurated shale and sandstone in a matrix of very fine to fine sand. The well-rounded pebbles of shale are as much as 3 inches long. In the area of outcrop the lower part of the unit contains scattered coal and shale stringers and shale pebbles and is commonly irregularly bedded. The rocks of the unit are, in part, regularly bedded, foreset bedded, crossbedded, and ripple marked.

Invertebrate fossils are rare in the Savanna Formation of this area. A few ostracodes, brachiopods, and fragments of crinoids are in samples of drill cuttings, and a fossiliferous sandstone crops out near Clarksville in the N½SE¼ sec. 3, T. 9 N., R. 23 W. The sandstone is very fine grained, weathered, iron rich, and it contains crinoids, gastropods, and probably brachiopods. A fossil locality in the Hartman quadrangle was described by Girty (Collier, 1907, p. 32). The fossils listed by Girty were collected on the south side of Tick Hill, probably from the Savanna Formation, in sec. 29, T. 9 N., R. 24 W., and include the following: *Crania?* sp. *Aviculipecten whitei*, *Aviculipecten* sp., *Leda?* sp., *Pleurophorus oblongus*, *Naticopsis nana*, *Naticopsis* sp., *Pleurotomaria?* sp., *Murchisonia?* sp., and Ostracoda. The fossiliferous rocks in the Savanna of the report area are probably all less than 150 feet above the base of the formation.

Plant fossils are common in the rocks of the Savanna Formation but generally occur as scattered fragments. A fossil of special interest is near the top of a cliff of sandstone in the NE¼SW¼ sec. 28, T. 9 N., R. 24 W. The fossil is apparently the cast of the trunk of a tree, in a vertical position, and is about 10½ feet long, about 2 by 3 feet across near the base, and about 1½ feet in diameter near the top. The fossil tapers at a greater rate near the middle of its length, and its outer surface consists of a series of small horizontal grooves and ridges. R. M. Kosanke of the U.S. Geological Survey stated (oral commun., 1965) that the plant was probably a tree fern, or possibly a lycopsid, with some of the outer layers removed. The plant lived in a damp continental environment, in or near fresh or mildly brackish water. This specimen is in the position of life, and was apparently rooted in and later surrounded by very fine sand. The enclosing sandstone unit is as much as 40 feet thick, is evenly to unevenly bedded, is thin bedded to massive, and has an irregularly channeled lower boundary. The sandstone unit generally overlies a coal bed as much as 3½ inches thick. This sequence of rocks probably represents a changing depositional environment. The swamp, or similar area, in which the coal originated was buried by sand on which continental plants grew. As these plants died some were buried by additional sand before they disintegrated. The sand was later covered by clay and silt.

QUATERNARY SYSTEM

TERRACE DEPOSITS

Alluvium has been deposited on two terrace levels by the Arkansas River and on at least two terrace levels by many of the smaller streams in the area. The terrace deposits of the Arkansas River consist of clay, silt, and sand, and pebbles and cobbles of siltstone, sandstone, chert, and quartz. Part of the alluvium deposited by the Arkansas River originated in or near the area of this report, but the chert and quartz pebbles and cobbles were derived from a distant source. The alluvium capping Regan Mountain is on the older river terrace level, and the deposit in sec. 3, T. 8 N., R. 23 W. is on the younger river terrace level. The terrace deposits of the streams in the area are composed of clay, silt, and sand, and pebbles, cobbles, and boulders of shale, siltstone, and sandstone. Part of the west side of the town of Clarksville rests on one of the older stream terraces. The youngest stream terraces are generally small, scattered along the present drainages, and only a few feet above the top of the Recent alluvium. The stream deposits are differentiated from the river deposits partly on the basis of the chert and quartz pebbles and cobbles transported by the river. However, several alluvial deposits in the area may have been reworked and their origin is doubtful. The terrace deposits near Montana, in the center of the Hartman quadrangle, may have been reworked. The oldest river terrace deposits and one of the older stream terrace deposits are probably equivalent to the Gerty Sand of Pleistocene age in Oklahoma (Miser, 1954).

ALLUVIUM

The alluvium deposited by the Arkansas River is mainly clay, silt, and sand, but also includes scattered granules, pebbles, and cobbles of siltstone, sandstone, chert, and quartz from local tributary streams or terrace deposits. The alluvium deposited by the smaller streams consists of clay, silt, and sand, and includes a larger percentage of granules, pebbles, and cobbles of siltstone and sandstone.

STRUCTURE

The Coal Hill, Hartman, and Clarksville quadrangles are in the western part and near the north boundary of the Arkansas Valley section of the Ouachita province, near the adjoining Ozark Plateaus province (fig. 1). The structure of the rocks in the three quadrangles consists of generally east-trending discontinuous folds and normal faults (pls. 3 and 4). The synclines and anticlines have gently irregularly curved axes and are symmetrical in cross section; the dips on the flanks are small. Most of the fault planes dip either north or south, and the surface traces of the faults are also irregularly curved. The structural relief in the area is approximately 1,600 feet, as measured on the base of the Hartshorne Sandstone from the axis of the Ouita syncline, in the south-central part of the area, to the upthrown block of the Clarksville fault in the northeastern part of the area.

SYNCLINES

The largest synclines are the Pond Creek Hills syncline, in the western part of the area, and the Spadra and Clarksville synclines, in the eastern part of the area. Parts of other major synclines—the Webb City, Denning, and Ouita—extend into the area, and a smaller syncline, the Hogskin Creek syncline, is in the north-central part of the area.

ANTICLINES

The major anticlines are the Possum Walk and Coal Hill anticlines, in the western part of the area, and the Knoxville anticline in the southeastern part of the area. Several other anticlines terminate within the area; the Ozark anticline, the Altus anticline, and an unnamed anticline terminate near the west border, and the Pryor and Dover anticlines, near the northeast corner. The Union City anticline, near the center of the area, is smaller but is economically important.

FAULTS

Faults are common in all parts of the area but seem to be more abundant along the flood plain of the Arkansas River. The faults are normal, and most of the fault planes dip southward. In this report, the term "displacement" is used for the stratigraphic throw. The amount of movement measured along the fault plane is greater than the amount of stratigraphic throw. A fault may be isolated or it may be part of a system of faults; most faults of large displacement are joined by one or more faults of lesser displacement. In this report the north-dipping fault planes are generally interpreted as terminating in the subsurface against the first south-dipping fault plane intersected.

The fault planes exposed in the area dip 44°–80°; however, fault planes interpreted to extend from the surface to a well or between wells generally dip 35°–45°. The contrast between the dip angles measured at the surface and the dip angles determined for the subsurface has several possible explanations. The exposed faults commonly have small displacements, and the dips of their fault planes may not be identical with the dips of the planes of the larger faults. It is also possible that the fault planes, in cross section, are curved or irregularly curved and have an average dip of 35°–45°. If the fault planes, in cross section, are curved or irregularly curved, their dip at the outcrop would generally differ from their dip in the subsurface.

The vertical displacement of some of the larger faults appears to be less at the surface than in the subsurface. For example, the vertical displacement of the south-dipping Coal Hill fault at the surface in the N½ sec. 23, T. 9 N., R. 26 W., is probably 600–630 feet. In well 15, about 1,000 feet south of the surface trace of the fault in the same area, the displacement is 670–720 feet. The total displacement of the two branches of the Coal Hill fault at the surface in the N½ sec. 24, T. 9 N., R. 26 W., at the place along the surface trace nearest well 16, is about 675 feet. The displacement of the fault in well 16, about 6,500–7,500 feet south of the surface trace, is about 1,100 feet. The difference in these amounts of displacement, for the Coal Hill fault and other faults in the report area, may be a result of recurrent movement along the fault during deposition, or of the downward addition of the displacements of intersecting lesser faults. If other faults are causing the increase in displacement with depth, they should perhaps be more commonly exposed near the surface trace of the larger fault.

Two faults were intersected by wells but were not mapped at the surface. A fault with about 100 feet of displacement intersects the Humble Oil and Refining Co. D. L. Evans 1 (well 20) at a depth of 4,495 feet (see pls. 2, 4). Another fault with about 40 feet of displacement was penetrated by the Stephens Production Co. W. H. Hooten 1 (well 31) at a depth of approximately 1, 950 feet. The amounts of displacement were inferred by comparing the logs of wells 20 and 31 with the logs of nearby wells. No fault was mapped in the area where the fault in well 20 would likely reach the surface, and the mapped faults closest to this area correlate with other faults in the subsurface. The fault in well 31 could be a projection of the fault mapped in the N½ sec. 10, T. 9 N., R. 24 W. However, the fault in sec. 10 probably dips toward the south, although the evidence supporting this interpretation is not conclusive. Because displacement across many of the faults in the mapped area seems to decrease upward in the subsurface, these two faults may not extend to the surface. If they intersect the surface, the displacements are probably very small. The direction of the dip of these fault planes cannot be determined; thus the fault in well 20 is arbitrarily depicted on plate 4.

The Center Point fault, near the northwest corner of the area, is not exposed but was mapped along McKinney Creek and Dirty Creek from the SW¼ sec. 25, T. 10 N., R. 26 W., to the S½ sec. 26, T. 10 N., R. 25 W. The fault plane dips south, and the maximum displacement along the surface trace is about 150 feet. In well 3 the displacement across this fault is about 825 feet. The difference between these amounts of displacement may be due in part to the additional displacement of another fault. This second fault is approximately parallel to the Center Point fault and is a few hundred feet north of the area of this report. The Center Point fault is joined by a secondary fault in sec. 28, T. 10 N., R. 25 W., and the combined displacement of these faults, and possibly the one to the north, is about 700 feet in well 5.

The Mount Vernon fault, poorly exposed in the northwestern part of the area, extends from sec. 10, T. 9 N., R. 26 W., through sec. 25, T. 10 N., R. 25 W., and northeastward beyond the mapped area, through sec. 28, T. 10 N., R. 24 W., and terminates in sec. 27, T. 10 N., R. 23 W. The Mount Vernon fault merges with the Center Point fault in sec. 26, T. 10 N., R. 25 W., and is joined by lesser faults in sec. 11, T. 9 N., R. 26 W., and in sec. 32, T. 10 N., R. 25 W. The displacement of the Mount Vernon fault in well 13 is about 40 feet, in well 19 about 60 feet, in well 6 about 270 feet, and in well 8, about one-third mile southeast of the exposure, it is about 600 feet and the average dip of the fault plane between the surface and the well is about 48°. The plane of this fault is exposed beside the road in the NE¼ sec. 28, T. 10 N., R. 24 W., where it dips 80° S.

The Coal Hill fault can be traced from the west border of the area, in sec. 22, T. 9 N., R. 26 W., to 1 mile west of the town of Hartman, in sec. 14, T. 9 N., R. 25 W. The Coal Hill fault is joined by several lesser faults and probably splits and rejoins between the towns of Denning and Coal Hill. The fault plane is not exposed but the surface trace can usually be located within a distance of 300 feet. The Coal Hill fault dips toward the south and where penetrated by well 16 has a displacement of approximately 1,100 feet. The greatest displacement at the surface is about 675 feet, across the two branches of the fault in the N½ sec. 24, T. 9 N., R. 26 W.

The Hartman fault is in the central part of the area and dips to the north. It can be located within a few feet on the east side of Horsehead Creek in sec. 13, T. 9 N., R. 25 W., and within 100 feet in the E½ sec. 9, T. 9 N., R. 24 W. A northwest-trending fault branches from the Hartman fault in the SE¼ sec. 7, T. 9 N., R. 24 W. This fault can be located within a few feet at the west end of the strip mine in the S½ sec. 7, T. 9 N., R. 24 W. Where the Hartman fault and the northwest-trending fault are apparently intersected by well 26 the displacements are about 155 and 690 feet, respectively. The displacements of these faults on the surface, where the surface trace of the fault is nearest the well, are about 150 and 75 feet, respectively. A fault reported to be in well 25, at a depth of 5,300 feet and with a displacement of 650 feet, may be the northwest-trending fault or a combination of the Hartman fault and its northwest-trending branch. Two faults were found in well 29, at depths of approximately 3,525 and 3,960 feet and with displacements of about 500 and 385 feet, respectively. These two faults are probably represented at the surface by the Hartman fault, although the displacement of the Hartman fault at the surface probably does not exceed about 250 feet. Where intersected by well 31 the Hartman fault has about 440 feet of displacement.

The Spadra fault borders the north edge of the flood plain of the Arkansas River in the western part of the area. The west terminus is in sec. 31, T. 9 N., R. 25 W., and the east end joins the Big Danger fault in sec. 22, T. 9 N., R. 24 W. The fault plane can be located within a distance of about 30 feet in the S½ sec. 13, T. 9 N., R. 25 W. and in the S½ sec. 18, T. 9 N., R. 24 W. Along the highway in the S½ sec. 13, T. 9 N., R. 25 W. the fault plane probably dips about 60° S. At this locality slickensides and very thin stringers of calcite occur along the fault where it is in shale. The maximum displacement along the surface trace of this fault is about 350 feet, in the town of Hartman.

The surface trace of the Clarksville fault extends from the N½ sec. 35, T. 10 N., R. 24 W., to the boundary of the area in sec. 31, T. 10 N., R. 22 W., and eastward into the Knoxville quadrangle. It can be best located in secs. 33, 34, and 35, T. 10 N., R. 23 W. within a distance of 200 feet. The fault plane dips to the south. The displacement at the surface along this fault increases eastward and reaches a maximum of about 1,150 feet at the east border of the area. Several lesser faults join the Clarksville fault.

An unnamed fault probably extends from near the SW cor. sec. 3, T. 9 N., R. 24 W., to the Clarksville fault in sec. 33, T. 10 N., R. 23 W. The west end of the fault and the southeast-trending branch in sec. 11, T. 9 N., R. 24 W., are depicted on maps of the coal mines in the area. The eastern part of the unnamed fault probably parallels Spadra Creek and causes the termination of the exposure of the basal sandstone of the Savanna Formation in the E½ sec. 5, T. 9 N., R. 23 W. This fault probably joins the Oakland fault and three lesser faults in addition to the Clarksville fault. The plane of the fault dips south. The maximum displacement along the surface trace may be about 170 feet, in the SE¼ sec. 2, T. 9 N., R. 24 W.

The Lamar fault, near the east border of the area, extends from the Clarksville fault in sec. 36, T. 10 N., R. 23 W., generally southward to the Big Danger fault in sec. 19, T. 9 N., R. 22 W. The fault plane dips west and can be most closely located on the surface in sec. 7, T. 9 N., R. 22 W. The greatest displacement at the surface is about 260 feet near the axis of the Dover anticline.

The Oakland fault trends irregularly eastward from sec. 5, T. 9 N., R. 23 W., near Clarksville where it probably joins an unnamed fault, to sec. 12, T. 9 N., R. 23 W., north of Lamar. The plane of the fault dips southward and is intersected by the north-dipping planes of two lesser faults. The surface trace of the Oakland fault can be most accurately mapped in the NE¼ sec. 9 and the NW¼ sec. 10, T. 9 N., R. 23 W., where it can be located within a distance of about 300 feet. The greatest displacement of the fault at the surface is approximately 330 feet, in sec. 10, T. 9 N., R. 23 W. The displacement of the fault is about 150 feet, in well 34, about 400 feet in well 35, and about 650 feet in well 36.

The Big Danger fault extends from sec. 26, T. 9 N., R. 25 W., to the east boundary of the Clarksville quadrangle in sec. 19, T. 9 N., R. 22 W., and it dips southward. It can be located on the surface within a distance of about 200 feet in the SE¼ sec. 23, T. 9 N., R. 24 W., and in the W½ sec. 23, T. 9 N., R. 23 W., and it has been intersected by several wells in the Spadra gas field. This fault is one of the group of faults located generally in and along the flood plain of the Arkansas River. The Big Danger fault divides into a zone of several faults in the area of the Spadra gas field. The greatest displacement at the surface at any one location across the zone is about 700 feet, near the town of New Spadra; the maximum total displacement near the surface, beneath the river alluvium, where the fault zone consists of two faults in and near the spadra gas field is about 800 feet, in the W½ sec. 19, T. 9 N., R. 23 W. The northern branch of the fault zone has a displacement of about 300 feet in well 37, about 400 feet in well 38, 180 feet in well 39, 300 feet in well 40, 190 feet in well 41, and 500 feet in well 42. The southern branch of the fault zone has a displacement of about 500 feet in well 37, about 400 feet in well 38, about 540 feet in well 39, about 550 feet in well 40, about 350 feet in well 41, about 540 feet in well 43, and about 350 feet in well 42. The location, dip, and displacement of these faults near the town of Spadra were determined mainly from the logs of shallow holes 22, 23, 25, 156, 157, 158, 159, 160, 161, and 162.

The unnamed fault near the north slope of Regan Mountain dips northward and probably extends from sec. 36, T. 9 N., R. 24 W., to sec. 34, T. 9 N., R. 23 W. The fault is not exposed and can be only approximately located with subsurface data. It probably terminates in sec. 34, T. 9 N., R. 23 W., against the Regan Mountain fault. The maximum displacement at the surface is about 200 feet near the NW cor. sec. 32, T. 9 N., R. 23 W. The displacement of the fault in well 42 is about 180 feet.

The unnamed south-dipping fault joining the Regan Mountain fault in sec. 28, T. 9 N., R. 24 W., combines with the southern branch of the Big Danger fault in the E½ sec. 22 T. 9 N., R. 23 W. The location of this fault was determined from logs of wells and shallow holes. The maximum displacement at the surface is about 250 feet in sec. 29, T. 9 N., R. 23 W. The displacement is about 250 feet in well 43, about 100 feet in well 42, and about 150 feet in well 41.

The Tick Hill fault extends from the McLean Bottom fault in the W½ sec. 25, T. 9 N., R. 25 W., to sec. 20, T. 9 N., R. 23 W. It dips southward and is joined by two faults near its west terminus. The fault was located with subsurface information; its greatest displacement near the surface, at the interface between the rocks of Pennsylvanian age and the river alluvium, southeast of the town of Spadra, is about 75 feet. The displacement of the fault is 100 feet in well 32 and 40 feet in well 38.

The Regan Mountain fault trends eastward from the Tick Hill fault in the S½ sec. 30, T. 9 N., R. 24 W., to the boundary of the area in the S½ sec. 30, T. 9 N., R. 22 W., and extends into the Knoxville quadrangle to the east. It dips south and joins or is joined by several south-dipping faults and a north-dipping fault. The fault plane is not exposed, but the surface trace can be located within a distance of a few hundred feet in the areas not covered by alluvium. The greatest displacement at the surface along the fault is probably about 200 feet in sec. 34, T. 9 N., R. 23 W. Where penetrated by well 47 the combined displacements of the Tick Hill and Regan Mountain faults total 850 feet. The displacement of the Regan Mountain fault is 105 feet in well 32 and 40 feet in well 44.

An unnamed south-dipping fault branches from the Regan Mountain fault in the SW¼ sec. 32, T. 9 N., R. 23 W., extends eastward to the border of the area in the S½ sec. 31, T. 9 N., R. 22 W., and was traced into the Knoxville quadrangle (Merewether, 1967) to the east. This fault is joined by several minor faults and the north-dipping Morrison Bluff fault. The fault can be located within a distance of about 30 feet near the edge of the river alluvium in the SW¼ sec. 36, T. 9 N., R. 23 W. The greatest displacement of this fault at the surface is probably about 175 feet, in the SW¼ sec. 31, T. 9 N., R. 22 W.

The Morrison Bluff fault extends eastward from the W½ sec. 32, T. 9 N., R. 24 W., and terminates against the unnamed fault described above in the N½ sec. 3, T. 8 N., R. 23 W. The surface trace of the fault can be located within a distance of a few hundred feet where bedrock is exposed. The fault dips northward, and its maximum displacement at the surface, in the NW¼ sec. 4, T. 8 N., R. 23 W., is about 375 feet.

The McLean Bottom fault, in the southwestern part of the area, was traced eastward from the quadrangle boundary in sec. 3, T. 8 N., R. 26 W., to the S½ sec. 20, T. 9 N., R. 24 W., where it joins the Big Danger fault. The McLean Bottom fault is joined near its east end by the Tick Hill fault and two minor faults. The position of the surface trace of the fault was determined mainly by the use of the logs of wells and shallow holes, but in the N½ secs. 29 and 30, T. 9 N., R. 24 W., the fault was located on the surface within a distance of several hundred feet. The fault plane dips southward and the greatest displacement at the surface is about 350 feet in the bedrock beneath the river alluvium in sec. 6, T. 8 N., R. 25 W. The displacement where the fault was intersected by well 32 is 780 feet.

The Dublin fault was traced eastward from its termination in sec. 10, T. 8 N., R. 25 W., to the border of the area in sec. 10, T. 8 N., R. 24 W., and into the Scranton quadrangle to the south (Haley, 1968). The Dublin fault dips southward and is joined by a north-dipping fault in the W½ sec. 4, T. 8 N., R. 24 W. The surface trace of the fault plane was located mainly by the use of subsurface information, but the position of the fault at the surface was established in the W½ sec. 4, T. 8 N., R. 24 W., within a distance of a few hundred feet. The greatest displacement at the surface is probably in the S½ sec. 4, T. 8 N., R. 24 W., and is about 150 feet. The displacement of the fault where intersected by well 48 is 520 feet.

An unnamed north-dipping fault was traced from the border of the area in sec. 11, T. 8 N., R. 25 W., to the W½ sec. 4, T. 8 N., R. 24 W., where it joins the Dublin fault. The position of the fault was determined mostly by the use of the logs of shallow holes. The maximum displacement of the fault at the surface is about 100 feet in sec. 6, T. 8 N., R. 24 W.

ECONOMIC GEOLOGY

COAL

The coal beds in the area of this report are in the Atoka, McAlester, and Savanna Formations. The location, extent, thickness, and mined areas of all exposed coal beds are shown on plate 3. The coal in the western part of the area is of low-volatile bituminous rank (pl. 3), and the coal in the remainder of the area is semianthracite. The rank of the coal was determined by Haley (1960, pl. 62), in a study of the Arkansas Valley coal field, on the basis of the percentage of dry, mineral-matter-free fixed carbon, in accordance with the specifications of the American Society for Testing and Materials (1939).

The Lower Hartshorne coal of the McAlester Formation is the only coal bed in the area sufficiently thick and extensive for current mining. The estimated reserves of the Lower Hartshorne coal are listed in table 5 and are tabulated in categories of rank, 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 information used in calculating the reserves was obtained from outcrops, maps of coal mines, shallow holes drilled during exploration for coal and natural gas, wells drilled for natural gas, and previous reports. The depth of the Lower Hartshorne coal in this area is everywhere less than 1,000 feet.

COAL BEDS IN THE ATOKA FORMATION

Coal beds in the Atoka Formation crop out in three parts of the area and were penetrated by most of the wells. Most of these coal beds are probably very limited in extent and all are probably less than 14 inches thick. The most widespread of these beds is described in the section concerning the stratigraphy of the Atoka Formation. The coal of the Atoka Formation in other parts of the Arkansas Valley coal field is of poor quality (Haley, 1960, p. 818). The apparent lack of thickness, continuity, and quality in the coal beds of the Atoka in this area indicates that any minable reserves would be small.

TABLE 5.—*Estimated original reserves of coal in the Lower Hartshorne coal bed, Coal Hill, Hartman, and Clarksville quadrangles*

[In millions of short tons]

Rank of coal	Thickness of coal (inches)			
	14–28	28–42	>42	Total
Measured and indicated reserves				
Bituminous	2.412	14.989	17.407	34.808
Semianthracite	8.510	59.072	40.148	107.730
Total	10.922	74.061	57.555	142.538
Inferred reserves				
Bituminous	8.639	1.513	----------	10.152
Semianthracite	35.943	101.852	90.242	228.037
Total	44.582	103.365	90.242	238.189
Total reserves				
Bituminous	11.051	16.502	17.407	44.960
Semianthracite	44.453	160.924	130.390	335.767
Total	55.504	177.426	147.797	380.727

COAL BEDS IN THE McALESTER FORMATION

The McAlester Formation contains, in addition to the Lower Hartshorne coal bed, several coal beds that are less than 14 inches thick. The thickness and lack of continuity of these beds obviate the calculation of minable reserves. The thickness, distribution, and partings of the Lower Hartshorne coal in the mapped area are summarized in the section of this report that concerns the McAlester Formation. Analyses of the Lower Hartshorne coal in the Arkansas Valley coal field were listed by Haley (1960, table 4).

The original reserves of coal in the Lower Hartshorne bed, where the thickness of the bed is at least 14 inches, are estimated to have been 380,727,000 short tons (table

5). As of January 1963 an estimaated 32,512,000 short tons of this coal had been mined. The amount of coal remaining in the Lower Hartshorne bed in this area is approximately 348,215,000 short tons, of which 33,150,000 short tons are low-volatile bituminous coal and 315,065,000 short tons are semianthracite. Most of the remaining coal would probably be mined underground, and underground mining generally recovers approximately 50 percent of the coal in the ground (Averitt, 1961, p. 24). On the basis of the preceding esimates, the recoverable reserve of coal in the area of this report is about 174,107,000 short tons, which includes an estimated 16,575,000 short tons of low-volatile bituminous coal.

COAL BEDS IN THE SAVANNA FORMATION

Coal beds are probably more common in the Savanna Formation of this area than in the Atoka or McAlester Formations, but they are discontinuous, and where exposed they do not exceed 10 inches in thickness. Several beds of coal crop out where the Savanna is exposed in the eastern and southeastern parts of the area (pls. 1 and 3).

OIL AND GAS

Crude oil has not been found in the area of this report, but natural gas has been discovered in reported initial potential amounts exceeding 1 million cubic feet per day (table 2) in 29 of the 51 wells in the area. The gas is in rocks of Pennsylvanian age, in the upper, middle, and lower parts of the Atoka Formation and the upper and middle parts of the Morrow Series. Sandstone of Pennsylvanian age has been the main target of those drilling for gas; consequently, the potential reservoir rocks of pre-Pennsylvanian age have not been adequately tested. The gas is apparently produced from anticlinal traps, fault traps, or combinations of both. However, the lithology of the bed containing the gas is probably not laterally consistent, and the relative porosity and permeability of parts of the bed must influence the location of the gas in these structural traps. Several gas-bearing sandstone beds have been penetrated in each of the gas fields, but no well in any one field produces gas from all of the gas-bearing beds of the field. The shape of the gas fields, depicted on plate 3, is a composite of the arbitrarily defined gas-producing areas surrounding the wells in the field. The gas-producing areas of the wells are delimited on the gas-bearing bed in the subsurface. A well is assumed to produce gas from the area within half a mile of the well, unless this area is crossed by a fault.

The total reported initial potential production of gas from all active wells in the area (Oct. 1, 1964) is about 331 million cubic feet per day. The 29 wells supplying this gas have an average potential production of approximately 11,400,000 cubic feet per day.

Most of the anticlines and several of the potential fault traps in the area have been at least partly explored for gas. Additional gas probably will be found in the anticlines, in the unexplored fault traps, and perhaps in the porous parts of lenticular sandstones outside the area of the structural traps.

BUILDING STONE

Some of the sandstone and siltstone exposed in the area may be adequate for use as building stone. The thin- to medium-bedded and regular-bedded or foreset-bedded sandstones are probably the best potential source of building stone or flagstone. In other places in the Arkansas Valley, flagstone is commonly obtained from foreset-bedded parts of the Hartshorne Sandstone. Good building stone was quarried in this area from the basal sandstone of the Savanna Formation in the S½NE¼ sec. 13, T. 9 N., R. 23 W., near Lamar. The exposure of this sandstone in the E½ sec. 1, T. 9 N., R. 23 W., might also be exploited for building stone. A sandstone of the Savanna in the NE¼SW¼ sec. 23, T. 9 N., R. 23 W., is even bedded and could possibly be quarried for flagstone.

ROAD METAL

Road metal in the Arkansas Valley consists of crushed sandstone and siltstone, shale fragments, coal mine refuse and clinkers, and stream and terrace gravel. Quarries are common in sandstone of the Hartshorne and Savanna Formations and are sources of the crushed rock used in the construction of highways and railroads. Shale fragments are used in some places to resurface secondary roads or as fill material. The shale is generally obtained from roadcuts or natural exposures. The fragments of shale, siltstone, and clinker in the piles of waste from underground coal mines are used to resurface secondary roads in many parts of the area. Road metal is also obtained from alluvium rich in gravel. The sources of road metal are determined mainly by the requirements for the material and the location of the construction project. Sandstone or siltstone suitable for crushed rock can generally be found in any of the formations exposed near the site of construction. The selection of materials to be used for fill or for resurfacing secondary roads apparently depends entirely upon the proximity of exposures of shale, gravel, or of mine waste. Deposits of gravel in river and stream terraces crop out in the S½ secs. 29 and 30, T. 9 N., R. 25 W., on the north side of Horsehead Creek in sec. 19, T. 9 N., R. 24 W., and along the edge of the terrace in the E½ sec. 13, T. 9 N., R. 24 W., and in the S½ sec. 7, T. 9 N., R. 23 W.

GRAVEL, SAND, AND CLAY

The alluvium and terrace deposits of the area contain sand and gravel in abundance. However, gravel is probably most accessible in the stream and river terrace deposits and in the stream alluvium. The river alluvium at the surface apparently consists mainly of very fine sand, silt, and mud. Clay can be obtained from the alluvium and terrace deposits of the area but is more readily available in the many exposures of shale. The clay of the weathered shale underlying the uppermost terrace deposits probably contains fewer impurities; however, unweathered shale in the Savannah Formation in the NE¼SE¼ sec. 3, T. 9 N., R. 23 W., has been used in the manufacture of bricks and tile.

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Geology of the Arkansas Valley Coal Field

GEOLOGICAL SURVEY PROFESSIONAL PAPER 536

This volume was published as separate chapters A–C

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

Library of Congress catalog-card No. GS 68-292

CONTENTS

[Letters designate the separately published chapters]