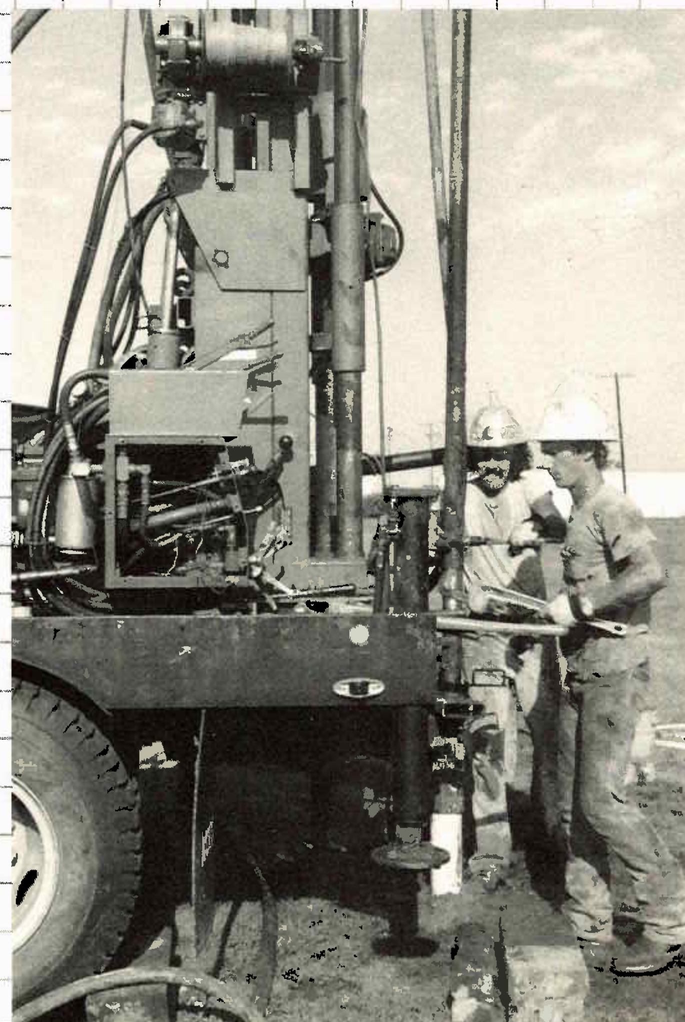
Oklahoma Geology Notes

OKLAHOMA GEOLOGICAL SURVEY / VOL. 46, NO. 1 — FEBRUARY 1986



On the cover—

Drill Rig Cores in Kay County

During the winter months, the Oklahoma Geological Survey's drill rig has been at work in Kay County, Oklahoma, helping geologist James R. Chaplin collect core samples for his mapping project in that county. Shown with the rig on the cover are (left to right) OGS drilling technicians Danny L. Swink and Charles (Chuck) Dyer.

Cores are necessary to geologic investigations in Kay County because of the poor exposure of shales and mudstones in the dip slope held up by the more-resistant but thinner limestones. Core data have confirmed subtle variations in lithology and thickness along the depositional strike (north- south) and from east to west across Kay County.

Core data also have aided in investigation of limestone resources in Kay County that may prove to be economically recoverable. Without core data, it would be difficult or impossible to assess variations in thickness and lithology of limestones and other rocks across the county.

Cover photo by LeRoy A. Hemish

Oklahoma Geology Notes

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Oklahoma Geology Notes, ISSN 0030-1736, is published bimonthly by the Oklahoma Geological Survey. It contains short technical articles, mineral-industry and petroleum news and statistics, reviews, and announcements of general pertinence to Oklahoma geology. Single copies, $1.50; yearly subscription, $6. All subscription orders should be sent to the Survey at 830 Van Vleet Oval, Room 163, Norman, Oklahoma 73019.

Short articles on aspects of Oklahoma geology are welcome from contributors. A set of guidelines will be forwarded on request.

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Contents

2 **Drill Rig Cores in Kay County**
4 **Coal Resources in Southeastern Pontotoc County, Oklahoma**
LeRoy A. Hemish
24 **GIS Guidelines for Authors/Publishers of Geologic Field Trip Guidebooks**
25 **Journal Issues Call for Papers**
26 **KU Professor Discovers Kansas Once Had Mountain Climate**
27 **Call for Papers: SME–AIME Annual Meeting**
28 **Geology Library Makes Decisions on What and What Not to Buy**
29 **Call for Papers Issued for Upcoming Excavation, Tunneling Conference**
30 **Notes on New Publications**
32 **Oklahoma Abstracts—AAPG, Mid-Continent Section, Annual Meeting, Amarillo, Texas, September 22–24, 1985**

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COAL RESOURCES IN SOUTHEASTERN PONTOTOC COUNTY, OKLAHOMA

LeRoy A. Hemish[1]

Abstract

A minable bituminous coal bed is present in southeastern Pontotoc County in an area not generally believed to contain coal of commercial value. The coal bed is correlative with the McAlester coal, named in Pittsburg County, Oklahoma. It occurs in the McAlester Formation of Desmoinesian (Pennsylvanian) age.

Analyses of two outcrop samples suggest that the coal is of low quality; on an as-received basis, the average percent sulfur is 4.5 and the average percent ash is 10.7. The resources are 8,877,000 short tons, and the recoverable reserves are 97,000 short tons.

Introduction

Pontotoc County is generally not included in that part of the eastern Oklahoma coalfield that contains coal beds of commercial value. However, Trumbull (1960) and Friedman (1974) included eastern Pontotoc County in the area that contains rocks bearing coal of noncommercial (doubtful) value. Trumbull (1960) divided areas containing coal of doubtful value into three classes: (1) areas containing thin or irregular beds, which locally may be thick enough to mine, (2) areas in which the coal is of poor quality, and (3) areas where information on the thickness and quality of the coal beds is meager or lacking.

Information gathered during the present investigation indicates that a part of southeastern Pontotoc County can now be included in the area of Oklahoma's coalfield that contains coal of commercial value.

Coal had been reported in southeastern Pontotoc County by Morgan (1924), by Bronaugh (1955), and by Archinal (1977). The purpose of this report is to identify the coal bed, to document its thickness and quality, to provide a map showing the coal distribution and related data, and to present a table of estimated resources and reserves.

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Location

The area of investigation (fig. 1) is located in the Western Region of the Interior Coal Province, along the southwestern edge of the eastern Oklahoma coal belt (Friedman, 1974, p. 7). Coal is known to occur in only a few sections in T1N, R7E in Pontotoc County just west of the Coal

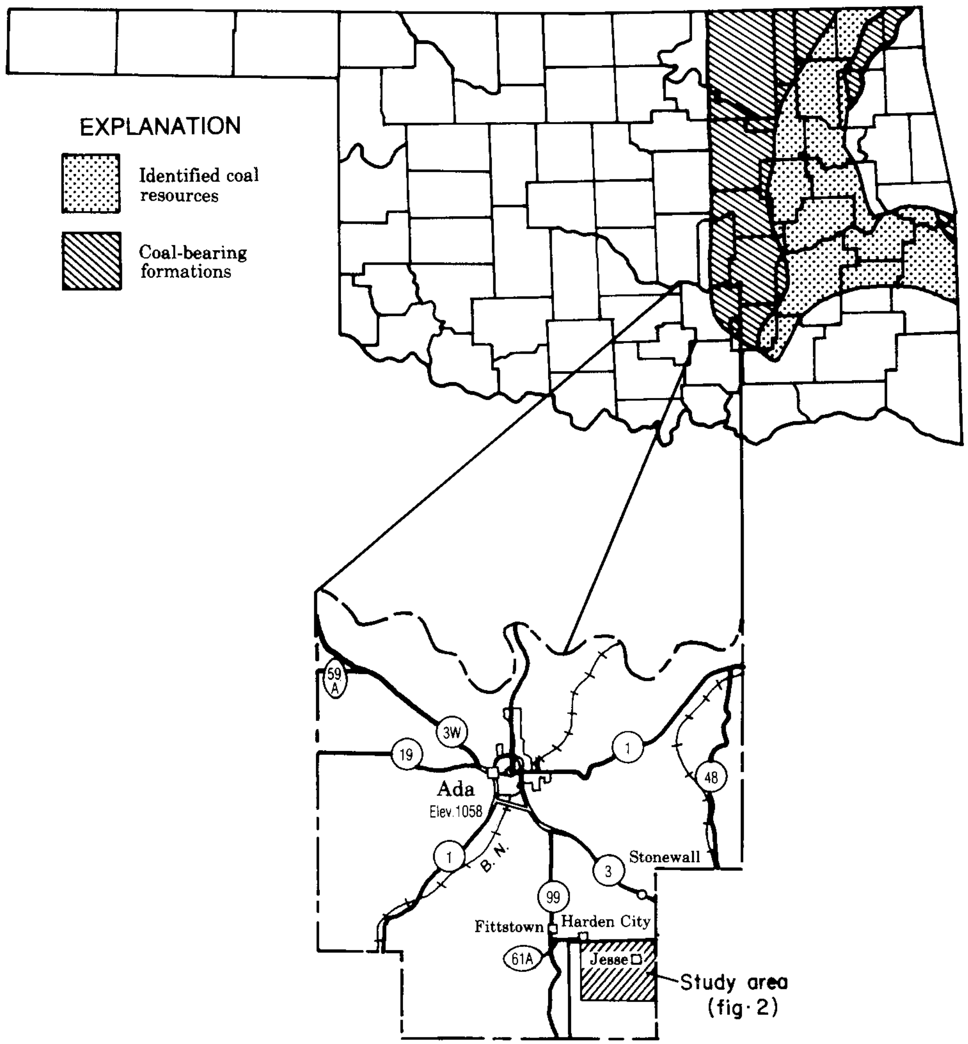


Figure 1. Index map of Oklahoma showing identified coal resources, area of coal-bearing rocks, the location of Pontotoc County, and the study area in southeastern Pontotoc County. Modified in part from Trumbull (1960) and Friedman (1974).

County line (fig. 2). The area is hilly, but easily accessible by road. Oklahoma State Highway 99 is about 6 mi west of the study area, and Oklahoma State Highway 3 is about 7 mi north. The city of Ada, served by the Atchison, Topeka & Santa Fe Railway and the Burlington Northern Railway, is about 20 miles to the northwest (fig. 1).

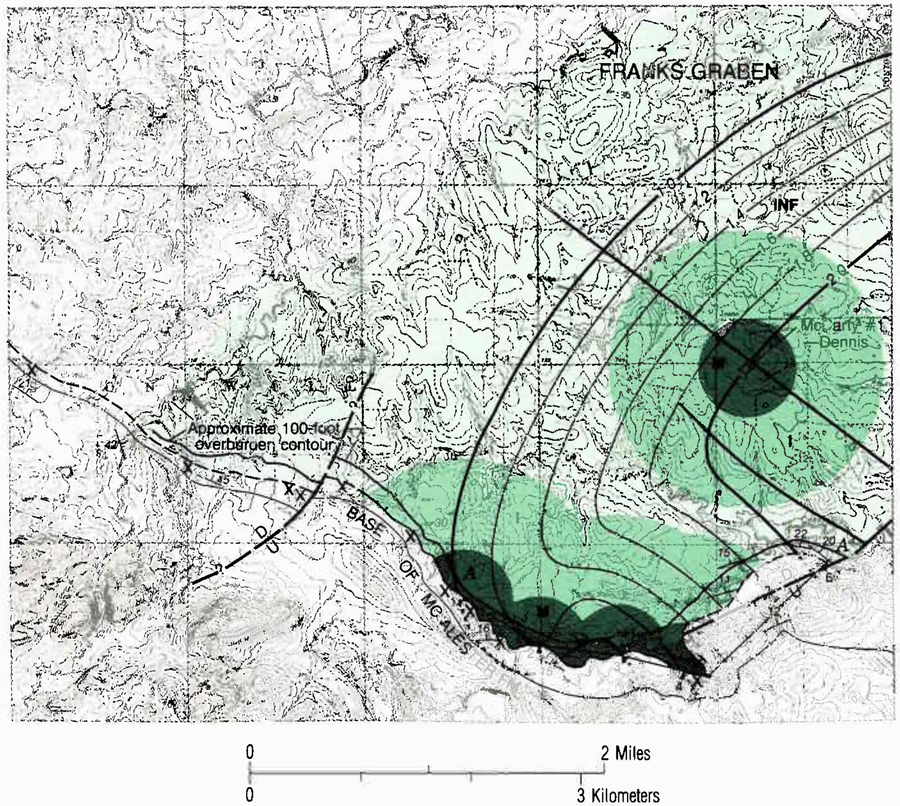
Procedures

The study area lies within the boundaries of the Harden City 7.5-minute series topographic map (1:24,000). Because of time and budget limitations, it was not within the scope of this investigation to prepare a detailed geologic map of the area. Published geologic maps by Morgan (1924), Miser (1954), and Hart (1974) and unpublished work by Archinal (1977) were used for guidance in the present field work, which was done in June of 1985. About one week was spent mapping the coal, primarily by locating the coal bed and/or a red-limestone marker associated with the coal (Morgan, 1924) and following their outcrops. Other field work accomplished during this time consisted in measuring six stratigraphic sections (appendix), recording characteristics of the red-limestone marker at several localities, taking numerous strike-and-dip measurements, collecting coal samples at two sites, photographing various outcrops, plotting the location of an old strip mine, and carrying out stratigraphic investigations in adjacent Coal County for correlation purposes. Points of observation such as outcrops, surface mine workings, and a drill hole were plotted on a base map prepared from the Harden City 7.5-minute topographic quadrangle map (fig. 2). The map also shows the approximate location of the base of the McAlester Formation, sites of strike-and-dip readings, and major faults. It depicts the approximate coal boundary, coal thickness, areas of reliability, and data points used in calculating resources and reserves.

Geology

Stratigraphy

All known coal in Pontotoc County occurs in the McAlester Formation of Middle Pennsylvanian age. Figure 3 is a generalized stratigraphic column showing the units in the McAlester Formation and the overlying and underlying formations as they occur in the study area. The McAlester Formation was named by Taff (1899, p. 437) for exposures near McAlester, Oklahoma. In its exposures in the study area the upper part of the McAlester Formation consists mostly of gray or brownish-gray shales, with a few thin beds of light-brown to dark-reddish-brown sandstone and a coal bed overlain by a thin carbonaceous limestone. The lower part



EXPLANATION

—▲2— —	Approximate coal outcrop, dashed where inferred; triangle indicates point of measurement, number corresponds to measured section in Appendix
—*1.0*- - - -	Isopach contour, dotted where reconstructed; interval 0.2 foot
D/U	Fault, dashed where approximately located; U, on upthrown side; D, on downthrown side
10	Strike and dip of beds
⚒	Small abandoned pit
⌖	Oil well
X	Outcrop of red limestone
A——*A′*	Line of cross section
M	Measured coal
I	Indicated coal
INF	Inferred coal

Resource calculations exclude coal less than 1.2 feet thick where overburden exceeds 100 feet.

Figure 2. Coal map showing outcrop line, data points, coal isopachs, 100-ft overburden contour, and areas of reliability. Map area indicated in figure 1.

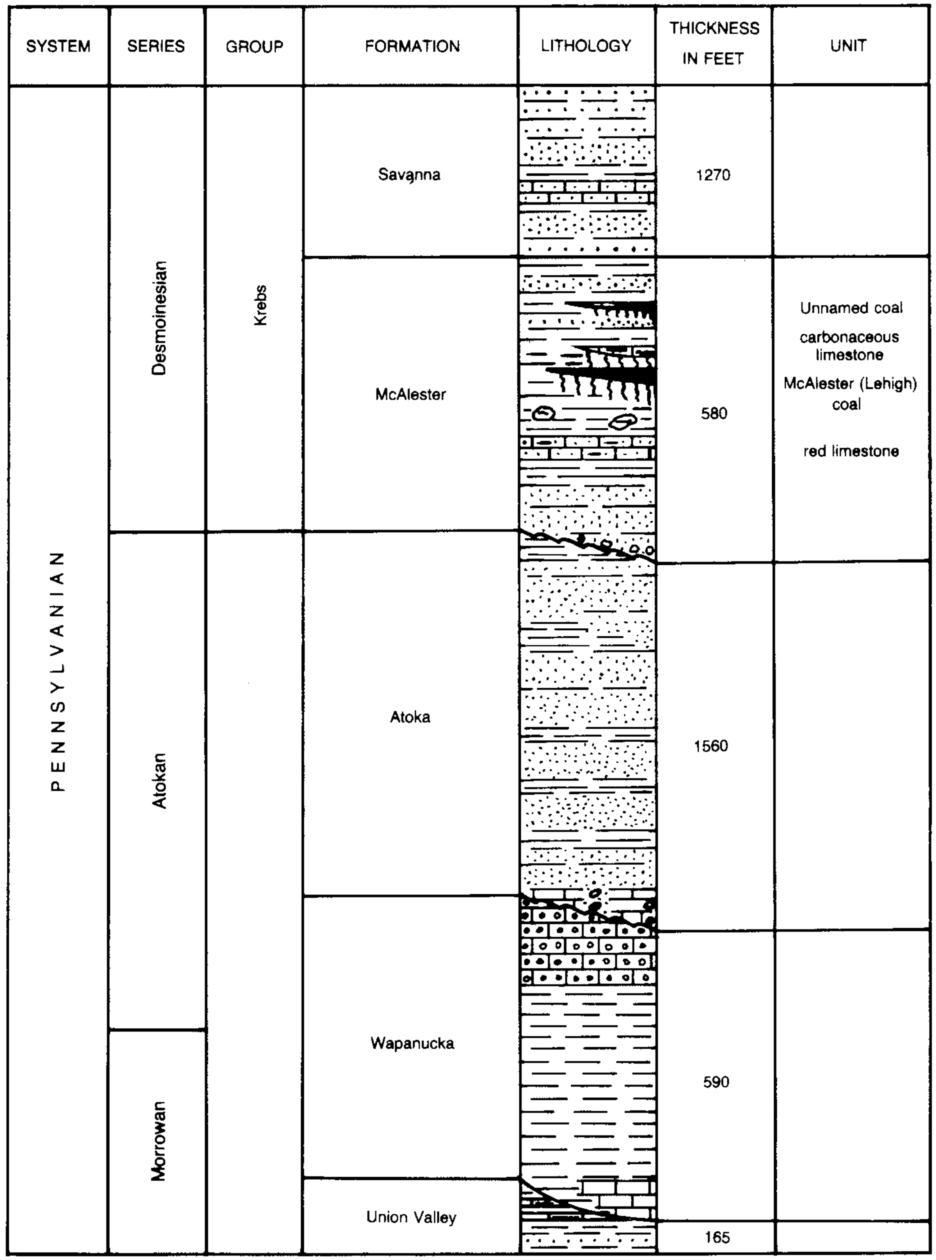


Figure 3. Generalized columnar section showing the McAlester Formation and associated strata in southeastern Pontotoc County, Oklahoma. Thickness of formations from Boyd (1938, p. 1562, fig. 2). (Not to scale.)

of the McAlester Formation consists of dark shales, a ferruginous red limestone, and reddish-brown beds of sandstone of variable thickness.

In secs. 13, 14, 15, 9, and part of sec. 8, T1N, R7E, the McAlester Formation rests unconformably on the Atoka Formation (Archinal, 1977). In the NW¼NW¼NW¼ sec. 8, T1N, R7E, the McAlester Formation overlies the Wapanucka Formation. To the west, in sec. 6, T1N, R7E, the McAlester Formation overlies the Union Valley Formation.

Morgan (1924, p. 69) recognized that the McAlester Formation truncates and overlaps successively older beds in a westerly direction. His observations were based on the occurrences of a ferruginous red limestone within the McAlester Formation and its relationship to the older formations when traced across T1N, R7E. However, field observations by the writer revealed other, similar limestone units within the McAlester and Savanna Formations, which makes correlation questionable in places. The red limestone was easily traced across secs. 14 and 15, but with less certainty in adjacent sections to the west. It was not found in sec. 13. The lack of bedrock exposures makes placement of the contact between the McAlester Formation and underlying formations arbitrary and uncertain.

Recognition of the contact between the overlying Savanna Formation and the McAlester Formation proved to be even more difficult, owing to the strikingly similar lithologic character of the rocks within these two formations in T1N, R7E. It was not the purpose of the present study to remap formation boundaries, so the mapping of Morgan (1924), Miser (1954), and Hart (1974) was followed in a general way. However, in the writer's opinion, their interpretations are questionable in places. For example, the previous writers mapped formation boundaries at angles oblique to the strike of the beds in places in secs. 6, 8, 9, and 13, T1N, R7E, owing to unrecognized local structures or faults, or perhaps due to overgeneralization.

Structure

Exposures of the McAlester Formation in the area studied generally dip N. 35–40° E. toward the Franks Graben at 10 to 45°, but in the N½ sec. 13, T1N, R7E, the beds dip N. 10–30° W. To explain this anomalous trend, the writer has inferred that a fault mapped by Hart (1974, sheet 1) in Coal County and in the southeast corner of sec. 12, T1N, R7E, Pontotoc County, extends southwestward across the N½ sec. 13 and into the east-central part of sec. 14 (fig. 2). In this vicinity the course of Coal Creek changes from a southeasterly direction to northeasterly. The upthrown side of the inferred fault is marked by a steep, 70-ft-high slope capped by sandstones of the lower McAlester Formation. Strike of the beds is generally parallel to the fault (N. 70° E.) in the N½ sec. 13, except in the vicinity of measured section 6 (appendix), where the strike of the beds changes to N. 70° W. (fig. 2).

Archinal (1977, pl. 1) tentatively mapped a fault extending northeasterly across secs. 16, 9, and 10, T1N, R7E. Field observations by the writer tend to confirm Archinal's interpretation. The outcrop line of the red-limestone marker is offset by about 1,000 ft in the SE¼ sec. 9, T1N, R7E (fig. 2). Evidence for other structural features was noted in the SE¼ sec. 8, where the rocks dip N. 44° W. at 32°, and in the NW½ sec. 6, where the rocks dip N. 65° W. at 46°.

McAlester (Lehigh) Coal

The earliest geological observation of coal in Pontotoc County was made by Morgan (1924, p. 68), who reported an operating strip pit from which the Lehigh coal was being mined in sec. 14, T1N, R7E (fig. 4a). Figure 4b shows this area as it presently appears.

The name "Lehigh coal" was the local name for the McAlester coal (Oklahoma Geological Survey, 1954, p. 126). Morgan (1924) believed that the coal in sec. 14 is the Lehigh, because it is overlain by a black, fossiliferous, carbonaceous shale which is also present directly above the Lehigh coal bed mined in 1924 in the vicinity of Coalgate and Lehigh in adjacent Coal County. Subsequent detailed mapping of the Atoka Formation by Archinal (1977, pl. 1) showed that the Hartshorne Formation is not present at the surface in Pontotoc County, and that the McAlester Formation rests directly on the Atoka Formation. Therefore, Archinal (1977, p. 20) interpreted the 12- to 14-in.-thick coal that crops out in secs. 14 and 15, T1N, R7E, to be the McAlester (Lehigh) coal.

The writer concurs with this interpretation on the basis of his present knowledge of the geology of the area. The fossiliferous, carbonaceous, shaly limestone that overlies the McAlester (Lehigh) coal in the Coalgate and Lehigh District (Knechtel, 1937, p. 134) was observed at four additional localities in the present study area (measured sections 2, 3, 4, 5; appendix). The site of the nearest outcrop of coal mapped as Lehigh by Knechtel (1937, p. 136, pl. 11) in the N½ sec. 30, T1N, R9E, Coal County, was visited by the present writer, but the area had been strip-mined in the late 1970's and reclaimed. No exposures of coal were found. Knechtel observed the characteristic layer of fossiliferous limestone that overlies the Lehigh coal at this site. Taff (1899, p. 454), in his work in the Coalgate–Lehigh District, also noted that the shale above the Lehigh coal "contains numerous fossil fauna composed principally of fresh or brackish water shells."

Knechtel (1937, p. 134) noted an unnamed thin coal bed about 30 ft above the Lehigh coal. In the present investigation, the writer observed a 3-in.-thick coal bed cropping out in sec. 13, T1N, R7E, Pontotoc County (measured section 6; appendix; fig. 5), and a stratigraphically equivalent, black, carbonaceous shale overlying a 6- to 8-in.-thick underclay (measured sections 3, 4; appendix; fig. 5) about 20 ft above the McAlester (Lehigh) coal. This unit is believed to be equivalent to Knechtel's unnamed thin coal. Owing to a facies change, the thin coal is absent to the west, and in the outcrop in the bluff above Coal Creek in sec. 15, T1N, R7E, (measured section 2; appendix), a 2-in.-thick, grayish-black, carbonaceous shale is present at the same horizon (fig. 5).

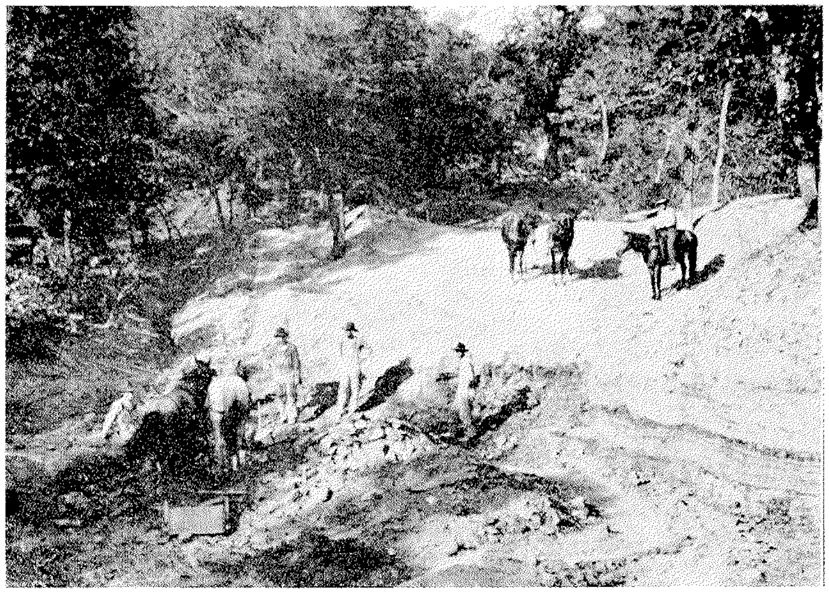


Figure 4a. View of operating strip pit in the NE¼SW¼NE¼SE¼ sec. 14, T1N, R7E, as it appeared in 1923. From Morgan (1924, pl. X. B.).

Figure 4b. View of abandoned strip pit at the location shown in fig. 4a as it appears today.

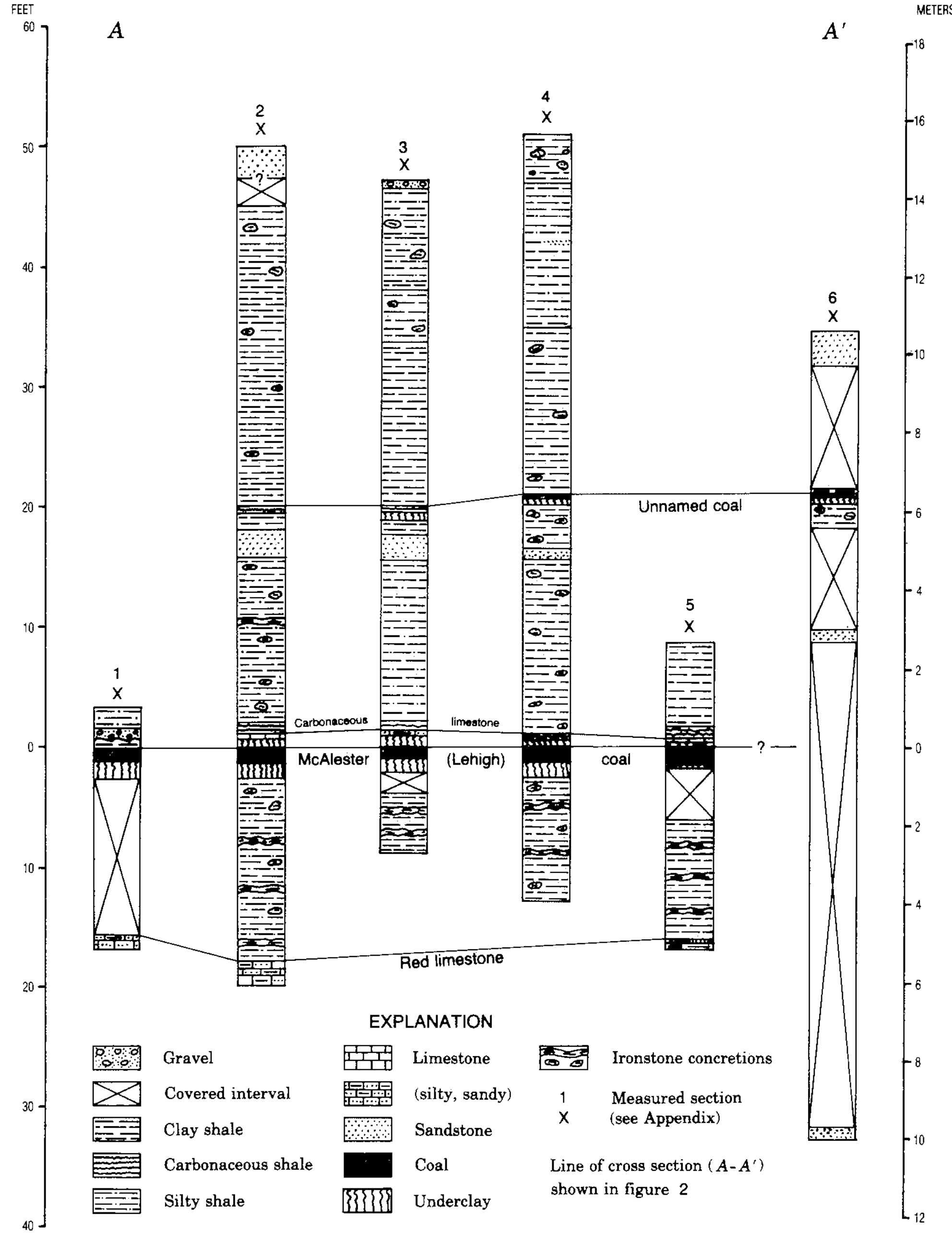


Figure 5. Correlations of key beds in the McAlester Formation in southeastern Pontotoc County.

Further evidence for identifying the thicker coal in the present area of investigation as the McAlester (Lehigh) has been provided by subsurface studies by Hyatt (1936, p. 960), Boyd (1938, p. 1568), Mann (1957, fig. 3), and Disney (1960, pl. 10). These authors have concluded that the Hartshorne Formation (which includes the Hartshorne coal) is not present in the Franks Graben west of a line running from the north edge of T2N, R8E southward through the C sec. 5, T2N, R8E, to the C sec. 17, T1N, R8E, Coal County. A 2-ft-thick coal was logged at a depth of 413 ft in an oil test well in the NW¼ sec. 12, T1N, R7E (fig. 2), which is west of the north-south line. The writer concludes that this coal is in the McAlester Formation and that it is equivalent to the coal that crops out updip in secs. 14 and 15, T1N, R7E. Boyd (1938, p. 1568), in his report on the subsurface stratigraphy around Jesse (fig. 2) based primarily on electric-log studies, noted coal in the McAlester Formation but did not identify the bed. The present writer believes that this coal bed is the McAlester (Lehigh).

In an area of Coal County directly east of the present study area, Archinal (1977, p. 22) was unable to identify coals solely on the basis of comparative chemical analyses. The ferruginous-limestone marker associated with the thicker coal in Pontotoc County has not been observed to the east in Coal County where the McAlester (Lehigh) coal has been positively identified by Knechtel (1937). Taff (1899, p. 437) did record a ferruginous bed below the McAlester coal in Pittsburg County. He stated that a thin band of buff fossil iron ore occurs below the McAlester coal near McAlester. Correlation of this bed with the ferruginous limestone in Pontotoc County is uncertain. However, on the basis of the stratigraphic evidence gathered for this report, the writer concludes that the thickest coal bed in T1N, R7E in Pontotoc County is the McAlester (Lehigh) coal.

Outcrops of the McAlester (Lehigh) coal observed by the author are plotted in figure 2. Exposures of the coal can be found only in secs. 14 and 15, T1N, R7E. The best exposure is in the bluff cut by Coal Creek in the NE¼SE¼ sec. 15, T1N, R7E (fig. 6), where the coal forms a prominent ledge. Excellent exposures of the strata above and below the coal (including the red limestone) are also present at this locality (measured section 2; appendix).

Field reconnaissance in sec. 13, T1N, R7E, did not reveal further outcrops of either the McAlester (Lehigh) coal or the red-limestone marker. Northwest of sec. 14, in secs. 8, 9, and 10, T1N, R7E, no exposures of the coal were found, but the red- limestone marker was traced to the northwest corner of sec. 8.

Based on standard geologic procedure for calculating coal resources, the boundary of the coal was extended 2 mi beyond the last observed outcrop in the SW¼NE¼ sec. 15, T1N, R7E (fig. 2). Most of the coal resources are classified as indicated and inferred. The writer believes that the coal bed thins and pinches out northwest of sec. 15; this can be verified by drilling.

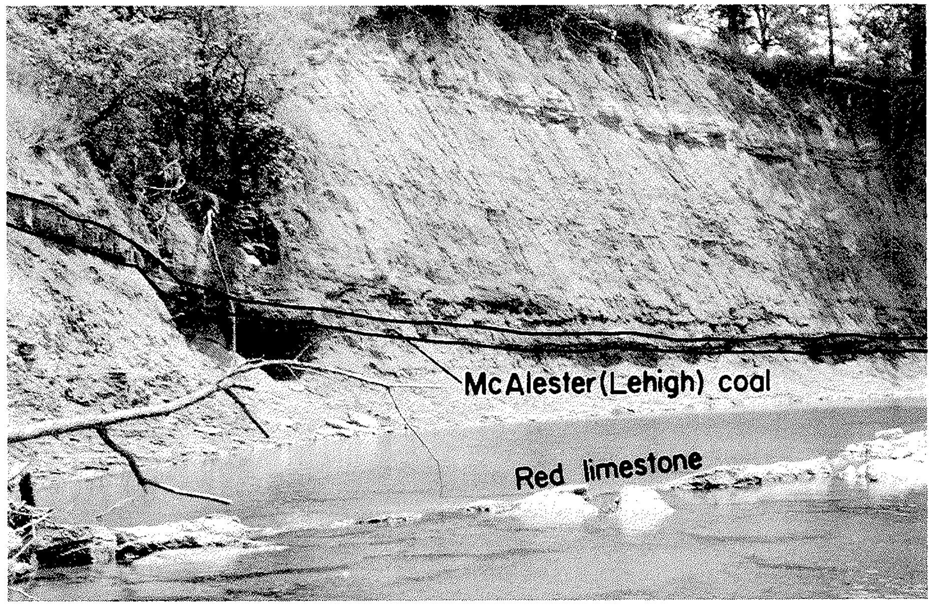


Figure 6. Outcrop of the McAlester (Lehigh) coal in the bluff overlooking Coal Creek in the NE¼NE¼NE¼SE¼ sec. 15, T1N, R7E. The coal bed is 14 in. thick at this location (measured section 2; appendix).

Coal Quality

Channel samples of the McAlester (Lehigh) coal were collected in the study area at two outcrops, in accordance with procedures described by Friedman (1974). Analyses of the samples and locations of the sample sites are given in table 1.

The McAlester (Lehigh) coal in Pontotoc County is tentatively assigned an apparent rank of high-volatile C bituminous (hvCb). Rank (or geologic maturity) was determined by standard procedures of the American Society for Testing and Materials (1984, p. 245). However, it should be noted that classification of coals using outcrop samples is not recommended by ASTM (1984, p. 243, 7.1.2.). Since no other samples were obtainable for classification purposes, and the coal where sampled on the outcrop appeared to be minimally weathered, the designation "apparent rank" is used for purposes of this report. Use of this terminology is in compliance with ASTM recommendations. Percentage of moisture in the coal seems excessive, probably owing to exposure of the coal to surface waters. Other analytical values, such as percentage of ash and percentage of sulfur, provide the reader with useful information and are probably close to values from a fresh sample. The low reported Btu values are in part a reflection of the high moisture content.

On an as-received basis, the average Btu/lb value is 9,772, the average

TABLE 1.—ANALYSES OF THE MCALESTER (LEHIGH) COAL IN PONTOTOC COUNTY

Sample Location[a]	Sample Condition[b]	Proximate Analysis (%) Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur (%)	Btu/lb	Apparent Rank[c]
5	1	13.3	37.8	37.4	11.5	4.0	10,172	
NW¼SW¼NE¼SE¼	2	NA[d]	43.6	43.2	13.2	4.7	11,729	hvCb
sec. 14, T1N, R7E	3	NA	50.3	49.7	NA	5.3	13,519	
2	1	17.0	34.6	38.5	9.9	5.0	9,372	
NE¼NE¼NE¼SE¼	2	NA	41.7	46.4	11.9	6.0	11,292	hvCb
sec. 15, T1N, R7E	3	NA	47.3	52.7	NA	6.8	12,820	

[a]Number corresponds to measured section (see appendix).
[b]1 = as received; 2 = moisture-free; 3 = moisture- and ash-free.
[c]hvCb = high-volatile C bituminous.
[d]NA = not applicable.

ash content is 10.7 percent, and the average sulfur content is 4.5 percent. On a moist, mineral-matter-free basis, the average Btu value is 11,135, which is within the 10,500–13,000 Btu/lb range listed in ASTM for high-volatile C bituminous coals (ASTM, 1984, p. 245). Considering the low quality of the McAlester (Lehigh) coal in Pontotoc County as compared to other available coals in the State, the thinness of the bed, the limitations imposed on surface mining by the steep dip of the bed, and current economic conditions in the coal industry, it is doubtful that the coal can be profitably mined at the present time. However, future technological and economic changes could create a demand for the coal, and it may one day be mined.

Resources and Reserves

A detailed summary of the coal resources and reserves is presented in table 2. Coal resources and reserves in Pontotoc County have been calculated in accordance with the criteria of Friedman (1974, p. 12–15). For the purpose of brevity all of the criteria are not repeated here; only the most important are highlighted and paraphrased.

Resources.—The broadest term applied to coal deposits identified or presumed to exist within a coal field, based on geologic data and geologic judgment. Resources include estimated original coal resources (all coal 10 in. or more in thickness, including coal that has been mined or lost in mining), remaining coal resources (all coal 10 in. or more in thickness, excluding coal that has been mined or lost in mining), and reserves (all coal recoverable at a profit under current economic conditions, based on 50-percent recovery for underground mining and 80-percent recovery for surface mining).

Measured, indicated, and inferred coal resources and reserves.—These terms are categories of reliability based on geologic evidence and judgment and are in accordance with standard procedure. Coal data points provide evidence of thickness, composition, continuity, depth, and attitude of coal beds. These data points may be at mine boundaries, in drill holes that penetrate coal, or at outcrops.

Measured resources are those for which data points are not more than 0.5 mi apart. Indicated resources are those for which data points are not more than 1.5 mi apart. Inferred resources are those for which data points are not more than 4 mi apart.

Evaluation of strippable resources (those minable by surface methods) is based principally upon thickness of coal and overburden (all unconsolidated and consolidated material that overlies the coal bed). The coal bed must have a minimum thickness of 10 in., and the ratio of overburden to coal must not be more than 60:1. For example, a coal bed 12 in. thick would be considered minable by surface methods to a depth of 60 ft.

Coal at depths greater than 100 ft must have a minimum thickness of 14 in. to be included in estimates of original and remaining resources. In this report, no depth limitations have been set for calculating coal

TABLE 2.—COAL RESOURCES AND RESERVES IN T1N AND T2N, PONTOTOC COUNTY[1]
(THOUSANDS OF SHORT TONS)

Category of Reliability	Depth (ft)	Remaining Resources 0.8 - 1.2 ft Acres	Tons	Remaining Resources 1.2 - 2.4 ft Acres	Tons	Total Remaining Resources Acres	Tons	Mined or Lost in Mining Acres	Tons	Original Resources Acres	Tons	Reserves Acres	Tons
	0-20	18	37	8	19	26	56	<1	Unknown	26	56	26	45
	20-40	18	37	6	14	24	51			24	51	1	1
Measured	40-100	15	29	12	28	27	57			27	57		
	>100			178	558	178	558			178	558		
	Total	51	103	204	619	255	722			255	722	27	46
	0-20	3	6	5	16	8	22			8	22	8	18
	20-40	3	6	5	16	8	22			8	22	2	4
Indicated	40-100	9	16	28	82	37	98			37	98		
	>100			1,374	4,229	1,374	4,229			1,374	4,229		
	Total	15	28	1,412	4,343	1,427	4,371			1,427	4,371	10	22
	0-20	14	25	2	6	16	31			16	31	16	25
	20-40	13	24	2	7	15	31			15	31	2	4
Inferred	40-100	34	62	15	54	49	116			49	116		
	>100			1,180	3,606	1,180	3,606			1,180	3,606		
	Total	61	111	1,199	3,673	1,260	3,784			1,260	3,784	18	29
	Grand Total	127	242	2,815	8,635	2,942	8,877	<1	Unknown	2,942	8,877	55	97

[1]All coal is identified as the McAlester (Lehigh) coal.

resources. In determining coal resources, the weight of bituminous coal is assumed to be 1,800 short tons per acre-ft. The number of acres (measured by planimeter) multiplied by 1,800 tons/acre-ft and multiplied by coal-bed thickness in feet equals the number of tons of coal.

Of the remaining resources, 8,393,000 short tons of coal (95 percent of the total) occurs at depths greater than 100 ft. Thickness of this deep coal ranges from only 1.2 to 2.0 ft. Present-day technology does not permit utilization of this bed. A small tonnage of reserves (97,000 short tons) has been included in table 2, although current coal economics probably would make mining only marginally profitable.

Summary

1. A coal bed of minable thickness (greater than 0.8 ft) is present in southeastern Pontotoc County.
2. The coal bed is believed to be correlative with the McAlester coal.
3. Analyses of outcrop samples of the coal suggest that it is of low quality; average percent ash is 10.7, average percent sulfur is 4.5, and average Btu/lb is 9,772 (all values on an as-received basis).
4. The coal resources are 8,877,000 short tons. However, about 99 percent of this total cannot be mined under current technology and economics.
5. The recoverable reserves are 97,000 short tons.

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Appendix

Measured Sections

1

SE¼NW¼SW¼NE¼ sec. 15, T1N, R7E, Pontotoc County. Measured in cutbank of southeastward-flowing intermittent stream, by LeRoy A. Hemish.

	Thickness (ft)
Silt, sandy, light-brownish-gray; contains abundant organic material (alluvium)	1.8
Gravel, light-brown, silty, sandy; contains abundant angular clasts of thin-bedded, dark-reddish-brown sandstone (alluvium)	1.0
Krebs Group	
McAlester Formation	
Shale, olive-gray to medium-gray with moderate-reddish-orange mottling at contact with underlying unit, highly clayey, weathered	0.7
Coal, black, soft, very highly weathered (McAlester [Lehigh] coal)	1.0
Underclay, light-olive-gray with pale-yellowish-brown staining (to water in stream)	1.5
Covered interval	13.0
Limestone, grayish-red, impure, silty, sandy, highly fossiliferous; crops out in creek bank downstream from exposure of coal	1.1
Total	20.1

2

NE¼NE¼NE¼SE¼ sec. 15, T1N, R7E, Pontotoc County. Measured in cutbank of Coal Creek, by LeRoy A. Hemish.

	Thickness (ft)
Krebs Group	
McAlester Formation	
Sandstone, grayish-orange to light-brown, very fine-grained, medium-bedded, noncalcareous, bioturbated; trails and burrows abundant on bedding surfaces; ripple marked in part; total thickness uncertain owing to slumping and cover on outcrop	5.0
Shale, light-olive-gray with dark-reddish-brown bands from 4 in. to 2 ft in thickness; weathers to small flakes on the outcrop; contains abundant light-brown to moderate-brown clay-ironstone concretions up to 14 in. in diameter and 2 in. in thickness	25.0
Shale, grayish-black, carbonaceous	0.2
Shale, yellowish-gray, weathered	1.8
Sandstone, light-brown to moderate-reddish-brown, very fine-grained, highly calcareous, bioturbated, medium-bedded, well indurated; forms resistant ledge on the outcrop	2.2
Shale, olive-gray, silty; includes thin layers of moderate-reddish-brown clay-ironstone concretions and one 2-in.-thick layer of clay ironstone about 7 ft from top of unit	13.8
Shale, dark-gray with medium-dark-gray and brownish-gray bands, fissile, soft, carbonaceous	1.0
Limestone, grayish-brown, very shaly, fossiliferous; grades into highly calcareous shale laterally along the outcrop; contains fossil hash and carbonaceous material	0.2
Underclay, medium-gray with pale-yellowish-orange bands; contains thin, discontinuous coal beds up to 0.5 in. in thickness; includes some small-scale channel-fill deposits that truncate the coal beds	0.9
Coal, black, banded; includes dark-reddish-brown iron oxide and gypsum deposits on cleat surfaces; finely cleated, hard (McAlester [Lehigh] coal)	1.2
Underclay, medium-gray with moderate-reddish-brown staining, unbedded, slickensided; contains black, carbonized plant remains	1.5
Shale, medium-light-gray with pale-red tones, highly silty; bedding nodular; contains discoidal clay-ironstone concretions occurring as 1- to 2-in.-diameter rings surrounding shale interiors, which look much like stacked bicycle tires, or where broken on the outcrop like broken ribs in a rib cage; as many as 20 were observed in one stack	15.2
Limestone, grayish-red, impure, silty, hard, highly fossiliferous; brachiopods, horn corals, and pelecypods abundant; forms rapids in creek; total thickness unknown	2.0
Total	70.0

3

SE¼NE¼NE¼SW¼ sec. 14, T1N, R7E, Pontotoc County. Measured in cutbank of Coal Creek, by LeRoy A. Hemish.

	Thickness (ft)
Gravel and silt, moderate-brown; includes topsoil and clasts of chert and limestone up to cobble size	0.6
Krebs Group	
McAlester Formation	
Shale, moderate-yellowish-brown, silty, weathered; includes layers of light-brown clay-ironstone concretions about 3 in. in thickness; also includes some slumped 1-ft-thick blocks of very fine-grained, grayish-orange, thin-bedded sandstone in upper part of unit	8.4
Shale, light-olive-gray; includes minor light-brown clay-ironstone concretions	4.5
Shale, dark-olive-gray with dark-reddish-brown mottling; includes a 2-ft-thick, dark-reddish-brown interval at top of unit; blocky	13.5
Shale, black, fissile, soft, very carbonaceous; stained grayish-yellow in part	0.3
Underclay, greenish-gray with moderate-reddish-brown staining and mottling; contains carbonized plant compressions; slickensided	0.8
Shale, medium-gray with grayish-red mottling; silty; bedding nodular	1.4
Sandstone, grayish-red with dark-reddish-brown blotches, very fine-grained, very calcareous, medium-bedded, bioturbated; includes abundant trace fossils on upper surface; well indurated; forms resistant ledge on outcrop	2.0
Shale, light-olive-gray, silty; bedding nodular in upper part; contains scattered ovate clay-ironstone concretions	13.5
Shale, grayish-black, carbonaceous, fissile, noncalcareous	0.7
Limestone, dark-gray with minor grayish-red staining, highly impure, carbonaceous, shaly; contains abundant fossil hash and coalified plant material	0.5
Underclay, medium-light-gray, plastic; contains abundant black, carbonized plant material	0.9
Coal, black, finely cleated, moderately friable (McAlester [Lehigh] coal)	1.0
Underclay, medium-light-gray with moderate-reddish-brown staining, plastic; contains black, carbonized plant material (lower contact covered)	1.2
Covered interval	1.7
Shale, medium-gray; includes light-brown clay-ironstone concretions occurring in 1-in.-thick layers	5.0
Total	56.0

4

NE¼SW¼NE¼SE¼ sec. 14, T1N, R7E, Pontotoc County. Measured in steep bluff and hillslope, south side of Coal Creek, by LeRoy A. Hemish.

	Thickness (ft)
Slumped material; mostly weathered grayish-brown shale with some gravel- and cobble-sized clasts of dark-reddish-brown sandstone	4.0

Krebs Group
McAlester Formation

Shale, light-olive-gray, silty; contains a few thin, discontinuous lenses of moderate-yellowish-brown, weakly indurated, very fine-grained sandstone	12.0
Shale, light-olive-gray to olive-gray; contains a few dark-reddish-brown clay-ironstone concretions about 1 to 2 in. in diameter; includes a grayish-red, 1-ft-thick, ferruginous shale bed at top of unit	14.0
Shale, black, very carbonaceous; includes a 0.5-in. layer of coaly shale at top of unit	0.3
Underclay, yellowish-gray with moderate-reddish-brown staining; contains abundant black carbonized plant fragments	0.5
Shale, light-olive-gray to medium-gray; includes abundant very dark-red clay-ironstone concretions	3.8
Sandstone, light-brown to moderate-reddish-brown, highly calcareous, very fine-grained, thin- to medium-bedded, extensively bioturbated, well indurated; forms ledge on outcrop and rapids in Coal Creek	0.9
Shale, medium-gray, silty; includes abundant dark-reddish-brown clay-ironstone concretions 1 to 3 in. thick	14.7
Shale, black with olive-gray and orange bands, carbonaceous; includes a 0.5-in.-thick bed of fossiliferous limestone at top of unit	0.2
Underclay, light-gray with grayish-yellow bands	0.6
Coal, black with dark-yellowish-orange and moderate-reddish-orange staining, soft, highly weathered (McAlester [Lehigh] coal)	1.2
Underclay, light-gray with light-brown staining	1.4
Shale, medium-dark-gray, contains abundant dark-reddish-brown clay-ironstone concretions that weather into 1-in. fragments on the outcrop slope	10.4
Total	64.0

5

NE¼SW¼NE¼SE¼ sec. 14, T1N, R7E, Pontotoc County. Measured in cutbank of intermittent stream about 120 yd southeast from juncture with Coal Creek and up gully to the south, by LeRoy A. Hemish.

	Thickness (ft)
Krebs Group	
McAlester Formation	
Shale, medium-gray to brownish-gray, flaky; moderate-reddish-brown staining on stratification surfaces	7.0
Shale, grayish-black, brittle, dark-reddish-brown iron oxide deposits on stratification surfaces	1.0
Limestone, dark-gray, weathers brownish-gray, impure, shaly, carbonaceous; contains abundant fossil hash; thins laterally and grades into highly calcareous shale	0.3
Shale, olive-gray with moderate-yellow and dark-reddish-brown	

staining, soft, noncalcareous; underclay in part; contains black, coaly veins and carbonized plant material	0.5
Coal, black, bright, extremely hard, pyritic, some white calcite on cleat surfaces (McAlester [Lehigh] coal)	1.3
Underclay, light-gray, plastic, total thickness not exposed	0.1
Covered interval	4.6
Shale, medium-dark-gray; includes several 1- to 2-in. layers of jointed clay-ironstone	10.0
Limestone, moderate-reddish-brown, impure, silty, very fossiliferous; brachiopods and pelecypods predominant	0.2
Shale, olive-gray; contains small clay-ironstone concretions about 1 in. in diameter; total thickness not exposed)	0.8
Total	25.8

6

SW¼NE¼NW¼NE¼ sec. 13, T1N, R7E, Pontotoc County. Measured in pasture above steep-walled ravine southwest from Coal Creek, by LeRoy A. Hemish.

	Thickness (ft)
Krebs Group	
McAlester Formation	
Sandstone, pale-yellowish-orange, very fine-grained, noncalcareous; poorly exposed; forms low resistant ridge crest	3.0
Covered interval	10.1
Shale, olive-gray, weathered	0.5
Coal, black, soft, weathered (unnamed coal)	0.3
Underclay, olive-gray with dark-reddish-brown mottling, sticky	0.5
Shale, medium-gray; contains abundant clay-ironstone concretions that weather to dark-reddish-brown fragments on the outcrop	2.0
Covered interval	8.6
Sandstone, dark-yellowish-orange, very fine-grained, noncalcareous, poorly exposed; total thickness uncertain	1.0
Covered interval	40.6
Sandstone, light-brown to grayish-orange, fine- to very fine-grained, noncalcareous, thick-bedded; weathers dusky-brown with irregular pitted surface on the outcrop	1.1
Total	67.7

GIS GUIDELINES FOR AUTHORS/PUBLISHERS OF GEOLOGIC FIELD TRIP GUIDEBOOKS

Guidebooks often contain some of the most site-specific information to be found in geological literature. However, sometimes it is difficult to locate these publications. Librarians have found that guidebooks are difficult to acquire and once obtained may be difficult to catalog and identify. A searcher usually wants to find a guidebook associated with a particular meeting or area.

These difficulties led the Geoscience Information Society to compile a list of guidelines for the authors and publishers of guidebooks. Using the guidelines will help assure that basic information is included on the cover and title page. GIS President Claren M. Kidd says that following these guidelines will help the reader locate a particular guidebook. She also suggests that the organization publish more copies than are needed for the field trip's participants.

Those who prepare guidebooks can contribute to the identification and control of the guidebook literature by applying the following guidelines:

Title page should include:

- Specific geographic area as part of a descriptive title, e.g., county, state, or province.
- Clearly indicated subtitle.
- Name and place of meeting when the field trip is held in conjunction with a meeting. If it is an annual meeting, specify the number of the annual meeting and the number of the field trip.
- Day(s), month, and year that the field trip is conducted or the date of publication if guidebook is not compiled for a specific field trip.
- Name of the organization(s) sponsoring the field trip.
- Name and number of the consistently phrased publication series, when applicable.
- Name of field trip leader.
- Title on cover and title page should be identical.
- If reprinted, list the original publication series, guidebook number, and year of publication.

Verso of the title page:

- Name and address of the publisher.
- Name and address of the distributor.
- Price of the publication.

General recommendations:

- Use good quality paper, printing, and binding (preferably, not spiral binding).
- Print more copies of the guidebook than are needed for the field trip participants.
- Send publication announcements containing all information that

appears on the title page and its verso to *Geotimes* and *Episodes*. If possible, send announcements to all libraries listed in the *Union List of Geologic Field Trip Guidebooks of North America* and to Geoscience Information Society members.

Deposit a copy of the guidebook in the USGS Library in Reston, Virginia, and a copy in the nearest library listed in the *Union List*.

Number the pages consecutively.

Identify all illustrations.

List all unbound illustrative material in a table at the front of the guidebook and include a pocket to hold all these pieces in the back of the publication.

JOURNAL ISSUES CALL FOR PAPERS

The Northeastern Science Foundation, Inc. will sponsor a symposium on Case Histories of Carbonate Reservoirs, to be held on June 4 and 5, 1986, at the Rensselaer Center of Applied Geology in Troy, New York.

Papers presented at this symposium will be published in the first issue of a new journal entitled *Carbonates and Evaporites*. The Foundation will publish one issue of the journal in 1986, two issues in 1987, and thereafter four issues per year.

For information on attending the Case Histories of Carbonate Reservoirs symposium and/or subscription to *Carbonates and Evaporites*, contact Gerald M. Friedman, Northeastern Science Foundation, Inc., P.O. Box 746, Troy, NY 12181.

KU PROFESSOR DISCOVERS KANSAS ONCE HAD MOUNTAIN CLIMATE

For the past few thousand years, the Kansas landscape has looked much as it does today—prairie grasses broken by occasional stands of trees. But 20,000 years ago, the state was covered by forests, said a University of Kansas professor of botany.

Philip V. Wells has evidence that most of the state was covered by spruce trees interspersed with aspens and meadowlands.

"The whole state was a spruce and aspen parkland," said Wells, whose evidence includes charcoal and snail-shell remains. "Where the forests had burned, you would see aspen or birch, trees found today in much of Canada or above 8,000 feet in the Rockies."

The key was a cooler climate brought by an invading glacier.

"Our winters are plenty cold enough for spruces today, but our summers are too hot and dry," Wells said. "The ice sheet may have changed the temperature and precipitation enough to let them grow. Cooler summers, with maximum temperatures of 80 degrees rather than 100, would have been the key."

By its very size, the glacier made the difference.

"We're talking about a mountain of ice—maybe 10,000 feet high—that moved into what is now the Dakotas, northeast Nebraska and central Iowa. That might have changed the jet stream, the air masses, so that we had more precipitation, more cloudy days and cooler summers."

Wells and paleontologist J. D. Stewart from the KU Museum of Natural History found evidence of a forest-covered Kansas while digging through a wind-blown silt—loess—that mantles much of the High Plains.

"In one site we found needles of the limber pine, a tree found today only in the Rocky Mountains," he said. In Jewell County, they uncovered a 300-foot-long horizon of spruce charcoal an inch or so thick, remnant of a forest fire.

"It was flat and dry enough, with enough forest, so you could have had jim-dandy forest fires that would have burned with the wind for long distances."

Ironically, the most pervasive evidence of forests wasn't fossil vegetation. It was snail shells—countless thousands of upland land snails. Most fossils don't survive in loess, but snail shells do.

"We found 15 to 20 snail species that are today found only in the Rockies," Wells said. "These snails couldn't survive in Kansas today, but they had enough moisture then. They fed on aspen-leaf litter."

Most of these snails had tiny, spiral shells smaller than a wheat grain, so the forest could have supported lots of them. "We found 30,000 snails in one pickup load of loess. Aspen-leaf litter and small snails would have covered the forest floor." Stewart and Wells also found bones of small mammals, such as red squirrels, that lived in such forests.

Conifers instead of corn, snowshoe rabbits instead of prairie dogs, forest instead of farm ground.

"This means that today's Rocky Mountain forest shrank to the west after the glacier receded," Wells said. "But the notion of a forest in Kansas isn't that hard to believe. After all, the elevations in western Kansas are pretty good—up to 4,000 feet in places—and the mountains are only a few hundred miles away."

A few hundred miles and a few degrees of temperature. On a snowy winter day, maybe it isn't too hard to believe.

CALL FOR PAPERS: SME–AIME ANNUAL MEETING

The Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers (SME–AIME) has issued a call for papers for the annual meeting, to be held February 24–27, 1987, in Denver, Colorado. The general theme of the meeting is the future of the minerals industry.

In the Coal Division, papers may be submitted for presentation at the following sessions: environmental, health and safety, preparation, research and development, surface mining, underground mining, and utilization.

The Industrial Minerals Division is accepting papers for presentation at sessions on economics of industrial minerals in the 1980's and 1990's—review and forecast; quality control testing and technical support for industrial minerals operations; cement; construction aggregates; groundwater, problems related to industrial minerals operations; and bulk handling of industrial minerals.

The sessions of the Mining and Exploration Division include geology; geotechnical aspects of heapleash design; future of solution mining; underground mining; open pit mining—case histories related to cost reduction and productivity improvement and practical applications of open pit slope stability techniques; and groundwater, problems related to industrial minerals operations.

The Mineral Processing Division seeks papers for presentation at sessions on fundamentals of mechanical design for crushers and grinding mills, bulk handling of industrial minerals, future of process control in the minerals industry, mill design in the next decade, fundamentals, innovative plant design changes in concentration processes, enhancing permeability of ores for hydrometallurgy treatment, extractive metallurgy, and process mineralogy.

The Minerals Resource Management Committee solicits papers for a session on computers, precious metals, and changing economics in the minerals industries.

The deadline is May 1, 1986, for submission of a 100-word abstract. For more information and a list of names and addresses of session chairmen, contact Lori A. Penrod Yacovella, Meetings Dept., Society of Mining Engineers of AIME, Caller No. D, Littleton, CO 80127; telephone (303) 973-9550.

GEOLOGY LIBRARY MAKES DECISIONS ON WHAT AND WHAT NOT TO BUY

What makes a good geology library? What titles should be included and why? These were some of the questions asked of Claren Kidd, OU geoscience librarian, in a recent survey by the Stanford-based Research Libraries Group (RLG). The survey was developed through a grant from Conoco Oil.

The goal of the survey was to determine what makes a good geology library and to see how libraries can share information, Kidd said.

The University of Oklahoma's Geology Library, supported in part by the Oklahoma Geological Survey, has been a member of RLG since the late 1970's. The Research Libraries Group consists of 34 U.S. libraries, of which the majority are part of state and private universities, and includes such prestigious schools as Yale, Princeton, and Columbia. The Geology Library at OU ranks among the top in the RLG for its collections in the geological sciences.

The RLG survey also was sent to the geoscience divisions of the New York City Public Library and the libraries of Columbia University, Stanford University, the University of Minnesota, the University of Iowa, and the State University of New York at Stony Brook. These libraries were chosen for the quality of their geoscience collections, and because their representative librarians meet yearly at the Geoscience Information Society's meetings held in conjunction with the annual convention of the Geological Society of America.

The survey required the representative librarians to answer questions related to approximately 400 titles which may or may not have been included in the particular library's collection. The titles were mainly those of geological journals that were randomly selected from GeoRef, an international, computerized database for the geological sciences. The survey's questions included: whether or not the title was owned by the library and, if owned, how the title was acquired; the primary reason the title was acquired; how difficult it is to maintain the title; the usefulness of the title to the library's patrons; why the title is essential to have on site; and whether or not the title would have been purchased if obtainable within a given period of time from a remote collection.

Although OU's Geology Library currently is able to access the databases of other libraries through the use of computers, the RLG wants to focus on how each of its member libraries can best direct its collection efforts for the good of the whole group. This could mean that each particular library specialize its collecting efforts along certain lines. The Geology Library at OU, for instance, might collect only items that relate to current and projected research of the School of Geology and Geophysics and the Oklahoma Geological Survey. Then through computer networking with the other RLG libraries, patrons would have almost immediate access to a much larger collection of titles than any one library could maintain financially or physically.

While many of the RLG's information-sharing plans remain in the planning stages, the data derived from the survey should help clarify the initial issues involved. Results of the survey will be available this spring.

Edward Rutledge

CALL FOR PAPERS ISSUED FOR UPCOMING EXCAVATION, TUNNELING CONFERENCE

A call for papers has been issued for the Eighth Rapid Excavation and Tunneling Conference (RETC), June 14–18, 1987, in New Orleans, Louisiana. The conference is designed to provide a forum for the exchange of new developments in the technology of underground rapid machine excavation and tunneling on a worldwide scale.

The RETC is jointly sponsored by the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) and the American Society of Civil Engineers (ASCE). The Society of Mining Engineers of AIME is coordinating the technical program.

On behalf of the Program Committee, a call for papers is issued covering the following topics: Tunnel Boring Machine Histories and Developments; Soft Ground and Roadheader Case Histories; Large Diameter Tunnels and Underground Chambers Case Histories; Shafts and Inclines Case Histories; Geotechnical Data for Underground Projects; and Lining and Permanent Support Methods.

Additional topics include: Improvements in Conventional Tunneling Methods; Underground Safety; Ground Water Control in Shafts and Underground Openings; Conventional and Mechanical Shaft Sinking; Shaft and Tunnel Lining Techniques; New Technology in Underground Excavation; Design, Construction, and Support of Large Underground Openings; Difficult Ground Conditions and Unforeseen Occurrences; Underground Contracting Methods and Disputes, Recent International Experiences, and Computer Applications.

Abstracts of 100 words or less should be submitted by July 1, 1986, to Darline D. Daley, Assistant Conference Manager, RETC, Caller No. D, Littleton, CO 80127.

Authors will be informed of the acceptance of their paper by September 2, 1986. Final papers will be due February 2, 1987.

NOTES ON NEW PUBLICATIONS

COSUNA Charts

Correlation charts covering four new regions of the U.S. are now available. The new charts cover the California, Appalachian, Northern Mid-Continent, and Midwestern Basin and Arches regions. Also available are earlier-released charts covering the Northern Rockies/Williston Basin, Southwest/Southwestern Mid-Continent, and Atlantic Coastal Plain.

COSUNA (Correlation of Stratigraphic Units in North America) is a research and correlation project begun in 1977 by AAPG's Research Committee in cooperation with the Committee on Stratigraphic Correlations. The new charts show complete stratigraphic columns depicting selected sites within the CSD (AAPG Committee on Statistics of Drilling) geological provinces of the United States (including Alaska).

Order from: AAPG Bookstore, P.O. Box 979, Tulsa, OK 74101. The price for the charts is $8 each, except for the set of three charts in the California Series, which is $18, and the set of two charts in the Appalachian Series, which is $12, plus postage and handling costs.

Economics and the Explorer

Rather than dealing with factors at work *within* exploration-related activities, this book focuses on factors influencing the industry from *outside*. Edited by Robert E. Megill, the 100-page volume is illustrated with numerous charts and graphs. The papers for this collection were solicited from a special symposium given at the AAPG 1984 Annual Meeting in San Antonio.

Order from: AAPG Bookstore, P.O. Box 979, Tulsa, OK 74101. The price is $12 for AAPG members, $16 for nonmembers, plus $3 for fourth-class shipping to addresses in North America. Oklahoma residents must add 6.25% sales tax.

Finding Work as a Petroleum Geologist: Hints for the Jobseeker

Author James A. Gibbs examines six areas of importance to the job-seeking geologist: (1) attitudes—how to improve and expand them; (2) employment conditions in industry; (3) preparing for your career—how to choose a college and curriculum, advanced degrees, contacts in industry, continuing education; (4) who are the employers; (5) contacting employers effectively; and (6) alternative strategies—self employment, staying close to the market and waiting.

Order from: AAPG Bookstore, P.O. Box 979, Tulsa, OK 74101. The price is $4 plus $1.50 for fourth-class shipping to addresses in North America. Oklahoma residents must add 6.25% sales tax.

Land Use and Land Cover and Associated Maps for Clinton, Oklahoma

This data set consists of four maps keyed to USGS topographic map Clinton at a scale of 1:250,000 (1 in. = about 4 mi). These maps are coded for statistical development. The maps are (1) land use and land cover, (2) political unit, (3) hydrological units, and (4) census county subdivision. Also included is one positive of the cultural base for Clinton.

Order OF 84-0534 from: U.S. Geological Survey, Mid-Continent Mapping Center, 1400 Independence Rd., Rolla, MO 65401.

1983 Minerals Yearbook, Volume III. Area Reports: International

Mineral data on more than 130 foreign countries and the importance of minerals in the economies of these nations is discussed in this 1,027-page volume, published in August of 1985. A separate chapter reviews the international minerals industry in general and its relationship to the world economy.

Order GPO Stock No. 024-004-02143-8 from: Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. The price is $26; add 25% to the price for foreign shipment.

A Summary of Current and Historical Federal Income Tax Treatment of Mineral Exploration and Development Expenditures

The Federal income tax treatment of mineral exploration and development expenditures is summarized, and changes in the tax treatment of these expenditures since 1951 are detailed and analyzed in this 13-page Bureau of Mines report by Phillip N. Yasnowsky.

Order IC 9011 from: U.S. Department of the Interior, Bureau of Mines, Section of Publications, 4800 Forbes Ave., Pittsburgh, PA 15213. The publication is free. Please enclose a self-addressed mailing label.

Mastodon-Bearing Springs and Late Quaternary Geochronology of the Lower Pomme de Terre Valley, Missouri

C. Vance Haynes, Jr., presents the stratigraphic framework from which the various fossils and archaeological finds of the lower Pomme de Terre River Valley in west-central Missouri can be related to one another and to radiocarbon dates and other samples. These relationships provide the basis for the reconstruction of the fluvial history of the Pomme de Terre River and paleoenvironmental changes during the last 100,000 years (the late Quaternary Period). The GSA Special Paper contains 42 pages plus an oversized insert.

Order SP–204 from: Geological Society of America, Publication Sales, Dept. 21, P.O. Box 9140, Boulder, CO 80301. The price is $10, postpaid.

OKLAHOMA ABSTRACTS

AAPG, Mid-Continent Section, Annual Meeting
Amarillo, Texas, September 22–24, 1985

The following abstracts are reprinted from the *Bulletin* of the American Association of Petroleum Geologists, v. 69, no. 8. Page numbers are given in brackets below the abstracts. Permission of the authors and of the AAPG to reproduce the abstracts is gratefully acknowledged.

Dolomitization Stages in Regressive Sequence of Hunton Group, Anadarko Basin, Oklahoma

ZUHAIR AL-SHAIEB and GEOFFREY B. BEARDALL, JR.,
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The Upper Silurian Henryhouse Formation, of the Hunton Group (Upper Ordovician–Lower Devonian), is a major hydrocarbon reservoir in the Anadarko basin. Detailed examination of Henryhouse cores was conducted at many localities in the basin, west of T10W. Sedimentary structures, lithology, fossil content, and fabric relationships were used as criteria to recognize various depositional facies. Subtidal, intertidal, and supratidal facies can be distinguished readily, and their spatial relationships consistently indicate a shallowing-upward sequence. Previously unreported nodular anhydrite (replaced and unreplaced) occurs at the top of the sequence, suggesting that hypersaline conditions developed in supratidal environments.

Three stages of dolomitization were documented in the Henryhouse Formation. Petrographic, cathodoluminescent, and isotopic techniques were used to investigate the genesis and textural relationships of various dolomite types. The following paragenetic sequence was discerned: (1) penecontemporaneous hypersaline dolomite occurring as brownish, hypidiotopic, 60–80 μm rhombs concentrated in the supratidal and intertidal facies; (2) marine-water and freshwater mixed dolomite occurring as white rims around preexisting hypersaline dolomite and as anhedral, white rhombs in vugs and molds; (3) deep burial vug, mold, and fracture-filling baroque dolomite.

Cathodoluminescence reveals that typical Henryhouse dolomite exhibits dull luminescing cores with other bright rims corresponding to the dark core and light rim seen in plane light. This zonation represents two stages of dolomitization.

Oxygen isotope ratios range from -2.2 to 9.9‰ (mean -4.6) vs. PDB, whereas the carbon isotope ratios range from 0 to $+3.3$‰ (mean $+1.4$) vs. PDB. The considerably light $\delta^{18}O$ reflects a freshwater influence.

Values of $\delta^{13}C$ may represent initial composition because of their resistance to alteration. [1316]

Misener Strike-Valley Sandstone Reservoir, Grant and Garfield Counties, Oklahoma

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The Middle and Upper Devonian Misener sandstone reservoir in Grant and Garfield Counties, Oklahoma, is a prolific but elusive hydrocarbon target. Isolated pods of dolomitic sandstone are preserved in strike-valley erosional lows cut into the underlying Sylvan Shale. Source of the Misener sand appears to have been Simpson sandstone, which subcrops to the north and east. This sand was originally transported south-southwest onto the Sylvan subcrop by a fluvial system. The path of this drainage system is indicated by reentrants of the Viola Limestone subcrop downdip into the Sylvan Shale subcrop. During the Late Devonian marine transgression, which culminated in the deposition of the Woodford Shale, these fluvial deposits were reworked into marine sands and concentrated along several strandlines during stillstands of the Woodford sea. Three distinct Misener trends are evident based on present well control: one adjacent to the Viola subcrop, one at a medial position in the Sylvan Shale subcrop, and one adjacent to the Hunton Limestone subcrop. Reservoir distribution along these strandlines is extremely erratic.

Reservoirs average 250 acres in extent and attain a maximum thickness of 60 ft. Primary production has ranged from 100 to 160 bbl of oil/acre-ft. Early institution of reservoir pressure maintenance can allow recovery of nearly 60% of the original oil in place. [1316]

Wrenching and Oil Migration, Mervine Field Area, Kay County, Oklahoma

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Since 1913, the Mervine field (T27N, R3E) has produced oil from 11 Mississippian and Pennsylvanian zones, and gas from two Permian zones. The field exhibits an asymmetric surface anticline, with the steeper flank dipping 30° east, maximum. A nearly vertical, basement-controlled fault occurs immediately beneath the steep flank of the surface anticline. Three periods of left-lateral wrench faulting account for 93% of all structural growth: 24% in the post-Mississippian to the pre-Desmoinesian; 21% in the Virgilian; and 48% in the post-Wolfcampian.

The Devonian Woodford Shale—and possibly the Desmoinesian Cherokee and Ordovician Simpson shales—locally generated oil in the

Mesozoic through the early Cenozoic, which should have been structurally trapped in the Ordovician Bromide sandstone. This oil may have joined oil previously trapped in the Bromide, which had migrated to the Mervine area during the Early Pennsylvanian from a distant source. Intense post-Wolfcampian movement(s) fractured the competent pre-Pennsylvanian rocks, allowing Bromide brine and entrained oil to migrate vertically up the master fault and accumulate in younger reservoirs.

Pressure, temperatures, and salinity anomalies indicate that vertical fluid migration presently continues at Mervine field. Consequently, pressure, temperature, and salinity mapping should be considered as a valuable supplement to structural and lithologic mapping when prospecting for structural hydrocarbon accumulations in intracratonic provinces. [1317]

Dolomites Formed Under Deep Burial Conditions: Hunton Group Carbonate Rocks (Upper Ordovician to Lower Devonian) in Deep Anadarko Basin of Oklahoma and Texas

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Petrographic and geochemical study of cores and cuttings from 25 boreholes ranging in depth from near surface to 30,000 ft (9.1 km) of the Hunton Group (Upper Ordovician to Lower Devonian), in the deep Anadarko basin of Oklahoma and the Texas panhandle, shows progressive burial diagenesis with increased depth. Limestone conformably overlying shale has been diagenetically altered to dolomite, commonly ferroan, chiefly below current depths of 10,000 ft (3.0 km).

The dolomite occurs as finely disseminated, 10 μm and larger rhombic crystals, and is most abundant near the base of the Hunton Group, particularly where an oolite unit overlies the thick marine Sylvan Shale inferred to be the chief source of Fe^{2+} and Mg^{2+} ions. Dolomite crystals are euhedral above about 10,000 ft (3 km). Below 10,000 ft, more complete dolomitization of the oolite produced hypidiotopic and xenotopic textures. Fluids associated with hydrocarbon migration (following dolomitization) dissolved the nonreplaced calcite, thereby creating intercrystalline and moldic porosity.

X-ray diffraction verifies a trend of higher dolomite concentrations in the same oolite horizon with increasing depth. Oolite samples from outcrop lack dolomite (100% $CaCO_3$); cores from 9,200 ft (2.8 km) are about 25% dolomite; and cores and cuttings from 15,000 ft (4.6 km) and below are +85% dolomite. Radioisotope-induced x-ray fluorescence shows that dolomites below 10,000 ft (3 km) are iron enriched relative to both nondolomitized oolite and dolomites of surface origin. We therefore conclude that dolomite has formed under deep burial conditions. [1317]

Atokan (Pennsylvanian) Berlin Field: Anatomy of a Recycled Detrital Dolomite Reservoir, Deep Anadarko Basin, Oklahoma

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Berlin gas field in Beckham County, Oklahoma, was discovered in 1977, and is the largest Atoka (Pennsylvanian) hydrocarbon accumulation in the Anadarko basin. It is an overpressured reservoir at a depth of 15,000 ft (4,572 m) and occupies a surface area of 41 mi^2 (106 km^2). The reservoir rock consists of recycled, detrital Arbuckle dolomite (Cambrian–Ordovician), and contains ultimate recoverable reserves of 242 to 362 bcf.

Arbuckle dolomite and limited exposures of Precambrian granite rocks were eroded from the Amarillo–Wichita Mountains in the Atokan and were deposited as a terrigenous, sandy dolomite clastic wedge adjacent to the uplift. In the late Atokan, the Elk City structure was uplifted and subaerially exposed in the vicinity of the northern limit of the dolomite clastic wedge. The detrital dolomite on the structure was concurrently eroded and recycled northward as a shallow marine fan delta. Subsequent recrystallization destroyed the detrital depositional texture and created the present intercrystalline porosity.

The deep Elk City structure consists of an upthrust block bound by the late Atokan unconformity that is genetically associated with the Berlin fan delta. Present relief on the upthrust block and overlying anticlinal folds formed during post-Atokan growth of the structure.

Berlin field provides a model of a large, localized clastic deposit derived from uplift and erosion of a prominent structure, and it is an example of the potential for large detrital stratigraphic traps around the perimeters of prominent structures that contain crestal unconformities. [1318]

Gravity-Slide Thrusting and Folded Faults in Western Arbuckle Mountains, Oklahoma

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One or more major gravity-slide thrusts have been documented in the Eola, Southeast Hoover, and Southwest Davis oil fields, and in the western Arbuckle Mountains, Garvin and Murray Counties, Oklahoma. The gravity-slide area initially covered portions of a least nine townships; it was more than 30 mi (50 km) long and 5–6 mi (8–10 km) wide. It involved a stratigraphic sequence greater than 5,000 ft (1,500 m), extending from the lower Springer Formation into the upper portion of the Arbuckle Limestone. The major slides moved to the northeast and northwest, probably in the Middle Pennsylvanian. Slides and faults were subsequently isoclinally folded in the Late Pennsylvanian. The tensional updip segment of the major folded slide fault now coincides with the trace of the Washita Valley fault. The compressional end of the slide

coincides with the Reagan fault in the east and the frontal Eola fault in the west. In the Lake Classen area the latest folding has turned all formations involved in the slide—and the associated faults—to a near-vertical position. Thus, the slide is exposed in a "profile view" on the south limb of the overturned Washita Valley syncline. On the north normal limb of the Washita Valley syncline, the slide is exposed in "plan view," with the Dougherty anticline and related folds representing compressional folding at the toe of the slide. Several tectonic breccias near the top of the Kindblade Formation of the Arbuckle Group probably mark the orogenic event. [1318–1319]

Clinton Gas Field: A Significant Stratigraphic Discovery

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Clinton gas field has developed into one of the most significant stratigraphic discoveries in Oklahoma. This field is important not only for the magnitude of its hydrocarbon reserves, but also for the model it provides for finding similar fields.

The Clinton field is part of the Clinton–Geary trend, which is productive from upper Red Fork sandstones of Desmoinesian age. This trend is a 65-mi long, 0.5–2-mi wide incised fluvial channel that runs through Blaine, Caddo, Canadian, and Custer Counties. The Geary field at the northeastern end of the channel was discovered and subsequently developed in the 1970's. In 1979, the Clinton field was discovered, and since that time no less than 50 productive wells have been drilled. Development of the field is still continuing at a rapid pace.

The Clinton–Geary channel developed on a pre-Pink limestone erosional surface and eroded a 200-ft deep valley, which was subsequently filled by stream deposits, predominantly sands, silts, and clays. Sandstones in the channel range from a few feet in thickness to almost 200 ft.

Individual wells in the Clinton field have had flow rates exceeding 10 MMCFGD, with calculated open flow in excess of 40 MMCFGD. Estimated reserves are 30–40 bcf of gas and 0.6–0.8 million bbl of oil for the best wells in the field. Ultimate recoveries for the field are estimated to be 0.75 tcf of gas and 15 million bbl of oil.

The Clinton field is the most prolific Red Fork gas field in Oklahoma. A thorough understanding of its depositional history may help us discover similar significant fields. [1319]

Use of Airborne Magnetics in Overthrust Areas

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Detailed airborne magnetic surveys have been useful in exploring overthrusts containing magnetic, igneous rocks. The structural configuration of these rocks can be closely approximated. The most important information is the thickness of igneous material overlying sediments and the dip of the overthrust base. Thicknesses and dips of magnetic rocks in overthrusts can be highly variable. Thickness variations of 20,000 ft have been found to occur over the course of 5 mi parallel with the toe of the thrust. The igneous to sedimentary rock contact can range from vertical to horizontal in the same distance.

Interpretations can be used to guide the exploration program in overthrust areas. Seismic surveys can be located in areas of thin granite cover so prospective structures in the underlying sediments might be located at shallower depths.

The Arbuckle Mountain Range is an example of an overthrust that can be explored in this fashion. This overthrust covers a large surface area; in places it is very thin and in others, very thick, being in contact with the basement. The thrust covers a large surface area in an intensely drilled basin. The sediments below the thrust cover an area large enough to "hide" several major oil fields.

Undrilled areas large enough to contain major oil reserves are becoming increasingly scarce. The use of magnetics to detect and map igneous overthrusts can find undrilled sedimentary areas large enough to contain major reserve prospects. [1319]

Recognition and Correlation of Morrowan-Age Wash Reservoirs in Roger Mills and Beckham Counties, Oklahoma

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Upper Morrowan-age "washes" in Roger Mills and Beckham Counties, Oklahoma, are prolific yet elusive targets for exploration and production geologists. Hydrocarbon reserves can average 14 bcf of gas/well from net reservoir sand thicknesses of less than 20 ft; however, precise sand trends are difficult to predict consistently. This unpredictability is directly related to the complex depositional history of the wash sediments. Upper Morrowan-age washes represent the initial sedimentary response to uplifting, overthrusting, and erosional unroofing of the ancestral Wichita Mountains. Prograding fan deltas largely overwhelmed normal basin sediments close to the mountain front. Farther basinward, interfingering of the two systems led to rapid vertical and lateral facies changes within the wash sequence.

Successful exploration in this sequence depends on recognition of reservoir facies and physical distribution, along with an understanding of the evolutionary nature of the wash sedimentary environment. Detailed correlation of individual sand bodies within the wash is essential. Core and cuttings data may then be integrated with log response to determine sand facies and reservoir characteristics. Reservoir quality is highly dependent on diagenetic history. High-resolution stratigraphic seismic control is useful in delineating sand trends. All available information should be integrated in an overall sedimentary response model for the area that reflects the structural and depositional evolution of the wash sedimentary wedge from its mountain front source to its distal basinward margin. [1320]

Development and Economic Significance of Springer–Britt Sandstone, Eakly Field, Caddo, Custer, and Washita Counties, Oklahoma

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In the fall of 1981, Lear Petroleum commenced drilling a seismic wildcat prospect in the deep Anadarko basin. The well was located in an area previously thought to be a poor prospect because of the small number of tests in the proximity and the low success ratio of drilled wells. The Lear wildcat discovered the Eakly field of the Pennsylvanian Springer–Britt sandstone at a depth of 15,450 ft. Because their leasehold in the offsets was expiring, four additional wells were drilled immediately, resulting in only one dry hole. During this period, Amoco also found production from the Britt sandstone along depositional strike approximately 10 mi southeast of the Lear discovery.

By the fall of 1982, it was evident that the trend had enough areal extent to potentially become one of the Anadarko basin's giant fields. With a market value of about $4.00/mcf, initial flow potentials from 2.5 to 12 MMCFGD at 7,000 to 9,000 psig, and depths under 16,000 ft, the Eakly trend became one of the most attractive exploration targets in the Mid-Continent region. Representative wells in the Eakly field today produce at rates up to 18 MMCFGD, and ultimate recoveries are estimated at 5–30 bcf of gas/well. The trend is still being developed and extends approximately 30 mi. Reserves estimated at 910 bcf of gas from 50 wells make the Eakly Springer trend one of the Anadarko basin's true giants. [1320]

Relation of Lower Morrow Sandstone and Porosity Trends to Chester Paleogeomorphology, Persimmon Creek Field Area, Woodward County, Oklahoma

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Thickness and porosity trends of several lower Morrow sandstone units were strongly influenced by the paleogeomorphology of the subjacent Mississippian Chester limestone in a study area near Persimmon Creek field in T20N, R22W, southwestern Woodward County, Oklahoma. Pre-Pennsylvanian streams flowing south-southwest across the Anadarko basin shelf created a dendritic drainage pattern with paleogradients of about 40 ft/mi (7.5 m/km), and intervening stream divides were 50–100 ft (15–30 m) above the valley floors. As the sea transgressed the area in the Early Pennsylvanian, cyclic transgressions and regressions led to deposition of four prominent lower Morrow sandstone members separated by shale units that are approximately parallel lithologic time markers.

The two lower members—a prograding beach complex and a delta front complex—experienced thicker sand deposition above the paleovalleys. In the overlying member (Brown sandstone), also a delta-front complex, thickest sand accumulation and best porosity development occur above the Chester paleodivides. The uppermost member shows little relationship to Chester paleotopography.

Persimmon Creek field is a small stratigraphic trap accumulation that occurs above a prominent southward-plunging nose of paleotopographic high on the Chester limestone surface. Four wells produce from two Brown sandstone units, a stream-mouth bar and an overlying channel sand that has prograded across the bar. Although the geometry of individual sandstone bodies such as these is almost impossible to predict prior to field development, Morrow sandstone prospects can be defined by locating the most likely sites of thick, porous sand accumulation controlled by Chester paleotopography. [1320]

Geology of Puryear Member of Upper Morrow Formation at Cheyenne Field, Roger Mills County, Oklahoma

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The Puryear member of the Pennsylvanian upper Morrow formation is the most prolific gas-producing unit in the deep Anadarko basin. The Puryear sandstone, a quartz sandstone and chert conglomerate, is the major depositional cycle in an overall regressive upper Morrow sandstone–shale sequence.

At Cheyenne field, the Puryear trends northwest–southeast, subparallel to the Amarillo–Wichita uplift, which is about 25 mi to the southwest. The unit pinches out to the north and northeast and is water-bearing to the south and southwest in the local area. Productive sandstone thickness ranges from 10 to 45 ft, with porosities of 14 to 18% and permeabilities averaging 0.5 to 1.5 md at drilling depths of 14,800 to 16,000 ft. Textural interpretations of the cored Puryear sandstone at El Paso's 1–6 Berry (Sec. 6, T13N, R24W) show a coarsening-upward, poorly sorted, matrix-supported conglomerate consisting of fine to coarse-grained quartz sandstone with pebble to cobble-sized, angular and subrounded chert clasts.

The Puryear member at Cheyenne field is interpreted as a delta-front deposit associated with a fan-delta system sourced from the Amarillo–Wichita uplift. [1320]