OKLAHOMA GEOLOGY

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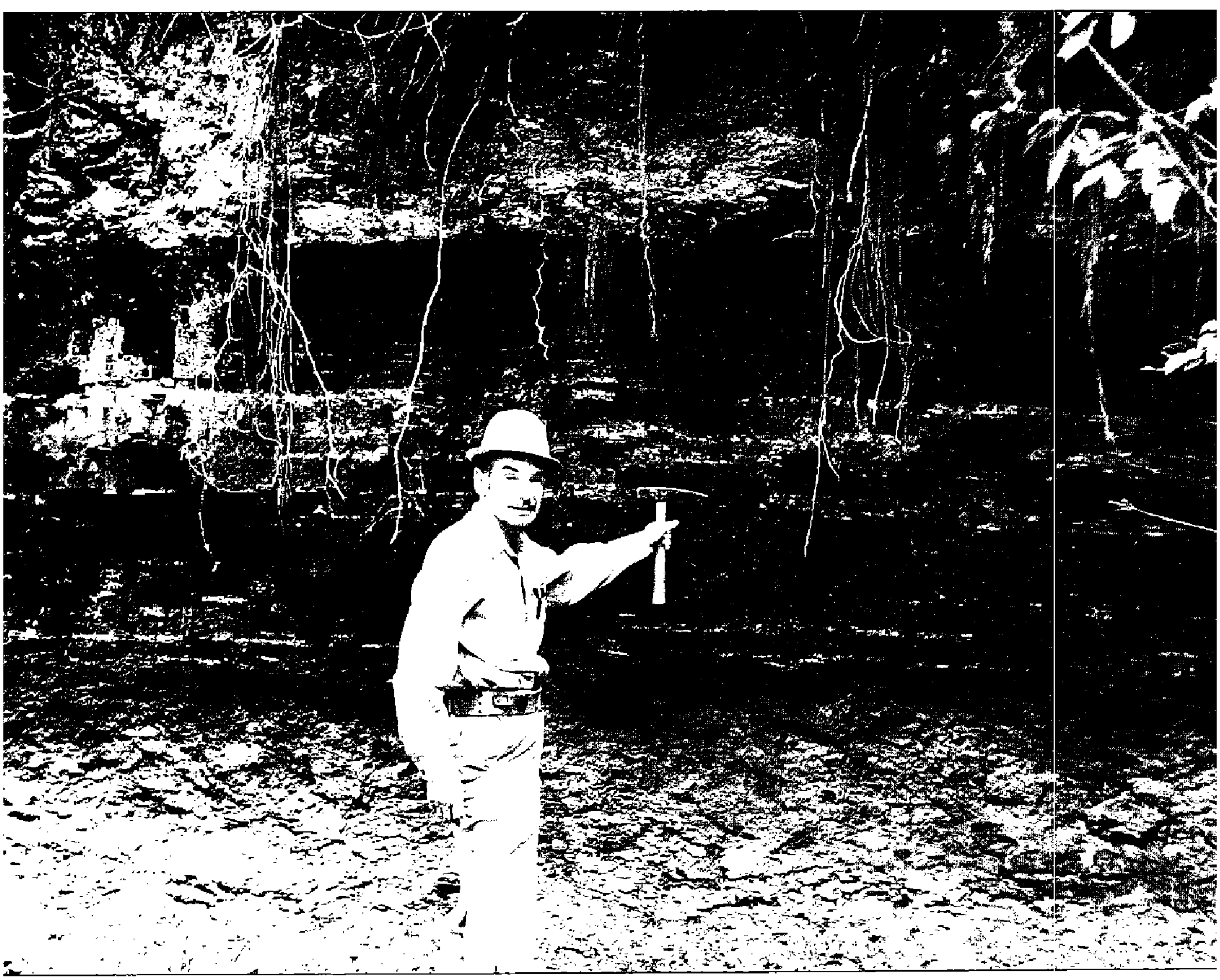

On the cover—

Secor Coal of the Boggy Formation

Pictured is an outcrop of the Secor coal, Boggy Formation (Desmoinesian Series), located in a stream bank (view is toward the north) in the SW¼ sec. 33, T. 5 N., R. 15 E., Pittsburg County, Oklahoma, 4 mi south of McAlester. The coal is overlain by black shale and underlain by plastic medium-gray claystone. How did the coal get there?

Field studies and core-hole data indicate that the Secor coal originated ~300 m.y. ago in a vast peat swamp. The slowly subsiding peat swamp formed south of a large prograding delta plain formed by a great river. The plants in this peat swamp grew in shallow water (2–6 ft deep) in a back barrier bay. South of the bay, arcuate, sandy beaches stretched east and west (in part, similar to the modern-day environment of South Padre Island). Up to 50 ft of peat formed from decayed roots, trunks, branches, stems, leaves, cones, and spores of mostly lycopod trees (*Lepidodendron* and *Sigillaria*), producing 3 ft of Secor coal at the site of the cover photograph and a maximum of 5 ft of Secor coal in the adjacent Peaceable Creek area of the Kiowa syncline in Pittsburg County. Areas of thin (0.2 ft) Secor coal show the boundary of the peat-swamp environment and proximity of open seas in southern Atoka, Pittsburg, Latimer, and Le Flore Counties.

Marine waters high in sulfate ions were tidally introduced into the bay through inlet channels in the barrier beaches, while iron ions were brought into the bay by freshwater streams from the north. Bacteria acted on these compounds in the peat swamp in the bay to produce iron sulfide (pyrite); organic sulfur was adsorbed on the maceral constituents. Thus, sulfur formed in the peat, which upon subsidence and burial by limy mud was preserved and subsequently altered to high-sulfur coal.

In the counties north of the Arkoma basin, little or no sea water had access to the Secor peat swamp. Peat formed in alluvial-deltaic plain environments, resulting in only 0.7–2.0 ft of Secor coal, which is low (0.7–1.0%) in total sulfur content in McIntosh, Muskogee, and Wagoner Counties.

Samuel A. Friedman

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OKLAHOMA GEOLOGY

CONTENTS

THE SECOR COAL AND ASSOCIATED STRATA IN THE BELAND–CREKOLA AREA, MUSKOGEE COUNTY, OKLAHOMA

LeRoy A. Hemish[1]

Abstract

Rocks exposed in the Beland–Crekola area in T. 14 N., R. 17 E., Muskogee County, Oklahoma, are in the lower part of the Boggy Formation (Desmoinesian). Low- to medium-sulfur, low-ash Secor coal occurs at minable depths within the lower Boggy in the area. Thickness of the Secor coal bed ranges from 0.2 to 1.2 ft, with an average of ~0.8 ft. Under current economic conditions, mining of the coal would be only marginally profitable without a premium price.

Three stratigraphically higher coal beds also occur in the area in association with the Secor coal: the Secor rider, Peters Chapel, and Bluejacket coals. Only the Peters Chapel (a high-sulfur, medium- to high-ash coal) is locally of minable thickness.

Structural complexities in the Beland–Crekola area hinder accurate geologic interpretations. Numerous folds and branch faults associated with the previously named Muskogee fault have raised the coal beds to elevations where they have been removed by erosion in some areas. Directly northwest of the Muskogee fault the Secor coal is downthrown and too deep to mine.

Introduction

The purpose of this paper is to clarify the coal geology of the lower part of the Boggy Formation in a structurally complex area around Beland and Crekola, T. 14 N., R. 17 E., Muskogee County, Oklahoma (Fig. 1). The coal bed that is of primary interest in the area is the Secor, known to be of superior quality in an area ~2 mi north of the Muskogee fault (Fig. 1), where it has been mined extensively in recent years (Hemish, 1986; 1988a,b; in preparation). Production of high-quality Secor coal was reported from a mine <2 mi north of the study area as recently as the early part of 1990. A sample of coal collected by the author at this mine and analyzed by the Oklahoma Geological Survey (OGS) Inorganic Chemistry Laboratory showed that the coal contained only 2.0% ash, 0.5% sulfur, and had a heat value of 14,530 Btu/lb (Hemish, 1988b, p. 71). However, opportunities for further exploitation of the Secor coal in that area are limited, owing to excessive thickness of overburden.

Field reconnaissance, exploration drilling, and the presence of small abandoned wagon pits all indicate that the Secor coal bed is present in the Beland–Crekola area. Because the OGS has recently had several inquiries concerning the availability of low-ash, low-sulfur coal in eastern Oklahoma, because such a coal commands a premium price on the market, and because of the energy crisis brought about by troubles in the Middle East oil-producing area, it was deemed advisable to make a study of the coal in the Beland–Crekola area. More than 50 exploration

[1]Oklahoma Geological Survey.

holes were drilled by coal companies in the 1970s and 1980s in parts of the area, and eight core holes were drilled by the OGS in the 1980s (Hemish, 1988c). Locations of the holes are shown in Figures 1 and 2. Thanks are herein expressed to James O. Dycus and Harvey Geizer for sharing their drilling data with the OGS for use in this study. Thanks also go to the Flusche family for permitting the OGS to drill core holes on their property.

Methods

Preliminary reconnaissance work in the Beland–Crekola area was started by the writer in 1983 as part of an investigation of the coal geology of Muskogee County (Hemish, in preparation). Aerial photographs were examined, and small abandoned strip pits were mapped. Where feasible, aerial photographs were also used for mapping rock units. Most areas were checked by vehicle traverse on roads and trails, and by foot in areas inaccessible by vehicle. Attitudes of rocks were recorded from Brunton compass readings. The beds are characteristically undulatory over the entire area, so some geologic judgment was necessary in making measurements in order to define the structures. Faults were mapped from aerial photograph interpretations, or from plotting elevation changes on coal beds, using drilling data. Folds were also mapped using these techniques.

Exposures of coal were very difficult to find because of concealment by unconsolidated surficial materials and disruptions by faults. Without drilling data for use in sequence correlations, and without chemical analyses of the coals to differentiate the beds on a quality basis, valid geologic interpretations would have been impossible. Several large areas remain unexplored. In these areas only speculative evaluation of the coal beds can be made. Figure 2 is a structure-contour map drawn on the Secor coal. It also shows three different map categories indicating the presence, probable presence, or absence of the Secor coal bed in the Beland–Crekola area. Owing to the complexity of the area, interpretive errors within these categories are probable. Thicknesses of the Secor and other coal beds are given in Table 1 for the data points shown in Figures 1 and 2.

Stratigraphy and Structure

General Statement

The coal beds of eastern Oklahoma are bituminous in rank and are in beds of Middle and Late Pennsylvanian age, 270–300 m.y. old (Friedman, 1974, p. 5–6). In general, the coal-bearing region of Oklahoma comprises two major structural provinces: a shelf area on the north, and the Arkoma basin on the south (Fig. 1, inset). Muskogee County is at the junction of these two major areas, on the west flank of the Ozark uplift. Rocks in the shelf area generally dip WNW at $<1°$; however, owing to local structures in the Beland–Crekola area, this generalization is inapplicable.

Rocks exposed in the study area are assigned to the Boggy Formation of the Krebs Group. Figure 3 is a generalized geologic column showing the part of the Boggy exposed in the study area.

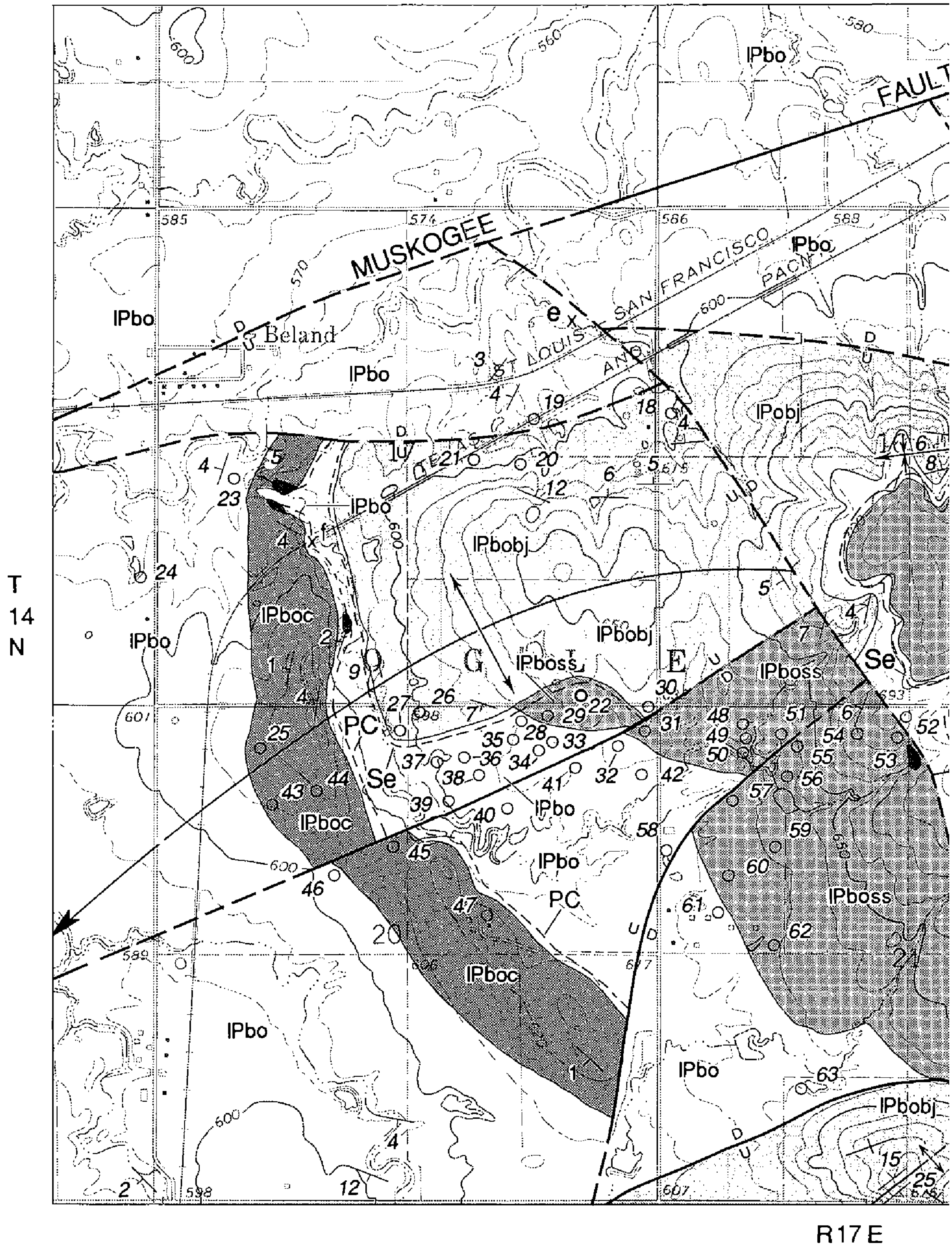
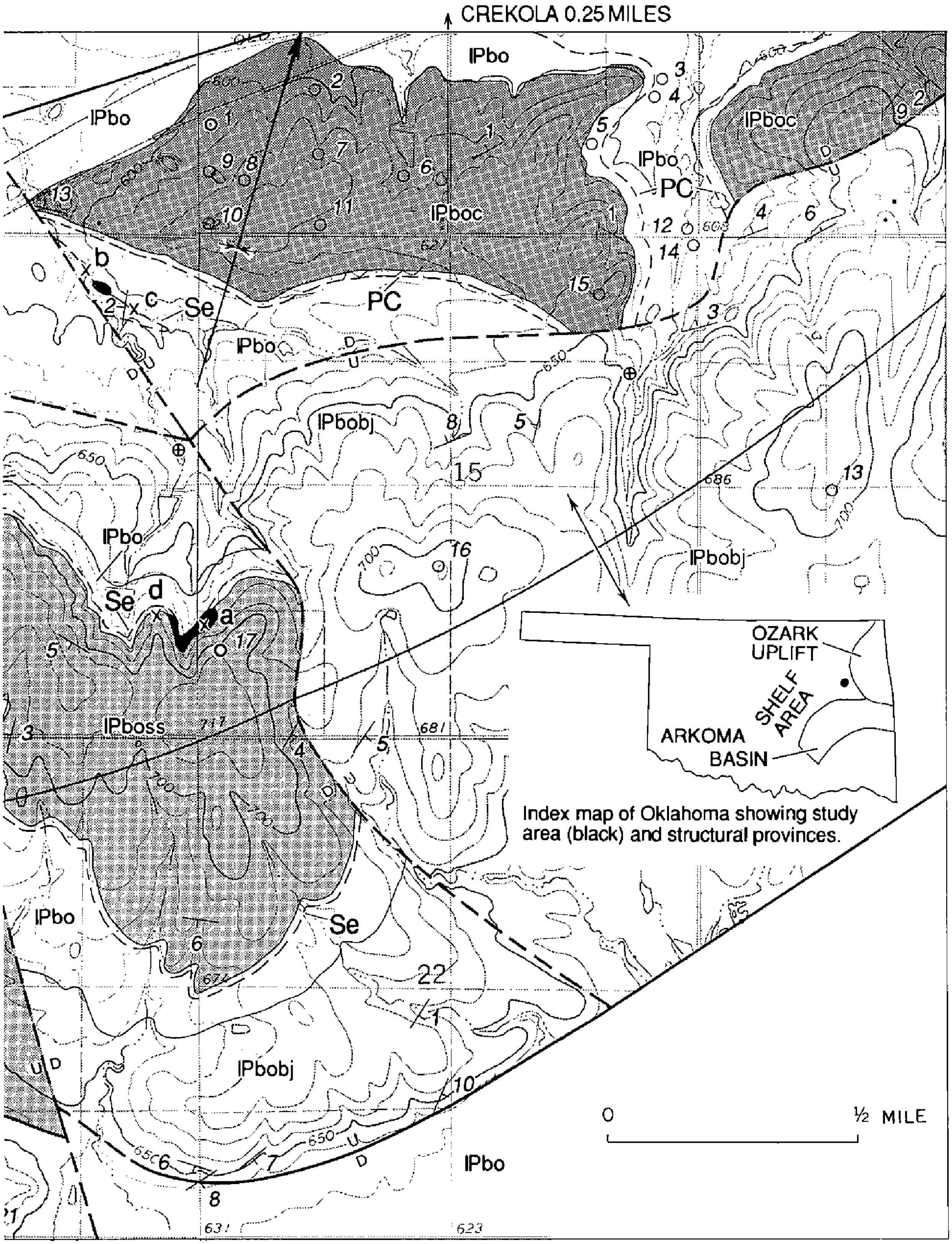


Figure 1. Geologic map of the study area. (Explanation on page 200.)



Index map of Oklahoma showing study area (black) and structural provinces.

FIGURE 1

EXPLANATION

PENNSYLVANIAN — *Desmoinesian* — Boggy Formation

IPbo	Unnamed shale; includes the Bluejacket coal bed and Inola Limestone Member (not mapped)
IPboc	Crekola Sandstone Member
IPbo	Unnamed shale; includes the Peters Chapel coal bed
IPboss	Unnamed sandstone
IPbo	Unnamed shale; includes the Secor coal bed
IPbobj	Bluejacket Sandstone Member

- Contact
- Coal bed boundary, approximately located; letter symbol indicates coal bed name: Se, Secor; PC, Peters Chapel
- Fault; dashed where inferred; U, upthrown side; D, downthrown side
- Anticline; showing direction or plunge
- Syncline; showing direction of plunge
- 6 — Strike and dip of beds
- Strike of vertical beds
- ⊕ Horizontal beds
- o 3 — Drill hole; number corresponds to identification number, Table 1
- x e — Point of coal exposure; letter corresponds to identification letter, Table 1
- Small abandoned coal pit

Stratigraphy of the Lower Boggy Formation

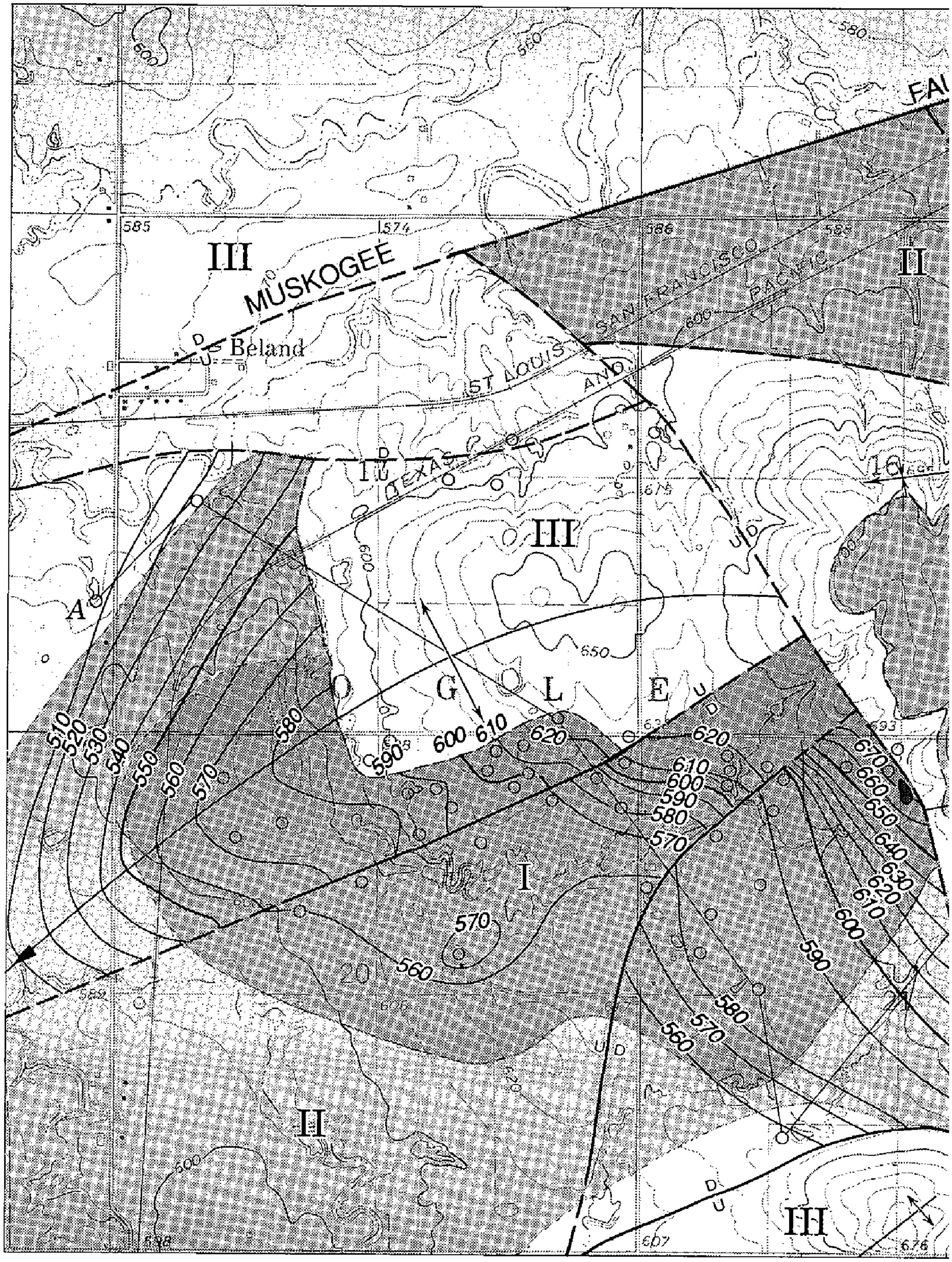
For purposes of this report, the lower Boggy Formation is defined as the interval from the base of the Bluejacket Sandstone Member upward to an arbitrary cutoff in the shale unit above the Inola Limestone Member (Fig. 3). Four coal beds have been identified in the lower Boggy Formation in the Beland–Crekola area. From oldest to youngest they are: Secor, Secor rider, Peters Chapel, and Bluejacket.

Prior to a report by Hemish (1986), considerable confusion existed concerning the sequence of rocks in the lower Boggy Formation in northwestern Muskogee County. General agreement prevailed in mapping the Bluejacket Sandstone. However, Oakes (1977), in his report on the geology of Muskogee County, mapped only two coals in the interval above the Bluejacket Sandstone: the Secor, and an unnamed coal just below the Inola Limestone (see Hemish, 1986, p. 175, fig. 4). Part of the confusion resulted from the failure to recognize that in addition to the Crekola Sandstone, which occurs just under the Bluejacket coal (Figure 4), a second sandstone occurs stratigraphically lower, but still above the Secor coal. The Peters Chapel coal (named by Hemish, 1986, p. 177) occurs between the lower, unnamed sandstone, and the Crekola Sandstone. Because only one coal bed was believed to be present in the interval between the Bluejacket Sandstone (below), and the Crekola Sandstone (above), the Peters Chapel coal was often confused with the Secor coal and mistakenly mapped as such (Wilson, 1935; Wilson and Newell, 1937; Stewart, 1949; Bell, 1959; Oakes, 1977). To further complicate matters, it appears that Oakes (1977, pl. 1) mismapped the unnamed sandstone between the Bluejacket Sandstone and the Crekola Sandstone as the Crekola. Figure 5 is an excerpt from Oakes's report (pl. 1) showing the geology of the Beland–Crekola area. The author's interpretation of the geology in the same area, resulting from recent investigations, is shown in Figure 1. Oakes's errors in mapping were revealed by core-drilling in the study area (Figs. 1,4) (Hemish 1988c). Without drilling data, correct geologic mapping is virtually impossible in areas such as this, where sandstone channels may be stacked (see Fig. 3; core hole 24, Fig. 4) and coals may be cut out or may be absent due to nondeposition.

The Crekola Sandstone was originally named by Wilson (1935, p. 510–511) from the village of Crekola, sec. 10, T. 14 N., R. 17 E., Muskogee County (just off the map, Figs. 1,2). He described it as a brown sandstone 10 ft thick. Wilson and Newell (1937, p. 55) described it as a thin-bedded, soft buff sandstone ranging from 4 to 10 ft thick. A formal type section was not designated by either Wilson or Newell. Therefore, in accordance with procedures recommended by the North American Stratigraphic Code (1983, p. 853–854) for establishing reference wells, a reference well for the Crekola Sandstone Member of the Boggy Formation is herein described and defined. The reference well (15, Figs. 1,4; Appendix) is located in the NE¼NW¼SW¼NE¼NE¼ sec. 15, T. 14 N., R. 17 E., Muskogee County, Oklahoma, ~0.6 mi southeast of Crekola, on the Barbara Flusche farm. Continuous 2-in. core was cut from below a 6.5-ft surface casing, to a depth of 66 ft. The upper 6.5 ft were drilled with a rock bit and cuttings were sampled, described, and bagged. Core-drilling was completed on July 16, 1986. Surface elevation was estimated from a topographic map at 642 ft above sea level.

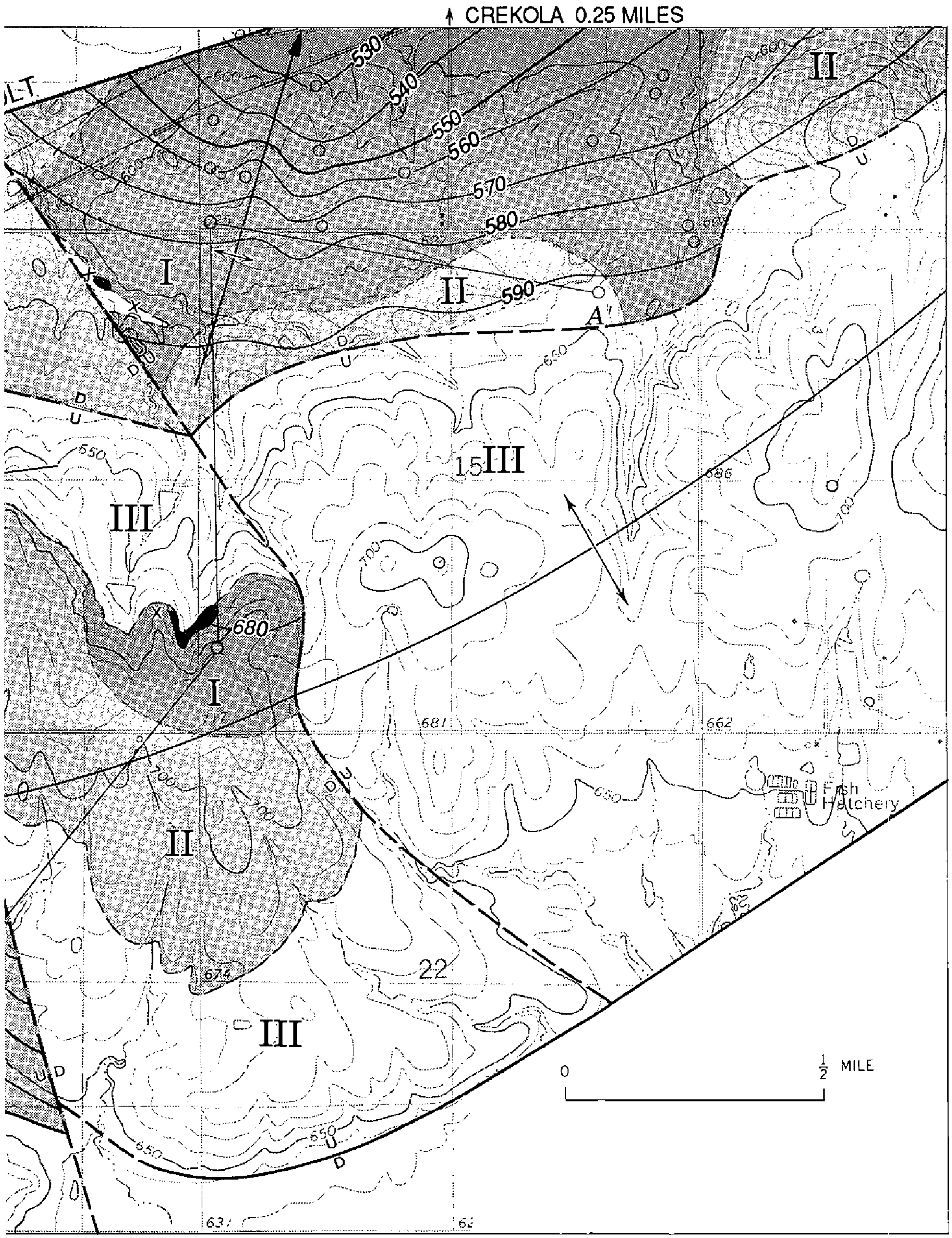
All the core-drilling was done by the Oklahoma Geological Survey. Cores and cuttings from the reference well have been boxed and labeled, and are available

T
14
N



R 17 E

Figure 2. Structure-contour map drawn on the Secor coal. Patterned areas show potential



for occurrence of minable Secor coal. (Explanation on page 204.)

FIGURE 2

EXPLANATION

Secor coal, approximately located

Fault; dashed where inferred; U, upthrown side; D, downthrown side

Anticline; showing direction of plunge

Syncline, showing direction of plunge

610 — Structure contours; drawn on top of Secor coal bed; datum mean sea level; contour interval 10 ft

Boundary separating areas of potential Secor coal occurrence other than where outcrop or fault contact are present

I	Category I -	Secor coal known to be present generally at <60 ft depths; locally, may be too thin to mine
II	Category II -	Secor coal may be present at minable depths; exploration drilling needed
III	Category III -	Secor coal known to be absent, believed to be absent, or is known from drilling or surface mapping to be too thin to mine

o Drill hole

x Point of exposure, Secor coal

Small abandoned pit in Secor coal

for study by the public at the Oklahoma Geological Survey Core and Sample Library.

A review of the literature reveals some of the problems earlier workers had in attempting to differentiate the Crekola Sandstone from the unnamed sandstone (stratigraphically first above the Bluejacket Sandstone). Bell (1959, p. 52–53) wrote that "the Crekola is variable in thickness and character in the Muskogee area," ranging from 4 to 20 ft thick, and occurring from only 11 ft to as much as 30 ft above the Bluejacket. Coleman (1958, p. 47) mapped the first sandstone above the Bluejacket as Crekola in T. 13 N., Muskogee County, and gave the following description: "The Crekola reaches its maximum thickness in sec. 8, T. 13 N., R. 18 E., where it consists of 18 feet of sandstone overlain by 7.7 feet of shale and silt which is overlain by 4 feet of sandstone."

Examination of the cross section (Fig. 4) strongly suggests that Coleman's lower sandstone unit is the unnamed sandstone and that only the 4-ft-thick sandstone is the Crekola. Oakes (1977, p. 31) apparently recognized that stacked channel sandstones were present in Muskogee County when he wrote: "The Crekola is probably included in the much thickened upper unit of the Bluejacket in the south part of T. 13 N." It seems likely the sandstone he referred to as the "Crekola" is the unnamed sandstone, and the stratigraphic interval he described is probably similar to that found in core hole 24, Figure 4, this report.

Structural complexities in the study area make stratigraphic interpretations even more difficult.

Structure

A major southwest-trending fault extends across the northwestern corner of the Beland–Crekola area (Figs. 1,2). The fault was named the Muskogee fault (south) by Wilson (in Wilson and Newell, 1937, p. 80, pl. 1) who stated that "the throw is as much as 600 feet, and the downthrown side is to the north." Huffman and others (1958, p. 92) said the "maximum stratigraphic displacement is 250 to 300 feet." Oakes (1977, p. 42) drew the Muskogee fault along a general southwest trend to sec. 18, T. 14 N., R. 17 E. He said: "The throw is probably not more than 40 feet in sec. 9, T. 14 N., R. 17 E." (in the Beland–Crekola vicinity).

Oakes drew an inferred fault through the southern parts of secs. 21 and 22, T. 14 N., R. 17 E. It is downthrown on the north side. Results of the present study indicate the throw on the fault is probably 100–150 ft. (The writer mapped Bluejacket Sandstone on the hill in the SW¼SE¼ and SE¼SW¼ sec. 21, T. 14 N., R. 17 E. at elevations above 650 ft just south of the fault; north of the fault, core-drilling [hole 63] showed the top of the Bluejacket Sandstone to be at about 550 ft.) Further evidence for verification of the existence of the fault was discovered by the writer when the OGS field vehicle became mired in a water seepage zone in a hill slope along the trace of the fault in the NW¼SE¼SW¼ sec. 21, T. 14 N., R. 17 E.

Newly mapped faults are branch faults extending generally southeast from the Muskogee fault (Fig. 1), with minor cross-cutting faults roughly paralleling the Muskogee fault in some areas. It is difficult to pinpoint the traces of faults in most places; however, they are indicated on Figure 1 with varying degrees of uncertainty.

Two faults are mapped with a high degree of confidence, primarily because of close-spaced drilling data. One fault extends northeast from the east-central part

TABLE 1.—THICKNESS, DEPTH, AND ELEVATION OF COAL BEDS IN THE BELAND–CREKOLA AREA, T. 14 N., R. 17 E.

Data point identification[a]	Coal bed	Thickness (ft)	Depth (ft from surface)	Elevation (ft above sea level)	Data source
Sec. 10					
1	Peters Chapel	0.7	26	580	Company log
	Secor	1.1	62	544	
2	Peters Chapel	0.7	22	583	Company log
3	Secor	0.8	33	562	Company log
4	Secor	1.0	30	564	Company log
5	Secor	0.9	40	567	Company log
6	Secor	0.4	58	560	Company log
7	Peters Chapel	0.6	18	607	Company log
	Secor	0.4	71	544	
8	Peters Chapel	0.5	20	600	Company log
	Secor	1.2	51	569	
9	Peters Chapel	0.7	19	593	Company log
	Secor	1.1	52	560	
10	Peters Chapel	0.7	16	609	Company log
	Secor	1.2	49	576	
11	Peters Chapel	0.6	18	611	Company log
	Secor	0.3	51	578	
12	Secor	0.9	19	588	Company log
Sec. 14					
13	No coal	N/A[b]	63[c]	647[d]	OGS core log
Sec. 15					
14	Secor	1.2	22	587	Company log
15	Peters Chapel	0.6	17	625	OGS core log
	Secor rider	0.2	46	596	
	Secor	0.2	47	595	
16	No coal	N/A	38[c]	672[d]	OGS core log
17	Secor	0.7	23	687	OGS core log
a	Secor	0.8	N/A	685	State mineral survey records
Sec. 16					
18	No coal	N/A	58[c]	547[d]	OGS core log
b	Secor	0.8	N/A	587	OGS meas. sec.
c	Secor	0.8	N/A	587	OGS meas. sec.
d	Secor	0.4+	N/A	684	OGS meas. sec.
Sec. 17					
e	Bluejacket	0.5	N/A	577	OGS Bull. 57
19	No coal	N/A	Unknown[c]	Unknown[d]	Company map
20	No coal	N/A	Unknown[c]	Unknown[d]	Company map
21	No coal	N/A	Unknown[c]	Unknown[d]	Company map
22	Secor	0.7	11	625	Company log
23	Bluejacket	0.1	5	568	OGS core log
	Peters Chapel	0.8	23	550	
	Secor rider	0.2	49	524	
	Secor	0.2	52	521	
f	Peters Chapel	0.5	N/A	582	OGS meas. sec.
Sec. 18					
24	Bluejacket	0.6	23	557	OGS core log
	Peters Chapel	1.2	43	537	

TABLE 1.—*Continued*

Data point identification[a]	Coal bed	Thickness (ft)	Depth (ft from surface)	Elevation (ft above sea level)	Data source
Sec. 20					
25	Peters Chapel	0.7	17	601	Company log
26	No coal	N/A	40[c]	561[d]	Company log
27	No coal	N/A	100[c]	498[d]	Company log
28	Secor	0.3	9	606	Company log
29	Secor	0.7	9	612	Company log
30	No coal	N/A	26[c]	604[d]	Company log
31	Secor	0.8	20	610	Company log
32	Secor	0.7	43	582	Company log
33	Secor	0.8	20	600	Company log
34	Secor	0.5	21	596	Company log
35	Secor	0.6	9	603	Company log
36	No coal	N/A	20[c]	584[d]	Company log
37	Secor	0.8	19	581	Company log
38	Secor	0.7	12	596	Company log
39	Secor	0.7	18	583	Company log
40	Secor	0.9	40	565	Company log
41	Secor	0.6	46	566	Company log
42	Secor	0.9	38	580	Company log
43	Peters Chapel	0.5	8	602	Company log
44	Peters Chapel	0.7	15	605	Company log
45	Peters Chapel	0.7	11	594	Company log
46	Peters Chapel	0.9	14	590	Company log
47	Secor	0.8	18	604	Company log
Sec. 21					
48	Secor	0.7	16	614	Company log
49	Secor	0.9	17	613	Company log
50	Secor	0.9	25	601	Company log
51	Secor	0.7	10	625	Company log
52	No coal	N/A	70[c]	615[d]	Company log
53	Secor	0.7	8	671	Company log
54	Secor	0.8	26	652	Company log
55	Secor	0.7	45	595	Company log
56	No coal	N/A	40[c]	597[d]	Company log
57	Secor	0.9	38	584	Company log
58	No coal	N/A	60[c]	555[d]	Company log
59	Secor	0.7	45	587	Company log
60	Secor	0.7	40	584	Company log
61	Secor	0.7	41	582	Company log
62	Secor	0.7	44	585	Company log
63	Bluejacket	0.2	29	601	OGS core log
	Secor	0.4	74	556	

[a]Drill hole sites are identified in Figure 1 by numbers; outcrops are assigned letters.
[b]Not applicable.
[c]Total depth drilled if no coal present.
[d]Elevation at bottom of drill hole if no coal present.

of sec. 19, across the northern half of sec. 20 and into the SW¼ sec. 16, where it terminates against a south-trending fault. The other of the two extends northeast along the southeastern side of sec. 20 into the NW¼ sec. 21, where it also terminates against the same south-trending fault. The presence of the two faults is indicated by offsets in the elevation of the Secor coal (Fig. 2). Both faults are downthrown to the south, and have displacements of about 20–30 ft.

Faulting is inferred at the base of steep slopes below outcrops of the Bluejacket Sandstone in the northern parts of secs. 14, 15, 16, and 17, based on aerial photograph interpretations and differences in elevation of the same stratigraphic units. The abrupt change in the attitude of the beds seems unrealistic without faulting. The fault in the northern part of sec. 15 and the NW corner of sec. 14 is extended across the SW¼ of sec. 11 (Fig. 1), based on observed lithologic differences between the Bluejacket Sandstone and the Crekola Sandstone.

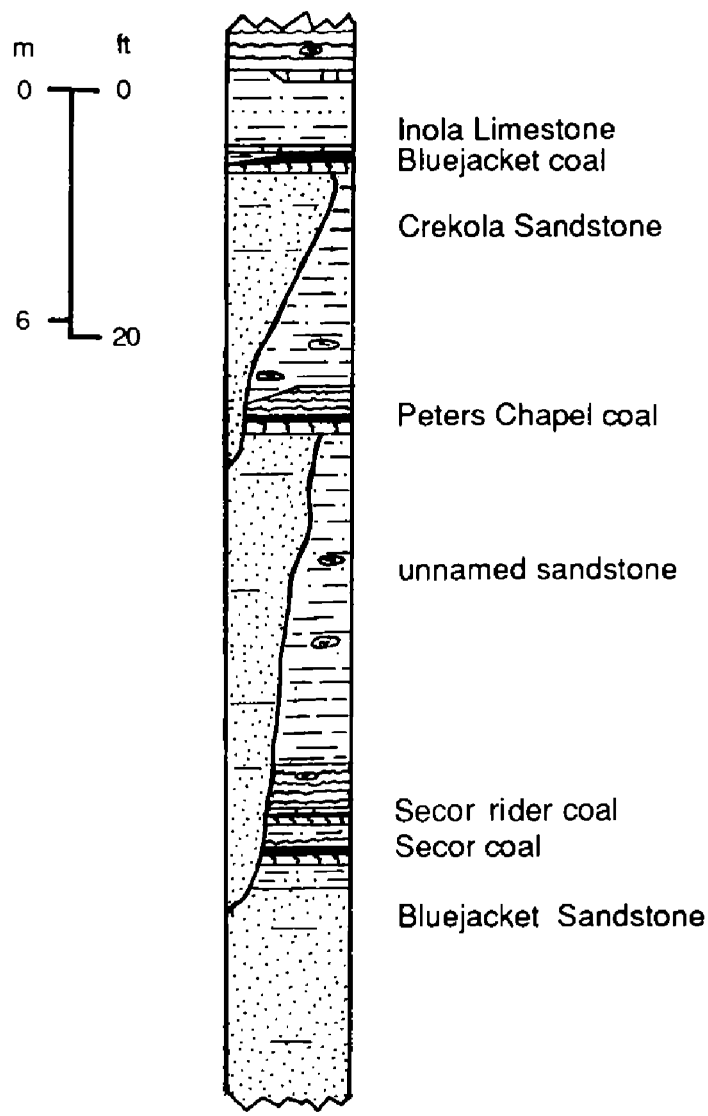


Figure 3. Generalized geologic column showing strata of the lower Boggy Formation (Pennsylvanian) in the Beland–Crekola area.

Two other inferred faults extend southeast from the Muskogee fault through secs. 16 and 21, and through secs. 9, 16, 15, and 22 (Fig. 1). Placement is based on drilling data and topographic expression. A small abandoned strip pit is located along the upthrown side of one fault in the NW¼NE¼NE¼ sec. 16; a similar pit is located along the downthrown side of the other fault in the SW¼NW¼NW¼NE¼ sec. 21 (Fig. 1). Drilling shows the Secor coal to be absent on the northeast side of this fault, but present ~0.5 mi to the northeast on the downthrown side of the other two faults. Again, the Secor coal is shown to be absent on the upthrown side of the easternmost of the two faults in the NE¼SE¼NE¼SW¼ sec. 15.

A broad, ill-defined anticline with southeast dips of 1–7° and northwest dips of 1–6° extends across secs. 14, 15, and 21, T. 14 N., R. 17 E. (Fig. 1). The easternmost of the two faults discussed above cuts across the fold in the SW¼ of sec. 15. The anticline is truncated by the other of the two faults near the abandoned coal pit in the NW¼NE¼ sec. 21. Both limbs of the fold are truncated by faults (Fig. 1).

A second, smaller, southwest-plunging anticline brings the Bluejacket Sandstone to the surface in the SE¼ sec. 17, T. 14 N., R. 17 E. The fold appears to be a westward extension of the anticline discussed above, with the axis displaced northward by faulting in the SW¼ sec. 16 (Fig. 1). Close-spaced exploration drilling defines the outcrop boundary of the Secor coal on the south limb of the fold (Fig. 2). The north limb of the anticline appears to be truncated by a minor fault paralleling the Muskogee fault. Apparently the fold is asymmetrical, with the north limb dipping more steeply. Drilling showed the Secor coal to be absent on the north limb (holes 18, 19, 20, 21, Fig. 1) at elevations where the bed should stratigraphically occur. The absence of the coal is probably due in part to faulting. Ironstone- and limestone-bearing black fissile shales crop out just north of the drill holes along the railroad tracks. The thickness of the shale beds suggests that they are stratigraphically above the Inola Limestone (Fig. 3), as well as the underlying coal beds, which indicates the Secor coal is too deep for mining.

A small northward-plunging syncline is present in the SW¼ sec. 10, T. 14 N., R. 17 E. (Fig. 1). The Peters Chapel coal is present at minable depths in the area, but is generally too thin to mine. The Secor coal occurs ~30 ft below the Peters Chapel, and appears at the surface on the west limb of the fold along a probable fault in the NE¼NE¼ sec. 16 (Fig. 1).

Coal Beds

Four coal beds are known in the lower part of the Boggy Formation in the Beland–Crekola area. In ascending order they are the Secor, Secor rider, Peters Chapel, and Bluejacket coals (Fig. 3). Of the four, only the Secor and the Peters Chapel coals are locally of minable thickness within the study area. Table 1 is a compilation of data from 63 drill-hole and core-hole logs and six outcrops spaced unevenly throughout the Beland–Crekola area (Fig. 2). The table presents information concerning the thickness, depth, and elevation of coal beds by name where they were encountered in the drill holes, core holes, or in outcrops.

Origin of the names of the four coal beds present in the study area was discussed by Hemish (1987). Interpretations concerning depositional environments of the strata in the lower Boggy Formation in east-central Oklahoma were presented by Hemish (1988d). Owing to structural complexities outcrop boundaries of the vari-

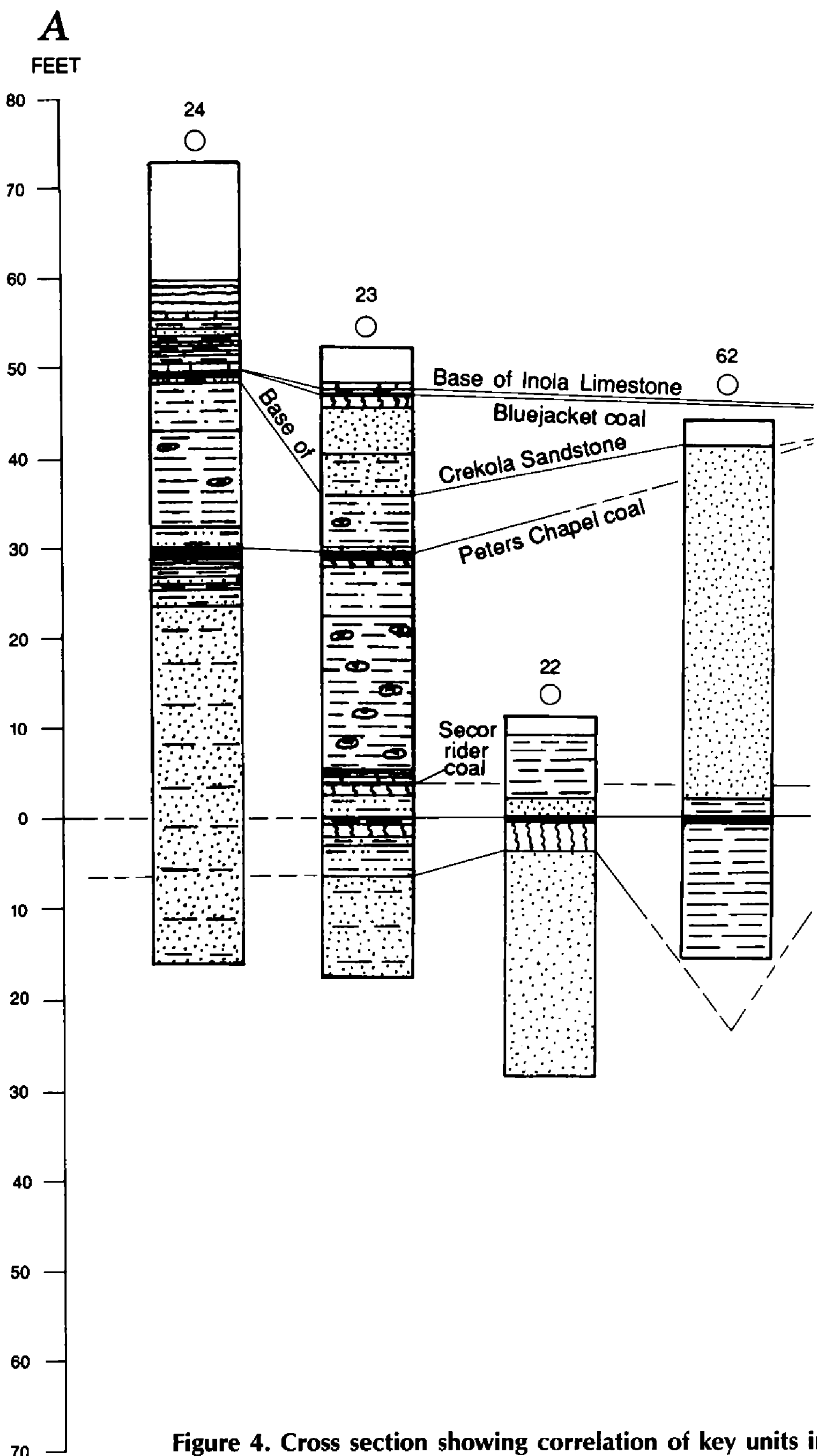
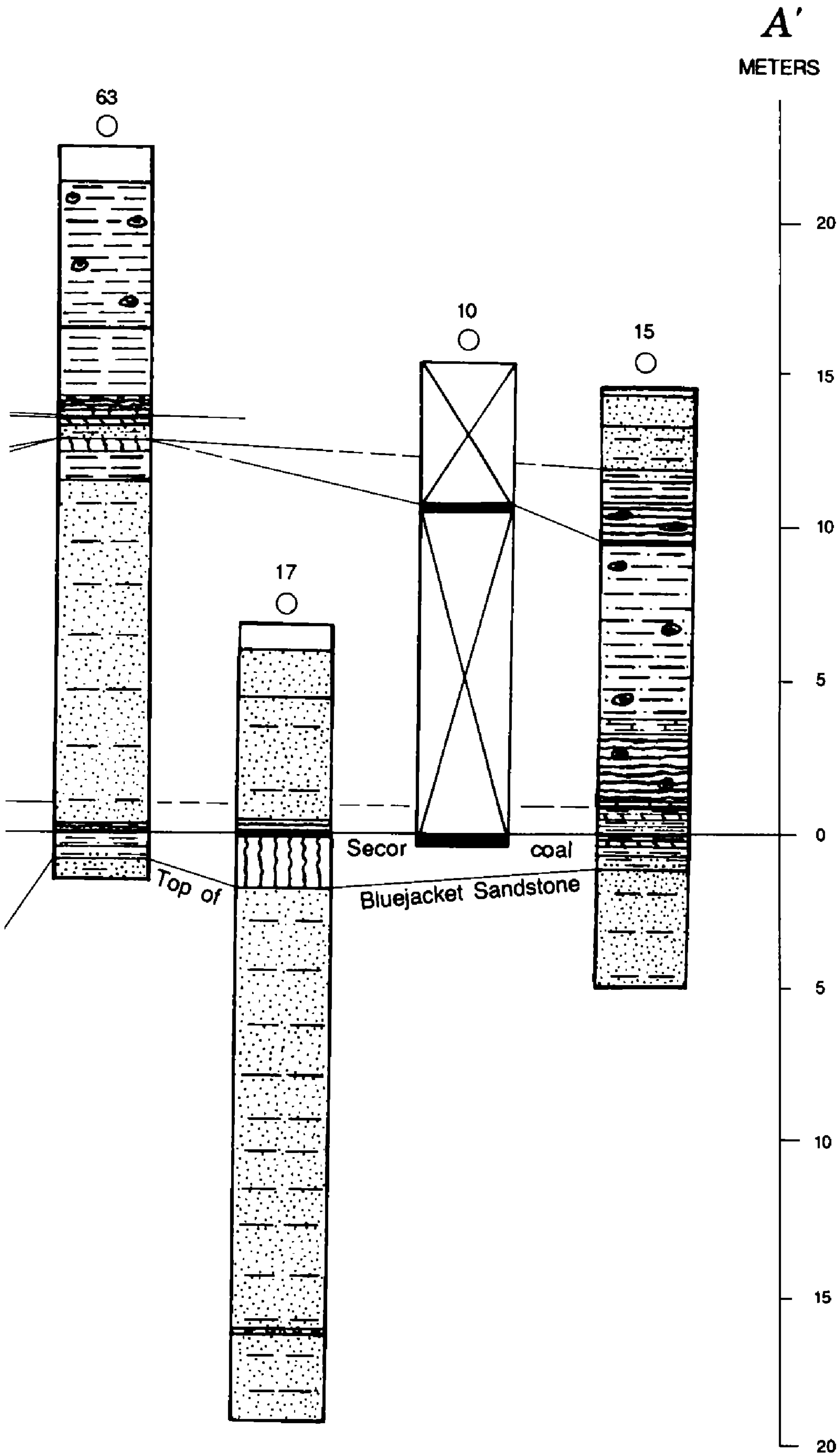


Figure 4. Cross section showing correlation of key units in the lower Boggy Formation in the Beland–Crekola area. Line of cross



section shown in Figure 2. Standard U.S. Geological Survey lithologic symbols used in columns. No horizontal scale.

ous coal beds in the Beland–Crekola area are virtually impossible to map for any extended distance. Where practical, the boundaries are shown in Figure 1 and the coal beds are identified by abbreviations. It is apparent that the presence or absence of the coal beds is most often controlled by fault contacts, and outcrops are rare.

The Secor coal occurs almost immediately above the Bluejacket Sandstone in the study area (Fig. 4). It generally is underlain by a few feet of shale and siltstone, but in hole 17 it is underlain by almost 6 ft of underclay. Thickness of the Secor coal ranges from 0.2 to 1.2 ft in the study area, with the average being ~0.8 ft. Chemical analyses of the Secor and various other coals are shown in Table 2. The best quality Secor coal appears to be in the SW¼ of sec. 15, T. 14 N., R. 17 E. (site 17). Company data indicates that the Secor coal in secs. 17, 20, and 21 is also of good quality. The Secor coal in the Crekola area (sec. 10) is generally of good quality, but is probably too deep for profitable mining except in the southeast part of sec. 10. Analytical data are limited, but, according to company records, the Secor has a sulfur content <1% at sites 12 and 14.

Sixteen samples of the Secor coal from throughout the study area (discounting an anomalous, nonrepresentative sample from site 23), average 1.4% sulfur. Ten

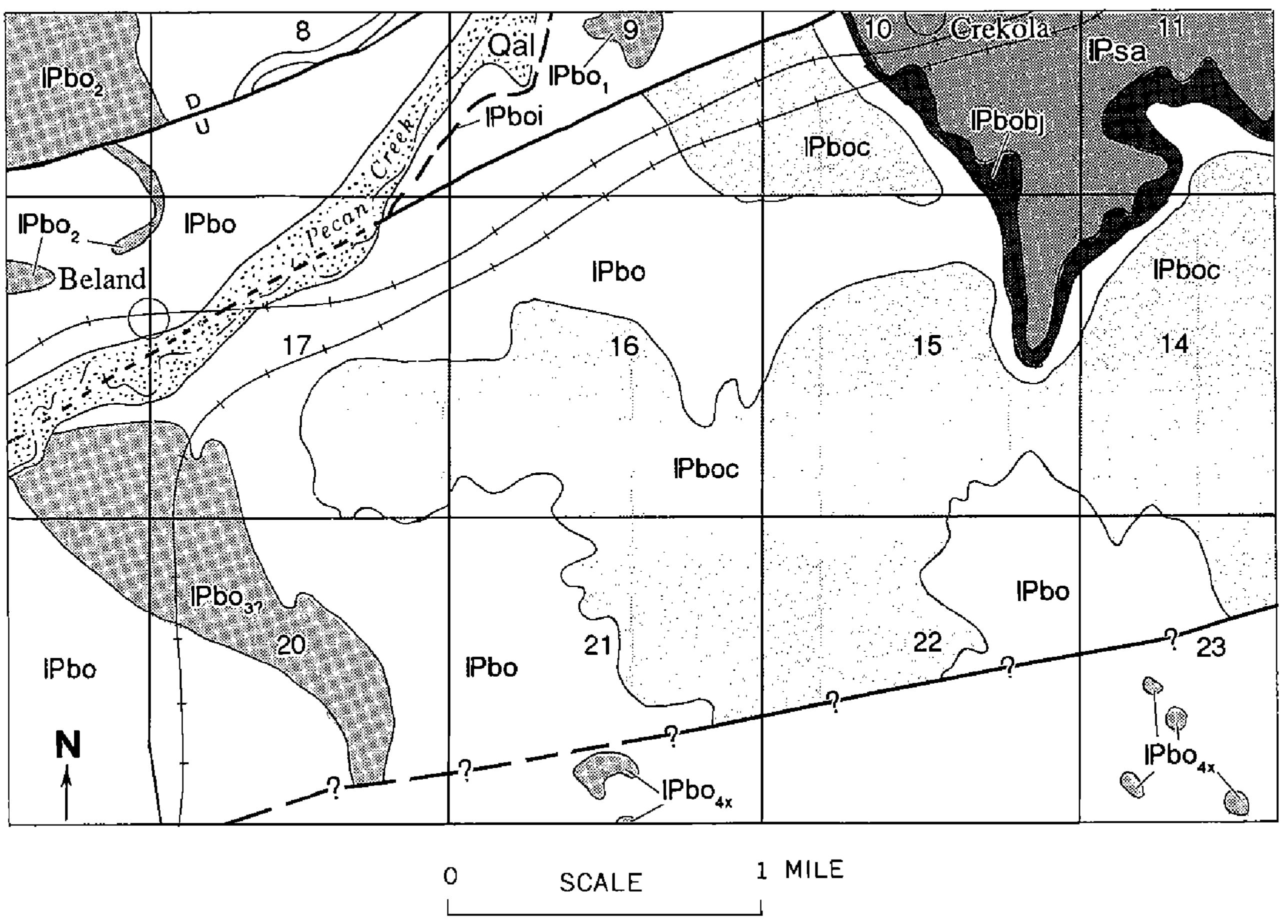


Figure 5. Excerpt modified from Oakes (1977, pl. 1) showing his interpretation of the geology of the Beland–Crekola area. All units described in explanation (on page 213) not shown in excerpt.

FIGURE 5

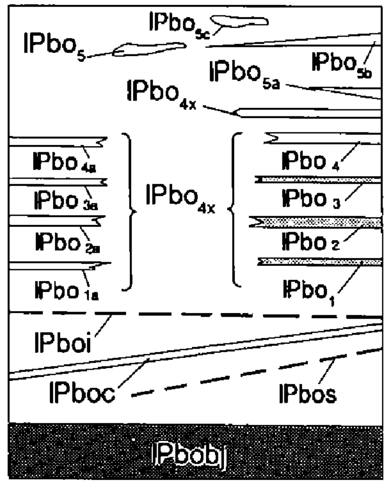
EXPLANATION

Qal

Alluvium
Sand, silt and clay on flood plains of present streams.

PENNSYLVANIAN

Desmoinesian



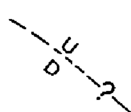
Boggy Formation

Predominantly sandy, silty shale, with thin silty to shaly, scarp-forming sandstones; about 700 feet thick along south side of T13N, 500 feet in T14N, and 450 feet in T15N. Upper and middle parts contain unnamed sandstones. IPbo$_1$ to IPbo$_5$ at top grades into three units northward, IPbo$_{5a}$ through IPbo$_{5c}$, IPbo$_{1a}$ to IPbo$_{4a}$ occur in Tps 13-14N; IPbo$_1$ to IPbo$_4$ occur in Tps 13-15N; IPbo$_{4x}$ may be strays from IPbo$_1$ to IPbo$_5$. Next below IPbo$_1$ is *Inola Limestone Member,* IPboi, generally less than 2 feet thick with subjacent thin coal seam. Next mappable bed below is *Crekola Sandstone,* IPboc. At base is *Bluejacket Sandstone Member,* IPbobj, 20 to 30 feet thick in Tps 13-15N, overlain by 15 to 30 feet of shale with sporadic workable coal called *Secor,* IPbos.
NOTE: Not all units shown for the Beland-Crekola area.

IPsa

Savanna Formation
Dark gray clayey to sandy shale; some fissile shale.

——— Contact



Fault; dashed where inferred; dotted where concealed; querried where probable; U, upthrown side; D, downthrown side

TABLE 2.—ANALYSES OF COAL SAMPLES COLLECTED IN THE BELAND–CREKOLA AREA

Sample site identification[b]	Coal bed	Type of sample	Proximate analysis (%)[a] Moisture	Volatile matter	Fixed carbon	Ash	Sulfur (%)	Btu/lb	Data source[c]
9	Peters Chapel	Core	4.3	36.7	48.3	10.7	6.8	12,867	Company
9	Secor	Core	3.3	35.6	50.1	11.0	2.7	12,947	Company
10	Peters Chapel	Core	3.0	31.3	52.2	13.5	0.9	11,136	Company
10	Secor	Core	2.8	36.8	54.7	5.7	1.4	13,853	Company
12	Secor	—[d]	—	—	—	—	0.6	—	Company
14	Secor	—	—	—	—	—	0.7	—	Company
15	Peters Chapel	Core	2.0	37.8	47.8	12.4	6.9	12,940	OGS
17	Secor	Core	1.7	38.5	56.5	3.3	0.8	14,538	OGS
C	Secor	Outcrop channel	2.5	33.2	53.6	10.7	0.9	12,544	Company
22	Secor	Core	2.0	37.1	57.5	3.4	0.7	14,402	Company
23	Peters Chapel	Core	1.3	38.3	45.7	14.7	6.1	12,463	OGS
23	Secor rider	Core	1.3	36.5	44.1	18.1	6.8	11,971	OGS
23	Secor	Core	1.6	26.5	32.9	39.0	7.0	8,315	OGS
24	Bluejacket	Core	1.3	36.9	46.9	15.0	7.2	12,498	OGS
24	Peters Chapel	Core	1.0	36.3	49.3	13.4	5.7	12,872	OGS
39	Secor	—	—	—	—	—	0.6	—	Company
41	Secor	Core	2.1	38.9	53.0	6.0	1.7	13,948	Company
46	Peters Chapel	—	—	—	—	—	2.8	—	Company
49	Secor	Core	3.7	37.9	55.0	3.4	1.2	14,100	Company
51	Secor	Core	13.2	29.1	48.3	9.4	0.7	10,427	Company
53	Secor	Core	2.8	41.1	47.9	8.2	2.6	13,497	Company
57	Secor	—	—	—	—	—	2.9	—	Company
59	Secor	Core	3.5	40.7	50.0	5.8	1.2	13,729	Company
61	Secor	—	—	—	—	—	1.3	—	Company
63	Secor	Core	3.5	31.0	47.2	18.3	3.1	11,454	OGS

[a]As-received basis.
[b]Identification symbol corresponds to data point on map, Figure 1.
[c]Company, coal company or other industry related source; OGS, Oklahoma Geological Survey.
[d]Dashes indicate data unavailable.

samples of the Secor coal (discounting nonrepresentative samples from sites 23 and 63) average 6.7% ash.

The Secor rider coal is discontinuous in the Beland–Crekola area. Where present it occurs from 1 to 3 ft above the Secor coal (holes 15 and 23). It is overlain by a thin, fossiliferous, impure limestone, which serves as a useful identifying marker bed. The Secor rider is a noneconomic coal bed in Muskogee County because of thinness and poor quality. Analytical data (Table 2) shows that it has a high ash content (18.1%) and a high sulfur content (6.8%).

The Peters Chapel coal is the next stratigraphically higher coal above the Secor rider. It occurs in the interval between an unnamed channel sandstone and the Crekola Sandstone (Figs. 3,4). Thickness of the Peters Chapel bed ranges from 0 (hole 63, where only an underclay is present at the Peters Chapel horizon) to 1.2 ft (hole 24, near the small abandoned strip pits just south of Beland).

In the northwestern part of sec. 20, T. 14 N., R. 17 E., the Peters Chapel coal occurs at <20 ft depth, but it is not of minable thickness. The Peters Chapel coal is also present in the small syncline in the SW¼ sec. 10, T. 14 N., R. 17 E., in the Crekola area, but again, it is not of minable thickness. The Peters Chapel coal is a high-sulfur, medium- to high-ash coal. Six samples from the study area have an average sulfur content of 4.9%. Five samples have an average ash content of 12.9% (Table 2).

The Bluejacket coal is the stratigraphically highest coal present in the Beland–Crekola area. Its thickness ranges from 0.1 to 0.6 ft, so it has no commercial value. It is identified by its close association with the overlying Inola Limestone. One sample (site 24) shows the Bluejacket to be a high-sulfur, high-ash coal, with a sulfur content of 7.2% and an ash content of 15.0% (Table 2).

Summary

1) Four coal beds are present in the lower part of the Boggy Formation in the Beland–Crekola area.

2) The area is structurally complex, making stratigraphic interpretations difficult.

3) New drilling information indicates that surface mapping in the Beland–Crekola area by previous workers (Fig. 5) was probably inaccurate. Figure 1 is the writers interpretation of the geology of the area.

4) Where structural complexities hinder identification of coal beds in the study area, the low- to medium-sulfur, low-ash Secor coal can generally be distinguished from the other coals, which have high-sulfur, and medium- to high-ash contents, by means of chemical analyses.

5) Because of general thinness in the study area, mining of the Secor coal under current economic conditions would be only marginally profitable without a premium price.

6) Additional exploration in some areas (Fig. 2) may show that the Secor coal is present at minable depths.

7) The information in this report is not intended for use as a mining plan, but it should be useful as a guide. Close-spaced grid drilling is recommended prior to development of any coal mines owing to the complexity of the geology in the area.

References

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

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

Friedman, S. A., 1974, An investigation of the coal reserves in the Ozarks section of Oklahoma and their potential uses; final report to the Ozarks Regional Commission: Oklahoma Geological Survey Special Publication 74-2, 117 p.

Hemish, L. A., 1986, Stratigraphy of the lower part of the Boggy Formation (Desmoinesian) in northwestern Muskogee and southwestern Wagoner Counties, Oklahoma: Oklahoma Geology Notes, v. 46, p. 168–187.

——— 1987, Names of coal beds in the northeastern Oklahoma shelf area: Oklahoma Geology Notes, v. 47, p. 96–113.

——— 1988a, Coal geology of the lower Boggy Formation in the shelf-to-basin transition area, eastern Oklahoma, *in* Johnson, K. S. (ed.), Shelf-to-basin geology and resources of Pennsylvanian strata in the Arkoma basin and frontal Ouachita Mountains of Oklahoma: Oklahoma Geological Survey Guidebook 25, p. 7–19.
——— 1988b, Stop 1: Secor coal in Pollyanna No. 5 Strip Mine, west of Muskogee, *in* Johnson, K. S. (ed.), Shelf-to-basin geology and resources of Pennsylvanian strata in the Arkoma basin and frontal Ouachita Mountains of Oklahoma: Oklahoma Geological Survey Guidebook 25, p. 69–72.
——— 1988c, Report of core-drilling by the Oklahoma Geological Survey in Pennsylvanian-age rocks of the northeastern Oklahoma coal belt, 1983–86: Oklahoma Geological Survey Special Publication 88-2, 174 p.
——— 1988d, Coalescence of the Secor and Secor rider coal beds in the Shady Grove Creek area, northeastern McIntosh County, Oklahoma, with interpretations concerning depositional environments: Oklahoma Geology Notes, v. 48, p. 100–119.
——— [in preparation], Coal geology of McIntosh and Muskogee Counties, Oklahoma: Oklahoma Geological Survey.
North American Commission on Stratigraphic Nomenclature, 1983, North American Stratigraphic Code: American Association of Petroleum Geologists Bulletin, v. 67, p. 841–875.
Oakes, M. C., 1977, Geology and mineral resources (exclusive of petroleum) of Muskogee County, Oklahoma: Oklahoma Geological Survey Bulletin 122, 78 p.
Stewart, Francis, Jr., 1949, A map of portions of Muskogee and McIntosh Counties, Oklahoma, with special reference to the Inola limestone and Secor coal: University of Oklahoma unpublished M.G.E. thesis, 81 p.
Wilson, C. W., Jr., 1935, Age and correlation of Pennsylvanian surface formations and of oil and gas sands of Muskogee County, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 19, p. 503–520.
Wilson, C. W., Jr.; and Newell, N. D., 1937, Geology of Muskogee–Porum district, Muskogee and McIntosh Counties, Oklahoma: Oklahoma Geological Survey Bulletin 57, 184 p.

Appendix: Core-Hole Log

15
(OGS Core and Sample Library No. C MM 54)
(Reference Well for the Crekola Sandstone)

NE¼NW¼SW¼NE¼NE¼ sec. 15, T. 14 N., R. 17 E., Muskogee County. Well cored by Oklahoma Geological Survey; lithologic descriptions by LeRoy A. Hemish. Drilled in pasture ~100 ft SW from pole shed, 700 ft FNL and 1,100 ft FEL. Surface elevation, estimated from topographic map, 642 ft.

	Depth to unit top (ft)	Thickness of unit (ft)
Sand, dark-yellowish-brown, very fine-grained, silty, contains organic material	0.0	0.5
KREBS GROUP		
Boggy Formation		
Sandstone, moderate-brown, ferruginous, very fine-grained, weathered (Crekola Sandstone)	0.5	0.5
Sandstone, light-brown, fine- to very fine-grained, ferruginous, weathered	1.0	3.2
Sandstone, moderate-reddish-brown with grayish-orange and		

dark-yellowish-orange bands, very fine-grained, silty, clayey, wavy-laminated and cross-laminated (Crekola Sandstone)	4.2	4.8
Siltstone, pale-yellowish-brown, shaly, sandy	9.0	1.2
Shale, dusky-yellowish-brown with dark-yellowish-orange and dark-gray bands, clayey	10.2	2.8
Shale, grayish-black with dark-yellowish-orange bands; includes thin layers of clay-ironstone	13.0	3.6
Shale, black, carbonaceous	16.6	0.4
Coal, black, moderately friable; dark-reddish-brown iron-oxide deposits on cleat surfaces; includes some pyritic laminae (Peters Chapel coal)	17.0	0.6
Shale, medium-gray to medium-dark-gray, silty, noncalcareous, bioturbated; contains some pyritic burrows and 0.5- to 1-in.-thick, light-brownish-gray, sideritic concretions	17.6	18.5
Shale, dark-gray, calcareous; contains sparse brachiopod shells	36.1	1.9
Shale, grayish-black to black, noncalcareous; includes some hard, dense, pyritic, sideritic concretions 0.5–3 in. thick	38.0	7.5
Shale, black, very calcareous, carbonaceous; contains small pyrite-filled burrows and marine shell fragments	45.5	0.4
Limestone, medium-dark-gray, hard, impure, silty; contains abundant fossil shell fragments	45.9	0.2
Coal, black, impure, interlaminated with carbonaceous shale; contains disseminated pyrite (Secor rider coal)	46.1	0.2
Shale, grayish-black, very carbonaceous, pyritic, bioturbated in lower part	46.3	0.1
Underclay, medium-light-gray, bioturbated, kaolinitic	46.4	0.2
Siltstone, medium-gray, hard, bioturbated, unbedded	46.6	0.2
Shale, black, silty, hard, carbonaceous, bioturbated	46.8	0.3
Coal, black, impure and shaly in upper 0.5 in.; contains numerous pyrite lenses ~0.25 in. thick and 0.75 in. long (Secor coal)	47.1	0.2
Shale, dark-gray, slickensided; includes a 0.25-in.-thick layer of black, bright coal at base of unit	47.3	0.4
Underclay, medium-light-gray; includes abundant black, carbonized plant compressions and disseminated pyrite	47.7	0.7
Shale, medium-light-gray, noncalcareous, silty, bioturbated; grades into underlying unit	48.4	1.6
Siltstone, medium-gray, shaly, noncalcareous, laminated, bioturbated; includes some thin laminae of light-gray, very fine-grained sandstone; grades into underlying unit	50.0	3.3
Sandstone, medium-gray and light-gray, very fine-grained, silty, shaly, noncalcareous, laminated, microfaulted in places, bioturbated; contains black, macerated plant fragments; includes numerous soft-sediment deformation features (Bluejacket Sandstone)	53.3	5.7
Sandstone, medium-dark-gray with light-gray laminae, very silty and shaly, very fine-grained, even-bedded, noncalcareous; includes black macerated plant fragments on some stratification surfaces (Bluejacket Sandstone)	59.0	7.0
Total depth		66.0

PETROLEUM-RESERVOIR WORKSHOP SCHEDULED FOR MARCH 1991

A major workshop on "Petroleum-Reservoir Geology in the Southern Midcontinent," co-sponsored by the Oklahoma Geological Survey and the Bartlesville Project Office of the U.S. Department of Energy, is being planned for March 26–27, 1991. The meeting will be held in Norman, with 200–300 attendees expected.

The program, being finalized at this time, will include about 20 oral presentations and 14 posters dealing with the following topics:

- *Clastic Reservoirs*—the influence of depositional environments, sedimentation, and diagenesis on reservoir heterogeneity and/or reservoir-development strategies;
- *Carbonate Reservoirs*—the influence of depositional environments, sedimentation, diagenesis, and karstification, on reservoir heterogeneity and/or reservoir-development strategies;
- *Fractured Reservoirs*—the effect of natural fracture systems on reservoir properties, and their influence on reservoir-development strategies.

The full program for the workshop will be printed in the February issue of *Oklahoma Geology Notes*. For further information contact Ken Johnson or Jock Campbell, Co-Chairmen, at (405) 325-3031.

NEW OGS PUBLICATION

SPECIAL PUBLICATION 90-5. *Hydrogeology and Karst of the Blaine Gypsum-Dolomite Aquifer, Southwestern Oklahoma,* by Kenneth S. Johnson. 31 pages. Price: $4.

SP 90-5 is the guidebook for a field trip held November 1–3, 1990, following the annual meeting of the Geological Society of America in Dallas. The trip, sponsored by the Hydrogeology Division of GSA, entailed 10 stops during a two-day visit to the Mangum–Duke–Hollis region of southwestern Oklahoma. Field-trip co-leaders were Kenneth S. Johnson, John R. Bozeman, Sue Bozeman, Paul Horton, and Donna L. Runkle.

Excerpts modified from author's text:

> Gypsum and dolomite beds of the Permian Blaine Formation make up a major karst aquifer that is being naturally and artificially recharged to provide irrigation water in 1,000 mi^2 making up the Hollis basin of southwestern Oklahoma. The Blaine aquifer is unique in being the only significant fresh-water aquifer developed in evaporite rocks in the United States. The Blaine typically is 180–220 ft thick, and it consists of a sequence of laterally persistent gypsum, dolomite, and shale interbeds. Gypsum and dolomite beds are partly dissolved by circulating ground waters, thus creating the karstic system comprising the aquifer. Karst features include major caves, sink-

holes, disappearing streams, springs, and underground water courses. Irrigation wells in the district typically are 50–300 ft deep. They commonly yield 300–2,000 gpm of water containing about 1,500–5,000 mg/L dissolved solids; principal chemical constituents of the water are calcium, sulfate, and carbonate, and these have little or no adverse effect on crops being grown. In addition to the natural recharge that occurs through karstic outcrops in the district, landowners practice artificial recharge by diverting excess runoff and surface drainage to natural sinkholes or to recharge wells drilled 50–150 ft deep into cavernous gypsum-dolomite units.

The purpose of the two-day field trip was to examine outcrops, karst features, ground-water production, recharge, and the hydrologic regime of the Blaine aquifer. Day 1 consisted of five stops focusing on evaporite geology, stratigraphy, caves, and karst development; day 2 consisted of five stops dealing mainly with karst development, hydrogeology, water use, and aquifer recharge.

SP 90-5 can be obtained over the counter or by mail from the Survey at 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031. Add 10% to the cost of publication(s) for mail orders, with a minimum of 50¢ per order.

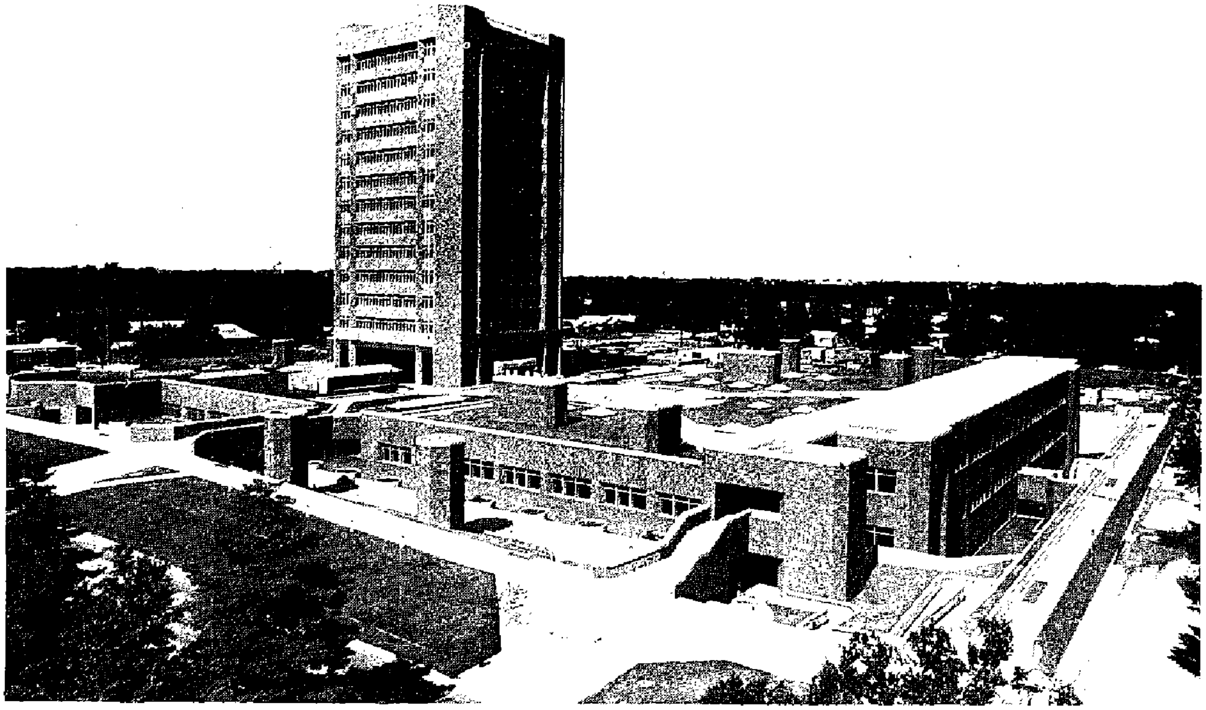
ARBUCKLE GROUP TO BE THE FOCUS OF FALL WORKSHOP AND FIELD TRIP

The Oklahoma Geological Survey will sponsor an "Arbuckle Group Core Workshop and Field Trip" October 29–31, 1991, in Norman. The workshop, coordinated by Ken Johnson of the OGS, will be held on Tuesday, October 29, and the field trip, led by Dr. R. Nowell Donovan of Texas Christian University, will examine excellent Arbuckle Group outcrops in the Wichita and Arbuckle Mountains October 30–31. It will be possible to attend the workshop, the field trip, or both events.

The Arbuckle Group is a thick sequence of shallow-marine carbonates in the Southern Midcontinent. It consists mainly of limestone in the deep-basin area of the southern Oklahoma aulacogen, and is mainly dolomite in the shelf areas. The unit has been of major interest as a target for oil and gas exploration in the last three years, since discovery of oil and gas in the prolific Cottonwood Creek and Wilburton fields. This workshop is intended to help in the exchange of information about this important petroleum reservoir.

We anticipate six to nine presenters of core information at the one-day workshop, with an attendance of 100–150 persons. Each presenter will be provided all or half of a seminar room to display core and appropriate materials for examination and discussion throughout the day. The core studies can focus on depositional, diagenetic, and/or structural aspects, based on petrologic, petrographic, and/or geochemical studies. Also, the studies can be based on hand specimens collected from outcrops.

Persons from industry, academia, or government who have been examining cores or outcrops of Arbuckle strata in the Southern Midcontinent are welcome to present their work at the workshop and/or on the field trip. A book, containing core-description articles by the presenters and the guide for the two-day field trip, will be prepared in advance of the workshop. To participate as a presenter, please contact Ken Johnson before February 1, 1991, at (405) 325-3031.



SARKEYS ENERGY CENTER DEDICATED

The newly completed Sarkeys Energy Center was dedicated Nov. 16 as part of the University of Oklahoma's Centennial Celebration. The Sarkeys Foundation of Norman recently awarded $3.3 million to complete construction of the $50-million building, named the Sarkeys Energy Center to commemorate the gift and the memory of S. J. Sarkeys, a pioneer Oklahoma oilman. The gift is the single largest in OU's history.

Located on a seven-acre site and containing 340,000 square feet, the Energy Center consists of two below-ground levels and a 13-story tower. Designed for energy efficiency, the Center houses the Laurence S. Youngblood Library, 207 teaching and state-of-the-art research laboratories, 30 classrooms, and faculty and administrative offices.

The Energy Center concept is as important as the building. Believed to be the first facility of its scope built by a university, the Energy Center encompasses more than 20 academic disciplines and individual research programs and consortia focusing on such energy-related topics as oil and gas exploration and recovery, energy and the environment, remote sensing, and production engineering. Also, the academic programs in the Center have active research efforts in methane conversion, surfactants, ultra-thin polymer films, and meteorology. Other programs being developed focus on national energy priorities, energy policy, technology transfer, and natural gas and its role in the future.

Since its inception, the Center was planned to foster an interdisciplinary approach to teaching and research and provide for interaction with industry. "One of the primary contributions of the Energy Center will be to integrate work and programs that have traditionally been separated by disciplinary boundaries," said Barney Groten, executive director of the Energy Center.

When fully occupied in the Spring of 1991, the Energy Center will house the College of Geosciences offices and its three academic units—the School of Geology and Geophysics, the School of Meteorology, and the Department of Geography. Two of the College of Engineering's six schools—Petroleum and Geological Engineering, and Chemical Engineering and Materials Science—are located in the Center.

In addition to the academic disciplines, other educational, research, and public service units to be part of the Energy Center include the Oklahoma Geological Survey; Energy Resources Institute; Science and Public Policy Program; Center for Natural Gas Research; Cooperative Institute for Mesoscale Meteorological Studies; Cooperative Institute for Applied Remote Sensing; GEOSAT Committee, Inc.; Oklahoma Mining and Mineral Resources Research Institute; Center for the Analysis and Prediction of Storms; Institute for Dryland Development; and Oklahoma Climatological Survey.

RMAG PLANS SYMPOSIUM ON HORIZONTAL DRILLING

The Rocky Mountain Association of Geologists is now soliciting papers for a ground-breaking volume on the geologic factors that affect the success of horizontal drilling. Slated to be published in the fall of 1992, the book will emphasize field experience and case histories in western North America. There also will be a place for more-theoretical studies. The editors are looking for papers of three types:

1) Case histories and field experiences with horizontal drilling anywhere in western North America. The emphasis should be on the geological factors that influenced the success or failure of the project. To illustrate the scope of the volume, examples of the formations and areas of interest include the Bakken Formation of the Williston basin, the Austin Chalk of Texas, the Niobrara Formation of the central Rocky Mountains, reservoirs on the North Slope of Alaska, the Weber Formation of northwestern Colorado, the Tertiary and Cretaceous coals of the Rocky Mountain basins, the Mancos Shale in western Colorado, the Mowry Shale of the Powder River basin, the Tertiary heavy oil beds of southern California, and appropriate examples from Oklahoma and other parts of the southern Midcontinent.

2) Papers on geologic principles and methods that affect horizontal drilling. These can cover such topics as physics and fractal analysis of fracturing, modeling and prediction of nonfracture reservoir heterogeneities, prediction of drilling problems, and core-log-seismic and remote-sensing analyses of fracture patterns.

3) Papers covering reservoir-engineering, economic, legal, land, regional geology, or historical aspects of horizontal drilling plays.

Abstracts of 250 words or fewer should be submitted by February 15, 1991, to: James W. Schmoker, U.S. Geological Survey, Mail Stop 960, Federal Center, Denver, CO 80225; phone (303) 236-5794.

AAPG SOUTHWEST SECTION CONVENTION
Abilene, Texas, February 9–12, 1991

Hosted by the Abilene Geological Society, the theme of this year's AAPG Southwest Section Convention is "Exploration in the 1990s—New Ways, New Pays, New Plays!"

Along with 22 talks and posters to be presented on Texas studies, there are three presentations on Oklahoma: "Stratigraphic Facies Relationships and Structural Trends of the Spiro Formation, Frontal Ouachita Mountains, Southeastern Oklahoma," by Lawrence K. Hinde; "New Exploration Frontier for Southwestern Oklahoma Mountain View–Meers Valley Area (Anadarko Basin)," by Charles C. Perry, Jr.; and "Exceptional Marine Sand Bodies in the Paleozoic of Oklahoma," by Richard D. Fritz.

A one-day, pre-convention field trip, "Cyclic Deposition of Pennsylvanian and Permian Sediments on the Eastern Shelf, Texas," will traverse Pennsylvanian (Cisco)–Permian (Wolfcampian) strata exposed near the axis of the northward-plunging Bend Arch.

Richard R. Bloomer will teach a short course entitled "Subsurface Methods for Fluvial Channel, Delta, and Submarine Canyon and Fan Prospecting."

For further information about the meeting, contact J. Bill Hailey, General Chairman, Delray Oil, Inc., 205 Wagstaff Bldg., Abilene, TX 79601; (915) 672-9411.

EXPLORATION in the 1990's

BRACHIOPOD DATABASE AVAILABLE FROM SMITHSONIAN INSTITUTION

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For further information, contact Rex Doescher, NHB E-207, Smithsonian Institution, Washington, DC 20560; phone (202) 357-4284, ext. 2211.

SEPM INSTALLS NEW OFFICERS

Officers of the Society of Economic Paleontologists and Mineralogists for the 1990–91 term are:

President: RODERICK W. TILLMAN, Consulting Sedimentologist
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Secretary-Treasurer: MICHAEL E. FIELD, U.S. Geological Survey, Menlo Park, California
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Editor, *PALAIOS:* DAVID J. BOTTJER, University of Southern California
Editor, Special Publications: BARBARA H. LIDZ, U.S. Geological Survey

UPCOMING MEETINGS

Seventh Annual V. E. McKelvey Forum on Mineral and Energy Resources, February 11–14, 1991, Reno, Nevada. Information: Buhler and Abraham, Inc., 8700 First Ave., Silver Spring, MD 20910; (301) 588-4177.

Mixed Carbonate–Siliciclastic Sequences Workshop and **Identifying Carbonate Facies Workshop**, April 7, 1991, Dallas, Texas. Information: Susan Green, Society for Sedimentary Geology, Box 4756, Tulsa, OK 74159; (918) 743-9765.

Oil and Gas Production Meeting, April 7–9, 1991, Oklahoma City, Oklahoma. Information: Sally Goldesberry, Society of Petroleum Engineers, Box 833836, Richardson, TX 75083; (214) 669-3377.

American Association of Petroleum Geologists, Annual Meeting, April 7–10, 1991, Dallas, Texas. Information: Convention Dept., AAPG, Box 979, Tulsa, OK 74101; (918) 584-2555.

Engineering Geology and Geotechnical Engineering, 27th Symposium, April 9–13, 1991, Logan, Utah. Information: James McCalpin, Dept. of Geology, Utah State University, Logan, UT 84322; (801) 750-1220.

Hydrocarbon Economics and Evaluation Meeting, April 11–12, 1991, Dallas, Texas. Information: Sally Goldesberry, Society of Petroleum Engineers, Box 833836, Richardson, TX 75083; (214) 669-3377.

Permian Basin Section–SEPM Annual Field Seminar: "Sequence Stratigraphy, Facies, and Reservoir Geometries of the San Andres/Grayburg/Queen Formations, Guadalupe Mountains, New Mexico and Texas," April 11–13, 1991, Permian Basin, Texas. Information: Sally Meador-Roberts, PBS–SEPM Field Seminar, P.O. Box 1595, Midland, TX 79702; (915) 684-7122.

Geological Society of America, South-Central/Rocky Mountain Sections, Annual Meeting, April 22–24, 1991, Santa Fe, New Mexico. Information: G. Randy Keller, Dept. of Geological Sciences, University of Texas, El Paso, TX 79968; (915) 747-5501.

Association of Exploration Geochemists, International Meeting, April 26–May 1, 1991, Reno, Nevada. Information: Richard B. Jones, Nevada Bureau of Mines and Geology, University of Nevada, Reno, NV 89557; (702) 784-6691.

Eighth Thematic Conference on Remote Sensing for Exploration Geology, April 29–May 2, 1991, Denver, Colorado. Information: Robert H. Rogers, Environmental Research Institute of Michigan, Box 8618, Ann Arbor, MI 48107; (313) 994-1200.

International Symposium on Land Subsidence, May 12–18, 1991, Houston, Texas. Information: Ivan Johnson, A. Ivan Johnson, Inc., 7474 Upham Ct., Arvada, CO 80003; (303) 425-5610.

Fifth National Outdoor Action Conference on Aquifer Restoration, Ground-Water Monitoring, and Geophysical Methods, May 13–16, 1991, Las Vegas, Nevada. Information: National Water Well Association, 6375 Riverside Dr., Dublin, OH 43017; (614) 761-1711.

SEPM Midyear Meeting: "Continental Margins: Tectonics, Eustasy, and Climate Change," August 15–18, 1991, Portland, Oregon. *Abstracts due January 31.* Information: Sam Boggs, Jr., Dept. of Geology, University of Oregon, Eugene, OR 97403; (503) 686-4573.

NOTES ON NEW PUBLICATIONS

Coal Geology of the Interior Coal Province, Western Region

Prepared for the Coal Geology Division field trip of the 1990 GSA annual meeting, this 301-page guidebook is divided into three parts. The first part contains the road log and descriptions of the surface coal mine sites visited. The second contains summaries of the coal geology and production history for each of the six states in the Western Region. The third part contains articles describing recent research on coals from the Western Interior Region. The book was edited by Robert B. Finkelman, Samuel A. Friedman, and Joseph R. Hatch.

Order from: Environmental and Coal Associates, P.O. Box 3168, Reston, VA 22090; (703) 648-6412. The price is $30 postpaid, domestic book rate.

Applications of Thermal Maturity Studies to Energy Exploration

Edited by Vito F. Nuccio and Charles E. Barker, this 175-page volume is divided into two sections. The first is a methods section in which papers describe different techniques used to determine thermal maturity. The second is an applications or case history section in which papers illustrate how thermal maturity studies are used to solve a geologic problem or to aid in hydrocarbon exploration. The book is based on a technical session for the 1989 Rocky Mountain Section, AAPG/SEPM meeting.

Order from: RMS–SEPM Publication Sales, P.O. Box 13947, Denver, CO 80201-3947. The price is $17; add $3 for shipping and handling.

U.S. Geological Survey–Missouri Geological Survey Symposium: Mineral-Resource Potential of the Midcontinent; Program and Abstracts

For the past several years, the USGS, in cooperation with 16 state geological surveys, has been conducting a series of research projects related to mineral-resource potential in the Midcontinent region. This work began in 1975 under the Conterminous U.S. Mineral Assessment Program (CUSMAP) as a transect of 1° × 2° quadrangle projects across southern Missouri and adjacent areas—the Rolla, Springfield, Harrison, Joplin, and Paducah Quadrangles. More recently, under the Midcontinent Strategic and Critical Minerals Project, map and data compilations at 1:1,000,000 scale and related topical studies have been undertaken for a much larger area, from latitude 36° to 46°N and from longitude 88° to 100°W; still more recently, Precambrian basement compilations have extended even farther north and west.

A public symposium was held to present summaries or progress reports on regional compilations and topical research that was done during the first five years of the Midcontinent project, as well as more detailed reports on the geology, stratigraphy, sedimentology, geochemistry, geophysics, and mineral-resource potential of the Harrison and Joplin CUSMAP Quadrangles.

Edited by W. P. Pratt and M. B. Goldhaber, this 42-page USGS circular contains the program of that symposium and 45 abstracts of papers that were presented orally or by poster. Types of mineral resources that were considered include Mississippi Valley-type lead–zinc deposits, Olympic Dam-type copper-, gold-, silver-, uranium-, and rare earth-bearing iron oxide deposits, sedimentary manganese deposits, industrial minerals, and coal and heavy-oil resources.

Order C 1043 from: U.S. Geological Survey, Books and Open-File Reports, Federal Center, Box 25425, Denver, CO 80225; phone (303) 236-7476. The circular is available free of charge.

Major Geohydrologic Units in and Adjacent to the Ozark Plateaus Province, Missouri, Arkansas, Kansas, and Oklahoma; Springfield Plateau Aquifer

The Springfield Plateau Aquifer, which is the uppermost aquifer in the Ozark Plateaus aquifer system, is defined and the geologic units that compose the aquifer are identified. J. L. Imes prepared this USGS hydrologic investigations atlas at a scale of 1:750,000 (1 in. = ~12 mi). Latitude 34°30′ to 39°30′, longitude 89° to 96°. Three color sheets measure 35 × 41 in. each. Maps showing the altitude of the top of the aquifer and thickness of the aquifer are presented. The predevelopment potentiometric surface of the aquifer shows ground-water movement generally is to the west and south, away from the province.

Order HA 0711-G from: U.S. Geological Survey, Map Distribution, Federal Center, Box 25286, Denver, CO 80225. The price is $7.20. (A $1 postage and handling charge is applicable on orders of less than $10.)

History of the School of Geology and Geophysics, The University of Oklahoma

Compiled and written by Professor Emeritus George G. Huffman and published in the University of Oklahoma's Centennial year, this 312-page volume traces the history of the School of Geology and Geophysics from 1900 to 1990. With OU noted worldwide as having the "first and best school of petroleum geology," this comprehensive history covers the golden period of the beginning of the concentrated use of geology and geophysics in the search for oil and gas, as well as paying tribute to pioneer geologists, faculty, staff, and alumni. Also chronicled are the many contributions of the school to science, industry, and technology.

Order from: University of Oklahoma Foundation, School of Geology and Geophysics, 100 E. Boyd, Room S-114, Norman, OK 73019; phone (405) 325-3253. The price is $25 paperbound and $30 hardbound; add $3 shipping and handling per book. Oklahoma residents must add 7% sales tax.

OKLAHOMA ABSTRACTS

The Oklahoma Geological Survey thanks the American Association of Petroleum Geologists, Geological Society of America, Society of Economic Paleontologists and Mineralogists, and the authors for permission to reprint the following abstracts of interest to Oklahoma geologists.

Middle Pennsylvanian Recurrent Uplift of the Ouachita Fold Belt and Basin Subsidence in the Arkoma Basin, Oklahoma

R. DOUGLAS ELMORE, PATRICK K. SUTHERLAND, and PERRY B. WHITE, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019

Recurrent uplift of the Ouachita fold belt in Oklahoma coincided with the disruption of the Arkoma basin following the deposition of the Boggy Formation (early Desmoinesian time). The Boggy, composed of sandstone-shale sequences that record southerly progradation of coal-bearing, fluvially dominated deltaic complexes into the Arkoma basin, was folded at the time of uplift of the Ouachita fold belt. The uplift ended the progressive subsidence of the Arkoma basin and shifted the depocenter to the northwest. Subsequently, the Thurman Formation (middle Desmoinesian), which had a source in the southeast, was deposited in the smaller resurgent foreland basin over the folded and eroded surface of the Boggy. Chert-pebble conglomerates in the Thurman were derived from the erosion of newly elevated Ordovician and Devonian cherts in the core of the Ouachita foldbelt. Sandstone-shale packages are found in both formations. The origin of the coal-bearing cycles in the Boggy are enigmatic, but they probably were controlled by a combination of factors such as glacio-eustatic changes in sea level and delta-lobe abandonment. In contrast, cycles in the Thurman probably were strongly influenced by episodic thrust faulting and uplift in the Ouachitas.

Reprinted as published in *Geology,* v. 18, p. 906, September 1990.

Evolution of Pre-Jurassic Basement Beneath Northern Gulf of Mexico Coastal Plain

DEWIT C. VAN SICLEN, Independent Geologist, Bellaire, TX 77401

Data from the northern Gulf Coast region reveal a late Paleozoic wrench fault system along which North America (NA) moved southeast (present directions) alongside the northeastern edge of future South America (SA), to where collision with that continent converted a broad continental embankment off the Southern

Oklahoma aulacogen into the Ouachita thrust belt. At the same time, Africa farther east, to which protruding SA was firmly joined (within the less-mobile megacontinent of Pangea), was continuing to advance the Appalachian thrusts on the opposite side of these faults. This relationship left no space between the American continents for the conventional remnant ocean or microcontinents.

By Late Triassic time, however, extension south of the Ouachita Mountains was forming the series of Interior rift (or salt dome) basins, at both ends of which new wrench faults transferred the extension southward to the DeSoto Canyon and South Texas rift (or salt dome) basins. Genetically, the Ouachita thrusts are part of the subduction zone along the front of a former SA forearc basin, which continued to receive marine sediments into middle Permian. The Wiggins arch southeast of it is a sliver of that continent, left with NA when the Interior basin rifting "jumped" from that forearc basin southward across bordering "outer basement highs" to begin opening the deep Gulf of Mexico (GOM) basin.

The Late Triassic crustal extension resulted from right-lateral translation of NA around the bulge of northwestern Africa. About 200 mi (320 km) of this placed Cape Hatteras against Africa's Cap Blanc, in the configuration from which the magnetic data indicate spreading began in the Central North Atlantic Ocean. The reality of this translation is confirmed by widespread rifting at the same time in western North Africa and between all three northern Atlantic continents; this drew the tip of the Tethys sea southward to Cape Hatteras and led to deposition of voluminous Late Triassic "red beds" and evaporites along it.

Reprinted as published in the American Association of Petroleum Geologists *Bulletin*, v. 74, p. 1512, September 1990.

Structural Interpretations of the Ouachita Frontal Zone Near Hartshorne, Oklahoma, Based on Reprocessed Seismic Reflection Data

W. J. PERRY, JR., W. F. AGENA, U.S. Geological Survey, Box 25046, Federal Center, Denver, CO 80225; and N. H. SUNESON, Oklahoma Geological Survey, University of Oklahoma, Norman, OK 73019

A 27-km-long seismic reflection profile across the frontal zone of the Ouachita thrust belt near Hartshorne, Oklahoma, acquired in support of the Ouachita COGEOMAP project, was reprocessed using standard techniques such as time-variant spiking deconvolution, surface-consistent residual statics, and post-stack migration. In order to better resolve steeply dipping events, processing included a technique of cascaded post-stack migrations. The reprocessed line clearly shows a triangle zone (TZ) in the frontal Ouachitas. The Choctaw thrust is the frontal imbricate along the southern margin of this complex, partially eroded TZ. The TZ and associated imbricates represent about 6 miles (10 km) of shortening. The Middle Pennsylvanian Hartshorne Sandstone appears to be merely peeled upward along the northern margin of the TZ and not significantly displaced laterally with respect to the Arkoma basin to the north.

The underlying Middle Pennsylvanian Atoka Formation occupies an unfaulted roof above a deeper imbricate zone, a duplex fault zone near the north end of the profile, bounded by floor and roof thrusts which structurally isolate the zone from overlying and underlying sequences. This deeper zone is unusual because it contains two foreland-dipping backthrusts between the floor and roof thrusts. The floor thrust of this deeper zone appears to be a decollement for a distance of more than 19 km north–south within the Upper Devonian and Mississippian shale sequence. Beneath the floor thrust of this deeper imbricate zone, the Hunton through Arbuckle (Devonian to Cambrian) Groups are cut by several steeply dipping faults, most of which appear to have been formed as extension faults prior to thrusting. The positions of several splay thrusts, which rise upward from the floor thrust, appear controlled in part by the positions of these deeper and older basement faults.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1990,* v. 22, no. 7, p. A231–A232.

The LaSalle Arch and Its Effect on Wilcox Sequence Stratigraphy

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The LaSalle Arch is a southerly trending anticline separating the Louisiana and Mississippi interior salt basins. The structural trend of the Arch is suspended along basement paleo-highs. The paleo-high beneath the Nebo–Hemphill field, as seen on reflection seismic data, is the nose of an Ouachitan thrust fault that was partially rifted during the opening of the Gulf of Mexico. The western limb of the Arch formed owing to differential subsidence expanding the stratigraphic section toward the southwest. The eastern limb of the Arch formed because of regional tilting to the east after deposition of the Claibornian Sparta Formation. Uplift of the LaSalle Arch occurred during the Late Cretaceous Period and is seen as a truncational unconformity within the Tayloran Demopolis Formation.

The Wilcox and Midway groups of central Louisiana have been subdivided into three genetic sequences. They are T_1 (the Midway), T_2 (the Holly Springs), and T_3 (the Carrizo). A genetic sequence is bounded above and below by condensed sections and represents a progradation into the basin followed by transgression. Each sequence represents a potential major migration route for the crude oil.

The high stand systems tract of T_1 and T_3 were deposited during falling sea level resulting in similar homogenous sheetlike sand bodies. The paleo-highs subtly controlled the location of depositional environments, but did not prevent progradation to the southwest. The high stand systems tract of T_2 was deposited during rising sea level resulting in heterogenous sediment dominated deltaic deposits that are very different from T_1 and T_3. Although the stratigraphic section expands to the southwest, giving the impression that the interval thins over the Arch, the LaSalle Arch did not control the location of depositional environments within T_2.

Reprinted as published in the American Association of Petroleum Geologists *Bulletin*, v. 74, p. 1501, September 1990.

Gulf Coast–East Coast Magnetic Anomaly I: Root of the Main Crustal Decollement for the Appalachian–Ouachita Orogen

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The Gulf Coast–East Coast magnetic anomaly extends for at least 4000 km from south-central Texas to offshore Newfoundland as one of the longest continuous tectonic features in North America and a major crustal element of the entire North Atlantic–Gulf Coast region. Analysis of 28 profiles spaced at 100 km intervals and four computed models demonstrate that the anomaly may be explained by a thick zone of mafic and ultramafic rocks averaging 13–15 km in depth. The trend of the anomaly closely follows the trend of main Appalachian features: in the Gulf Coast of Louisiana, the anomaly is as far south of the Ouachita front as it is east of the western limit of deformation through the central Appalachians. Because the anomaly continues across well-known continental crust in northern Florida and onshore Texas, it cannot plausibly be ascribed to an edge effect at the boundary of oceanic with continental crustal compositions. The northwest-verging, deep-crustal events discovered in COCORP data from the Ouachitas and Appalachians suggest an analogy with the main suture of the Himalayan orogen in the Tibetan Plateau. In this paper the anomaly is identified with the late Paleozoic Alleghenian megasuture, in which the northwest-verging crustal-detachment surfaces ultimately root.

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Evolution of Antivergent Folds on a Paleozoic Accretionary Prism, Arkansas: An Alternative View

ABDOLALI BABAEI, Dept. of Geological Sciences, Cleveland State University, Cleveland, OH 44115

Rocks around the western plunge of the Benton uplift in the Ouachita Mountains of western Arkansas show multiple periods of deformation during the Ouachita orogeny. Seismic-reflection interpretations and surface geology are consistent with a thick section of highly deformed Paleozoic rocks that are separated as thrust sheets by north-vergent regional-scale thrust faults. North-vergent folds develop in such a setting; however, south-vergent folds with the axial planes dipping opposite to the direction of underthrusting are also observed on the Benton uplift. Development of such folds has been explained by models such as mechanical decoupling along zones of low shear strength in trenches, backthrusting, and backfolding, but none explains the south-vergent folds of the Benton uplift, mostly because of lack of adequate field data. Geometrical analyses show that reactivation of thrust faults during a secondary phase of deformation tightened and reoriented open folds of an initial phase and, as a result, developed the macroscopic and mesoscopic anti-

vergent folds in the Benton uplift. Curvilinear map traces of the thrust faults and broad open folds that refold earlier structures indicate that there was continuous deformation after the development of antivergent folds.

Reprinted as published in *Geology*, v. 18, p. 987, October 1990.

Petrology of Five Principal Commercial Coal Beds of Oklahoma

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University of Oklahoma, Norman, OK 73019

Forty channel, drill-core, and grab samples were collected from 26 locations from the Iron Post, Croweburg, Secor, McAlester/Stigler, and Hartshorne/Lower Hartshorne coal beds, five principal commercial coals in the Oklahoma coalfield. Selected chemical (volatile matter, fixed carbon, total sulfur, and calorific value) and petrographic (vitrinite reflectance and white-light maceral) analyses were performed to assess coal rank, coal quality, and organic composition.

Coal rank was assigned using the mean maximum vitrinite-reflectance value. For comparison, rank was also assigned by chemical parameters and was similar to that assigned by vitrinite reflectance. Coal rank ranges from high-volatile C to low-volatile bituminous, with medium- and low-volatile bituminous ranks restricted to the Stigler, Hartshorne, and Lower Hartshorne coal beds.

All studied coal samples have high vitrinite-maceral group contents (76.8 to 95.1%), low to moderate inertinite-maceral group contents (2.0 to 23.2%), and low liptinite-maceral group contents (0 to 6.4%). Samples with no liptinite macerals were primarily of medium-volatile and low-volatile bituminous rank.

Reprinted as published in *Coal Geology of the Interior Coal Province, Western Region*, p. 185, 1990.

Coal Geology of the Senora Formation (Pennsylvanian) in Northeastern Oklahoma

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University of Oklahoma, Norman, OK 73019

Six commercially important coal beds are present in the Senora Formation in northeastern Oklahoma in parts of Craig, Mayes, Nowata, Rogers, Tulsa, and Wagoner Counties. The coal beds are Desmoinesian (Middle Pennsylvanian); from oldest (lowest) to youngest (highest), they are the Weir-Pittsburg, Tebo, Mineral, Fleming, Croweburg, and Iron Post coals.

Remaining coal resources for the six-county area (in the Senora Formation) total 1,033,431,000 short tons (937,322,000 MT), of which 102,212,000 tons (92,706,284 MT) are recoverable reserves. The Weir-Pittsburg coal contains the most remaining resources (496,066,000 tons) (449,932,000 MT) and the most recoverable reserves (31,817,000 tons) (28,858,000 MT).

Standard analyses indicate that the coals of the area are predominantly high-volatile A bituminous in rank. Coal from the Croweburg coal bed has the highest overall quality. It has an average sulfur content of 1.2%, and an average ash content of 6.2%, both on an as-received basis. On a moist, mineral-matter-free basis, the Croweburg coal averages 14,048 Btu/lb (32,645 kJ/kg). The other coals have comparably high heat values, but their sulfur and ash contents are higher, averaging 4.3% and 10.8%, respectively.

During 1989, seven coal companies reported production of 1,016,566 short tons (922,025 MT) of coal from 10 mines in the study area. All tonnage came from the Croweburg and Iron Post coal beds and was mined by surface methods in Craig, Nowata, and Rogers Counties.

Reprinted as published in *Coal Geology of the Interior Coal Province, Western Region*, p. 146, 1990.

Thermal Maturation by Vitrinite Reflectance of Woodford Shale near Washita Valley Fault, Arbuckle Mountains, Oklahoma

BRIAN J. CARDOTT, Oklahoma Geological Survey, University of Oklahoma, Norman, OK 73019; WILLIAM J. METCALF III, Shell Offshore Inc., One Shell Square, New Orleans, LA 70161; and JUDSON L. AHERN, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019

Vitrinite reflectance was measured on 40 grab samples from outcrops of the Woodford Shale (Upper Devonian–Lower Mississippian) collected near the Washita Valley fault in the Arbuckle Mountains in south-central Oklahoma. Samples are widely distributed over 40 km. Sample localities range from 60 m to 7.63 km normal to the Washita Valley fault trace. Vitrinite reflectance values were measured from standard kerogen concentrate pellets.

Mean random (% $\bar{R}_e$; plane-polarized light, stationary stage) reflectance values from low-gray vitrinite are 0.35–0.77% $\bar{R}_e$ with a weighted average of 0.54% $\bar{R}_e$ based on 14 to 98 measurements per sample with an average of 46.

Variation in vitrinite reflectance values is attributed to geologic history (e.g., tectonics), organic variables (e.g., geochemical gelification or vitrinitization of huminite; liptinite maceral and/or bitumen impregnation of vitrinite maceral), and analytical error (e.g., kerogen concentration process; number of reflectance measurements).

Implications of the data specific to the Arbuckle Mountains include: the Woodford Shale is immature to marginally mature with respect to the generation of oil; high heat flow associated with the rifting stage of the southern Oklahoma aulacogen was diminished by Early Ordovician; the Woodford Shale was never deeply buried; and frictional heating from the Washita Valley fault did not raise near-surface temperatures enough to be resolved by vitrinite reflectance measurements.

Reprinted as published in *Applications of Thermal Maturity Studies to Energy Exploration*, p. 139, 1990.

Formation Resistivity as an Indicator of Oil Generation—Bakken Formation of North Dakota and Woodford Shale of Oklahoma

JAMES W. SCHMOKER and TIMOTHY C. HESTER, U.S. Geological Survey, Box 25046, Federal Center, Denver, CO 80225

With the onset of oil generation in organic-rich low-porosity shales, nonconductive hydrocarbons begin to displace conductive pore water. As this process continues, formation resistivity increases from the low levels typical of water-saturated shales and can reach hundreds of ohm-m if sufficient oil is generated. In this study, formation resistivity of selected organic-rich shales is compared with geochemical indicators of hydrocarbon generation and thermal maturity in order to quantify relationships between resistivity and oil generation.

The upper and lower shale members of the Bakken Formation (Upper Devonian and Lower Mississippian) of the Williston basin, North Dakota, and the Woodford Shale (Upper Devonian and Lower Mississippian) of the Anadarko basin, Oklahoma, are used here as illustrative examples. An increase of volatile hydrocarbons (S_1) in core samples indicates that a resistivity of about 35 ohm-m marks the onset of observable oil generation in these three organic-rich shales. This resistivity value is used to map regions of the study areas where the Woodford Shale and the Bakken Formation have generated oil and where free oil might possibly be produced from fracture systems.

Crossplots of formation resistivity versus vitrinite reflectance (R_o) indicate that the level of thermal maturation required for oil generation is about $R_o = 0.44\%$ in the upper member of the Bakken Formation, $R_o = 0.50\%$ in the lower member of the Bakken Formation, and $R_o = 0.57\%$ in the Woodford Shale of the study area.

Reprinted as published in the American Association of Petroleum Geologists *Bulletin*, v. 74, p. 1345, August 1990.

Thermal Maturity, Organic Geochemistry, and Burial History of Pennsylvanian Rocks, Cherokee Basin, Southeastern Kansas

CHARLES E. BARKER and JOSEPH R. HATCH, U.S. Geological Survey, Box 25046, Federal Center, Denver CO 80225; ROBERT H. GOLDSTEIN and ANTHONY W. WALTON, Kansas Geological Survey, University of Kansas, Lawrence, KS 66046

Vitrinite reflectance (R_m) and Rock-Eval pyrolysis data suggest that Pennsylvanian source rocks in southeastern Kansas have generated oil at least locally. Some of the heating required for oil generation may result from lateral movement of fluids from the Sedgwick and (or) Arkoma basins, or possibly spots of increased crustal heat flow. The presence of hydrothermal fluids is corroborated by fluid inclusion

data. In some wells, the warm fluids have increased R_m to as high as 1.4% against the regional background level of 0.5–0.7%, suggesting the rocks are marginally mature to mature with respect to oil generation. Rock-Eval T_{max} data generally parallel the R_m profiles confirming that the locally high R_m values are a real signal.

Organic geochemical evidence from Rock-Eval pyrolysis also indicates oil generation has occurred. Hydrogen index (HI) versus oxygen index plots show that the Pennsylvanian source rocks contain a mixture of type II and III kerogen in marine mudrock and type III kerogen in the mudrock associated with coal-bearing rocks. Total organic carbon (TOC) levels are generally favorable in the source mudrocks with most in the range of 0.3 to 5 wt%. One contraindication for oil generation is that the HI values are somewhat low, generally ranging from 50 to 150 mg hydrocarbon/g TOC. However, S_1 peak values exceed 1 mg/g rock in the moderate to high TOC mudrocks, an indication of oil generation.

Present-day geothermal gradients in southeast Kansas range from 35 to 50°C/km and the mean annual surface temperature is 13°C. Lopatin analysis using paleogeothermal gradients of 40°C/km or higher with a late Paleozoic through Mesozoic surface temperature of 20–25°C suggests that oil generation could have occurred at, or just after, peak burial. Merriam indicates pre-Cretaceous erosion removed up to several thousand feet of rock (amount depending on position in the basin). Therefore, maximum temperature resulting from burial occurred in the Permian to earliest Mesozoic. The timing of the entrance of hydrothermal fluids into the rocks is poorly constrained. However, the simplest hypothesis is that the hydrothermal fluid flow would coincide with near-maximum burial.

The importance of the hydrothermal fluids is that they would locally enhance thermal maturity and increase total oil generation, possibly explaining the spotty occurrence of oils that can be geochemically correlated to Cherokee Group sources.

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Segmentation of the Meers–Duncan–Criner Fault Zone, Oklahoma: Implications to Active Tectonics in the Midcontinent

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717 Spear Street Tower, One Market Plaza, San Francisco,
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Based on degree of geomorphic expression, the northwest-striking Meers–Duncan–Criner fault zone in southern Oklahoma consists of at least five segments. Two segments (the Meers and Criner fault) exhibit surface expression suggestive of Quaternary activity. Paleoseismic data indicate that two Holocene events on the Meers fault were proceeded by a period of quiesence that lasted for possibly hundreds of thousands of years, indicating temporal clustering of surface ruptures. The Criner fault, which lies about 120 km southeast of the Meers fault, displaces Pleistocene, but not Holocene, fluvial deposits. Different rupture histories on these two segments coupled with a lack of surface expression along the 120-km-long intervening

Duncan segment, suggest that there have been spatial variations in Quaternary activity along the fault zone and that segmentation is an important behavioral characteristic of the fault zone.

Paleoseismic evidence of Quaternary surface ruptures along the Meers–Duncan–Criner fault zone, which has been historically aseismic, demonstrates that the historical record is too short to identify some potentially hazardous seismic sources in the mid-continent. Large paleoseismic events on the fault zone, which lies along the Southern Oklahoma aulacogen, coupled with the spatial association of large historical events and other reactivated rifts in the mid-continent, further supports the hypothesis that present-day deformation is localized along pre-existing zones of crustal weakness. Fault segmentation and temporal clustering may be important characteristics of other potentially active source zones in the mid-continent.

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Ground-Magnetic Profiles Across the Meers Fault, SW Oklahoma: Quaternary Reactivation of a Late Paleozoic Fault Zone

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Ground-magnetic surveys between 1 and 4 km long across the Holocene scarp of the Meers fault and its extension to the northwest provide evidence of Quaternary reactivation of the late Paleozoic fault zone and show a change in the sense of throw of magnetic basement along strike. Magnetic basement is interpreted to be offset up-to-the-south by as much as 2 km along the northwestern section and the extreme southeastern section of the scarp. In the central section of the fault near Blue Creek Canyon the magnetic basement is offset up-to-the-north. The depositional history of the Anadarko basin to the north, as well as deformation of lower Paleozoic sedimentary rocks directly north of the Meers fault, indicate that most deformation and consequently most of the offset of magnetic basement across the Meers fault occurred during the Ouachita orogeny in Pennsylvanian time. In contrast to the along-strike variation in displacement direction of magnetic basement, Quaternary offset is consistently up-to-the-north along the Holocene scarp. This contrast in sense of offset, together with the fact that Permian sedimentary rocks are essentially undeformed across the fault, indicates that the Quaternary movement along the Meers fault is a small-scale reactivation of this pre-Permian structure. The extent to which the older structure influenced the location of Quaternary movement is apparent in models of at least three of the magnetic profiles where splays on the surface are coincident with offsets of magnetic basement at depth.

Interpretation of the ground magnetic surveys northwest of Blue Creek Canyon confirm Purucker's 1986 interpretation, based on the USGS 1954 aeromagnetic survey, of a dike-like feature parallel to and directly south of the Meers fault and northwest of Blue Creek Canyon. The amplitude of the magnetic anomaly associated with this dike-like feature is as high as 1600 nTesla. Core from a hole drilled by

the Oklahoma State Geological Survey shows that the anomaly-producing rock is gabbro and possibly a horse block (Kenneth Luza, oral communication, 1990). Preliminary magnetic models indicate that the gabbroic body dips steeply to the northeast along the Meers fault.

Southeast of Blue Creek Canyon, the magnetic profiles and the USGS 1954 aeromagnetic survey show a magnetic high on the northeast side of the fault zone. This high is interpreted as a magnetic body that underlies the Carlton Rhyolite exposed in the area north of the Blue Creek Canyon fault.

The change in sense of offset of magnetic basement along strike and the presence of the gabbroic sliver within the near-linear Meers fault zone are inhomogeneities that may influence the extent of possible coseismic ruptures.

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Meers Fault, Oklahoma: Segmented, Slow Deformation?

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Young surface deformation along the Meers Fault has taken place along two distinct segments. The part of the fault comprising some 27 km length, exhibiting the well known surface scarp, makes up one segment. This is separated by a drainage divide north of Saddle Mountain from a northwestern segment, of about equal length, with no surface scarp. Pending investigation, there is no evidence for deformation across the stranded older gravel deposits capping the drainage divide. This divide separates southeastward drainage and regional slope toward the southeast from northwestward flowing drainage and regional slope toward the northwest.

The northwest segment exhibits obvious stream deflections, which can result from either vertical deformation up-to-the-north or left lateral movement. Dominantly vertical reverse deformation is suggested by geometric constraints, as for the scarped segment. Deflection of stream lines decreases systematically to the northwest and ends near Unap Mountain. Surface deformation cannot be traced further. This location is coincident with the westernmost higher peaks of the Wichita Mountains.

Relict stream channel deposits are exposed and show nearby parallel flow along the fault in the surface rocks of both segments: on the upthrown side of the scarped segment and on the downthrown side of the non-scarped segment. These relict channels contain relatively coarse, unconsolidated deposits, rather than fine-grained, ponded, still-water sediments. This suggests simultaneous fault-parallel adjustment of drainage during surface folding. Folding is seen in moderately consolidated but unlithified Quaternary surficial deposits along both segments. Equivocal evidence suggests that the most recent surface deformation took place during different periods along the two segments, and that the scarped segment is younger.

Scarp height in the southeast segment, and length of stream deflections in the northwest segment each suggest that greatest recent displacement has been in the easternmost part of the individual segments.

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The Northwest Extension of the Meers Fault, Oklahoma

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The geology of southwestern Oklahoma is dominated by the Wichita Uplift. The Uplift is bounded to the north–northeast by the Anadarko Basin. The uplift is composed primarily of the Cambrian Wichita Granite Complex and Precambrian Raggedy Mountain Gabbro Complex.

The Frontal Fault Zone separates the Wichita Uplift from the Anadarko Basin. Three faults dominate the fault zone near the Wichita Mountains; the Meers (originally Thomas), the Blue Creek Canyon, and the Mountain View faults.

Along the northwestern trend of the Meers Fault, beyond the fault scarp, substantial deflection of stream alignments, buried A-soil horizons, gravels coated by seeping oil from the fault zone, and A-soil horizon and shale fragments eroded from the upthrown block, suggest an active northwestern extension of about 30 km length. The fault bifurcates in the Sugar Creek area. Bulk soil ^{14}C dates on two samples collected from this area give ages of 1090 $\pm$ 80 BP and 760 $\pm$ 70 BP years.

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Implications of Geomorphic Studies on Contemporaneous Deformation of the Wichita Uplift and the Meers Fault, Southwest Oklahoma

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Evidence for Holocene displacement along the Meers Fault, which borders the northeast flank of the Wichita Uplift in southwestern Oklahoma, has been documented by several studies within the last decade. This investigation initially concentrated on gathering geomorphic evidence in the Wichita Mountains that might reveal the nature of regional deformation and its relation to displacement along the Meers Fault. An extensive geomorphic investigation of the Wichita Mountains identified numerous granitic pediments and grouped them by morphology and physiographic relationships.

The second phase of the study focused on placing the pediment groups' development and physiographic relationships into a more regional context. This was accomplished by performing a literature review of the Texas and Oklahoma High Plains geomorphic evolution. Based on this literature review and on a geomorphic analysis of the present High Plains surface, the pediment groups in the Wichita Mountains appear to be linked to periods of persisting climatic stability that occurred during Late Tertiary and Quaternary time.

Reconstruction and extrapolation of High Plains surface gradients in west Oklahoma indicate that the pediment groups, which are believed to have once exhibited equivalent elevations, are now offset by as much as 350 feet vertically. Based on an apparent late Pliocene and Early Pleistocene age for the offset pediments, the calculated average Quaternary Uplift rates for the eastern portion of the Wichita Uplift range from 0.12 to 0.18 feet per 1,000 years. The uplift appears to be limited to the eastern Wichita Uplift, and occurs at rates that are low even when compared to calculated rates of deformation in epierogenic settings.

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Geochemical and Mineralogical Clues to Depositional Environments for Pennsylvanian, Metal-Rich, Black Shales, Midcontinent Region, U.S.A.

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Organic geochemical (TOC, Rock-Eval, $\delta^{13}C$, pyrolysis-GC); elemental (ICP, 35 elements; total sulfur) and mineralogical analyses (X-ray) were performed on 195 core and mine samples of 14 different Middle and Upper Pennsylvanian marine black shales from Iowa, Missouri, Kansas and Oklahoma. These analyses show significant regional, stratigraphic, and within bed variations in metal contents/ratios, organic matter compositions, and mineralogy. As exemplified by analyses (39 samples, six locations) of the Stark Shale Member of the Dennis Limestone (Missourian): TOC, the proportion of terrestrial organic matter, V, Mo, Zn, and U contents, and V/(V+Ni) generally increase northeastward, whereas, illite/kaolinite, and the proportion of samples containing apatite decreases. Complex within bed variations are shown by analyses of 22 samples from the 52 cm thick Stark Shale Member in Wabaunsee County, Kansas. Here, four cycles occur in which TOC ranges from <2.5 to 20–30%; hydrogen index, 55 to 460 mg/g; V, 42–3900 ppm; P, 0.02–3.2%, and V/(V+Ni), 0.46–0.89.

For the northeastern part of midcontinent region, a greater stratification of the shale depositing environments is indicated by higher V, Mo, Zn, and U contents, and higher V/(V+Ni). The high relative amounts of terrestrial organic matter, detrital kaolinite and low relative amounts of marine apatite in shales from this area suggest that fresh water plumes were responsible for the increased stratification. Likely sources for fresh water, terrestrial organic matter and detrital kaolinite would be the extensive Pennsylvanian peat swamps to the east.

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Scientific Drilling Along the Southern Midcontinent–Texas Craton Transect

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A series of shallow drill holes immediately south of the Wichita Mountains in southern Kiowa and Tillman counties, Oklahoma, is critical to deciphering both (1) location of the Grenville suture and tectonic state of the southern margin of the Proterozoic midcontinent and (2) tectonic framework and geologic history of the early stages of the Cambrian southern Oklahoma aulacogen. The exposed sequence of Raggedy Mountain Gabbro Group (~528–577 Ma.) intruded by Carlton Rhyolite Group and Wichita Granite Group (both ~525 Ma.) in the Wichita Mountains, Oklahoma, is well documented. However, the relation of these exposed rocks to the subsurface Navajoe Mountain Basalt/Spilite Group and Tillman Metasedimentary Group is not established. Both of these rock units occur in apparent contact/juxtaposition with the Raggedy Mountain Gabbro in the subsurface south of the Wichita Mountains at depths of less than 800 meters. A shallow drilling project in which several hundred meters of core is obtained from each of the main subsurface bodies and their contact zones will establish the age and geochemical characteristics of the rock units and their structural and stratigraphic relationships. It should also be possible to determine if these rocks are part of the aulacogen or part of an earlier Proterozoic geosynclinal sequence.

Proposed drilling sites are on the up side of a complex fault zone that marks the approximate southern boundary of the aulacogen and near the presumed Grenville suture. The sites also occur in proximity to several COCORP seismic lines that, just to the south, show horizontal layering to depths of about 12 km and to the UTD-UTEP large-aperture seismic experiment. Systematic sampling should provide further insights into the nature of these major crustal boundaries and possibly to the origin of the deep horizontal layering. A further consequence of the proposed drilling is that an important sequence of Permian strata can be sampled for detailed stratigraphic analysis and correlation.

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