Oklahoma Geology Notes

OKLAHOMA GEOLOGICAL SURVEY / VOL. 46, NO. 5 — OCTOBER 1986

On the cover—

Folded Woodford Shale, Ouachita Mountains

An outcrop of folded Woodford Shale (Upper Devonian–Lower Mississippian) is featured on the cover of this issue. The outcrop occurs along a tributary of Long Creek at the Bengal locality west of Bengal in the Ouachita Mountains, Latimer County, Oklahoma. The Woodford Shale is equivalent to the middle division of the Arkansas Novaculite (Lower Devonian–Lower Mississippian). The Woodford Shale is limited in the Ouachita Mountains to the frontal belt, the area between the Choctaw and Ti Valley faults. The Bengal locality is the easternmost known exposure of the Woodford Shale in the Ouachita Mountains.

A black shale layer in the black chert was collected for vitrinite-reflectance analysis and organic geochemical analysis to determine the hydrocarbon source-rock potential of the Woodford Shale in the Ouachita Mountains as part of the COGEOMAP project of the Oklahoma Geological Survey, Arkansas Geological Commission, and U.S. Geological Survey.

Brian J. Cardott

Photo by Brian J. Cardott

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

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STRATIGRAPHY OF THE LOWER PART OF THE BOGGY FORMATION (DESMOINESIAN) IN NORTHWESTERN MUSKOGEE AND SOUTHWESTERN WAGONER COUNTIES, OKLAHOMA

LeRoy A. Hemish[1]

Abstract

Four coal beds, members of four distinct cycles of sedimentation, have been identified in the interval between the Bluejacket Sandstone Member and the Inola Limestone Member of the Boggy Formation in northwestern Muskogee and southwestern Wagoner Counties, Oklahoma. Three of these coal beds have been uniquely identified previously: the Secor coal, a few feet above the Bluejacket Sandstone; the Secor rider coal, ~19 ft above the Secor coal; and the Bluejacket coal, almost immediately below the Inola Limestone. The fourth coal bed, occurring about midway between the Secor rider coal and the Bluejacket coal, is herein informally named the Peters Chapel coal.

Correlations across the Arkansas River show that rock units in the lower Boggy Formation thin or pinch out to the north, with the exceptions of the Secor coal, which thickens in the vicinity of Porter, and the Bluejacket coal, which thickens north of Red Bird. Of the four coal beds, the Bluejacket coal is the only one known to be present north of T16N.

Deposition of lower Boggy Formation sediments in the study area probably occurred in a graben, contemporaneous with faulting and subsidence. Bounding faults on the south and southeast are the NE-trending Muskogee and Pecan Creek faults; a series of NE-trending faults in the vicinity of Porter marks the northern edge of the graben. Convergence of beds to the north indicates that the downthrown block was tilted toward the south.

Introduction

The purpose of this paper is to clarify the stratigraphy of the lower part of the Boggy Formation in northwestern Muskogee and southwestern Wagoner Counties, Oklahoma. Review of the literature, examination of geologic sections of coal-mining-permit documents submitted to the Oklahoma Department of Mines by coal companies, and conversations with consulting geologists and other interested professional people have made it apparent that considerable confusion exists concerning the sequence of rocks in the lower Boggy Formation in the study area.

[1]Oklahoma Geological Survey.

Wilson and Newell (1937) investigated the geology of the Muskogee–Porum district, which includes part of the present study area in northwestern Muskogee County. Stewart (1949) mapped T13–15N, R17E, with special reference to the Secor coal and the Inola Limestone, at a time when little was known about equivalent rocks in adjacent areas.

Lontos (1952) and Govett (1959) reported on the geology of Wagoner county. Campbell (1957) reported on the geology of the Jamesville area in northwestern Muskogee County, and Bell (1959) wrote on the geology of the Muskogee area, including part of the present study area. Friedman (1974,1982) investigated the coal resources of northeastern Oklahoma. His reports included a description of the stratigraphic relationships of the various coal beds. Oakes (1977) published a compilation of field investigations and material from previously published works in Muskogee County.

More recently, private companies have made available to the Oklahoma Geological Survey 167 coal-exploration drilling logs from Wagoner County and 270 logs from Muskogee County. New data have also come from six new strip mines in Wagoner County and 10 new strip mines in Muskogee County, and from detailed field studies by the writer during 1982–83.

Stratigraphy and Structure

In general, the coal-bearing region of northeastern Oklahoma comprises parts of 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 (Wilson and Newell, 1937, p. 74). The shelf is on the northwest flank of the Ozark uplift, and rocks in the study area generally dip WNW at $<1°$, away from the axis of the uplift.

Sedimentary rocks in the area of investigation range in age from Cambrian to Pennsylvanian. Most rocks exposed at the surface in southwestern Wagoner and northwestern Muskogee Counties are Pennsylvanian clastic rocks, including shales, siltstones, and fine-grained sandstones. Coal-bearing Pennsylvanian rocks are cyclic, indicating repeated withdrawals of the sea, erosion, and submergence.

Blatt and others (1980, p. 685) stated that cyclic alternations of marine and nonmarine facies can be explained much more simply by steady regional subsidence combined with delta switching. Delta switching occurs when a delta distributary channel progrades seaward and after a time abandons the route to form a new delta lobe in an adjacent region. Through time the old delta lobe subsides to allow encroachment of the sea. In this manner successive delta lobes overlie one another, forming stacked, overlapping sequences.

Rocks of the Arkoma basin are also mostly clastic, nearly all units thickening toward the southwest, away from the study area. Rocks in the Arkoma basin have been compressed into an E–W syncline between the Ouachita Mountains and the shelf. In general, rocks of the Boggy Formation and older formations in the Arkoma basin and on the shelf are extensively folded and faulted. Fold amplitudes are relatively small in rocks

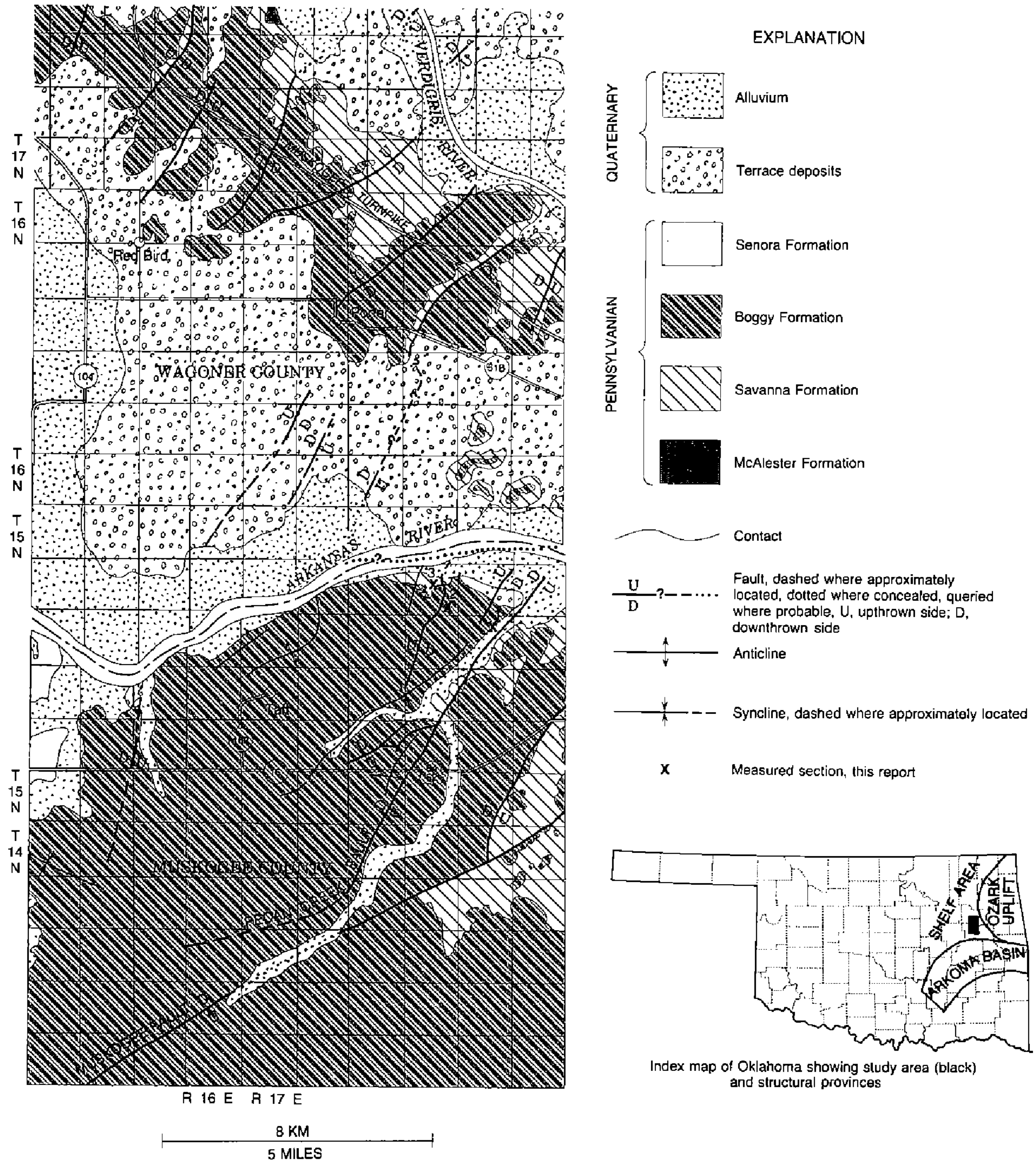


Figure 1. Geologic map of the study area. Modified from Govett (1959) and Oakes (1977).

younger than the Boggy Formation, indicating that major tectonic activity occurred before deposition of the overlying Senora Formation.

The Boggy Formation is exposed in a belt that extends northward across eastern Oklahoma through the study area (Fig. 1). Much of the bedrock in the area north and east of the flood plain of the Arkansas River is concealed by Quaternary(?) alluvial and eolian deposits. In places south and west of Porter, terrace materials are as thick as 21 m (70 ft) (Lontos, 1952, p. 10), so knowledge of the Boggy rocks can be acquired only through subsurface studies. Owing to concealment of bedrock and a paucity of detailed drill logs for shallow depths in this area, correlations of key stratigraphic units across the Arkansas River have been problematical in the past. Major faults in the study area are shown in Figure 1. Of primary concern is the Muskogee fault, which forms the southern boundary of the area of this report. Huffman (1958, p. 92) stated, "The fault is downthrown on the north and maximum stratigraphic displacement is 250 to 300 feet." Oakes (1977, p. 42) wrote, "The throw is probably not more than 40 feet in sec. 9, T. 14 N., R. 17 E." Wilson and Newell (1937, p. 75) stated that the major faults in Muskogee County mark the margins of crustal blocks, each of which is ~9.6 km (~6 mi) wide.

Another major fault extends southwestward through the area and has a throw of ~60 m (~200 ft), down to the northwest; this fault was called the Pecan Creek fault by Wilson and Newell (1937, p. 81). Govett (1959, pl. 1) mapped several NE-trending faults in southwestern Wagoner County. Mapped traces of these faults (Fig. 1) have been modified to some extent during the present study. Several minor faults, synclines, and anticlines are shown in Figure 1; these features are taken from a structure-contour map drawn on the Secor coal (Hemish, in prep.).

Figure 2 is a cross section constructed by the writer, in which newly acquired data are used to clarify the stratigraphic relationships of the rocks on either side of the Arkansas River. Correlations have been established on the basis of similarity of lithologic sequences and the stratigraphic position of individual beds.

In light of these new findings, it is proposed that a new name, Peters Chapel, be informally applied to a coal bed previously mapped and variously referred to verbally and in published and unpublished documents as the "Bluejacket coal," "Upper Secor coal," "Secor rider coal," and "Secor coal."

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 between the Inola Limestone Member and the lower unit of the Taft Sandstone Member. Figure 3 is an oil-well log showing electric-log characteristics of the lower Boggy Formation and associated strata. The log represents a location in Okmulgee County about 20 mi west (downdip) of the study area, where a representative section of the overlying strata can be portrayed. Major coal beds and selected stratigraphically significant members are identified.

The stratigraphy of the lower Boggy Formation in northwestern Muskogee County, according to the present study, is contrasted with generalized stratigraphic columns from previous studies in Figure 4. All investigators agree on the identification, thickness, and stratigraphic position of the Bluejacket Sandstone, which is the lowermost member of the Boggy Formation. However, there is little agreement concerning the number of units, the sequence of units, or the thickness of intervals separating the

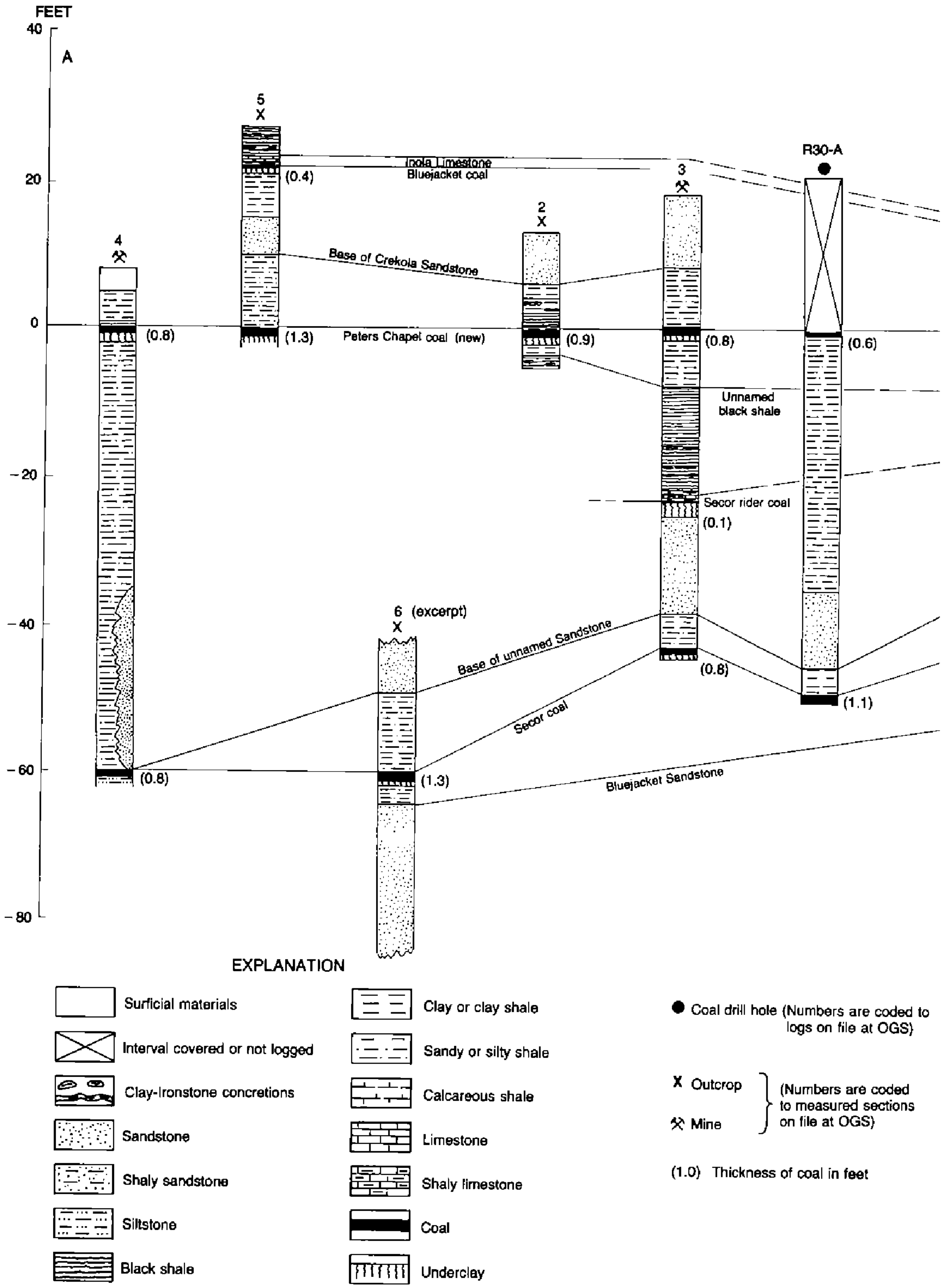
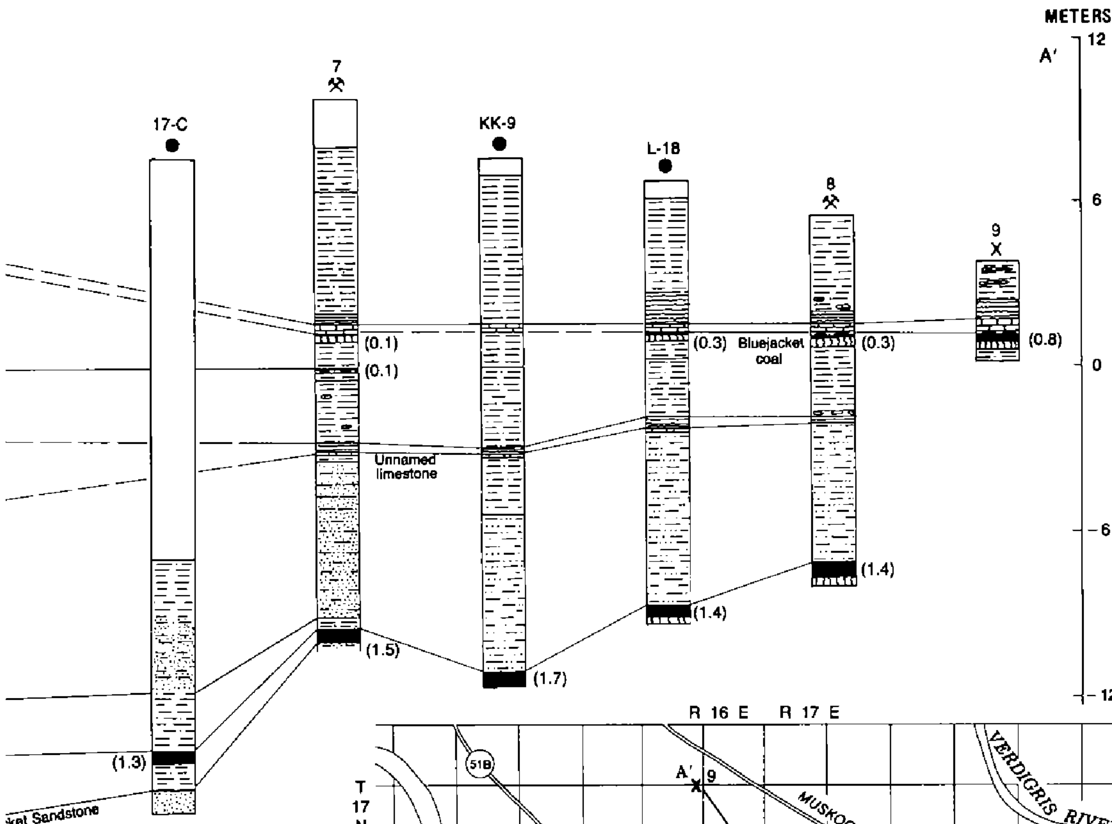


Figure 2. Correlations of key stratigraphic units in the lower part of the Boggy Formation in the study area. No horizontal scale.



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6
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17-C
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KK-9
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8
9
(0.1)
(0.1)
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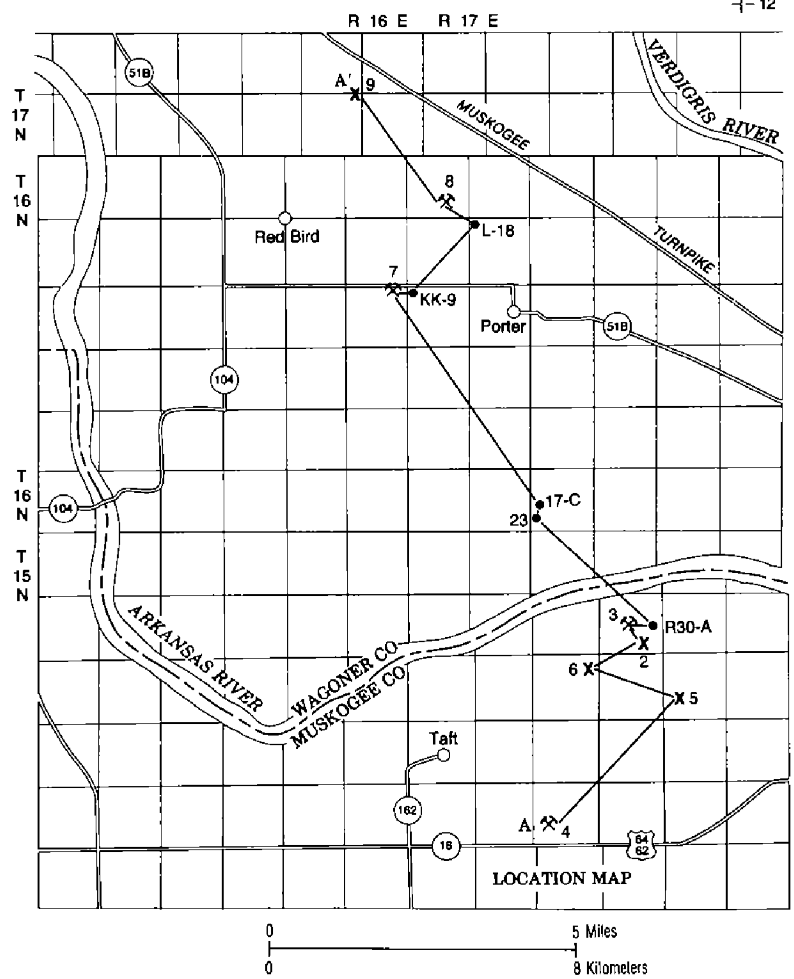
Bluejacket coal
(0.3)
(0.8)
Unnamed limestone
(1.4)
(1.4)
(1.5)
(1.7)
(1.3)
Bluejacket Sandstone



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VERDIGRIS RIVER
MUSKOGEE
TURNPIKE
A′ 9
8
L-18
Red Bird
7
KK-9
Porter
51B
104
17-C
23
ARKANSAS RIVER
WAGONER CO
MUSKOGEE CO
3
R30-A
2
6
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Taft
162
A
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LOCATION MAP
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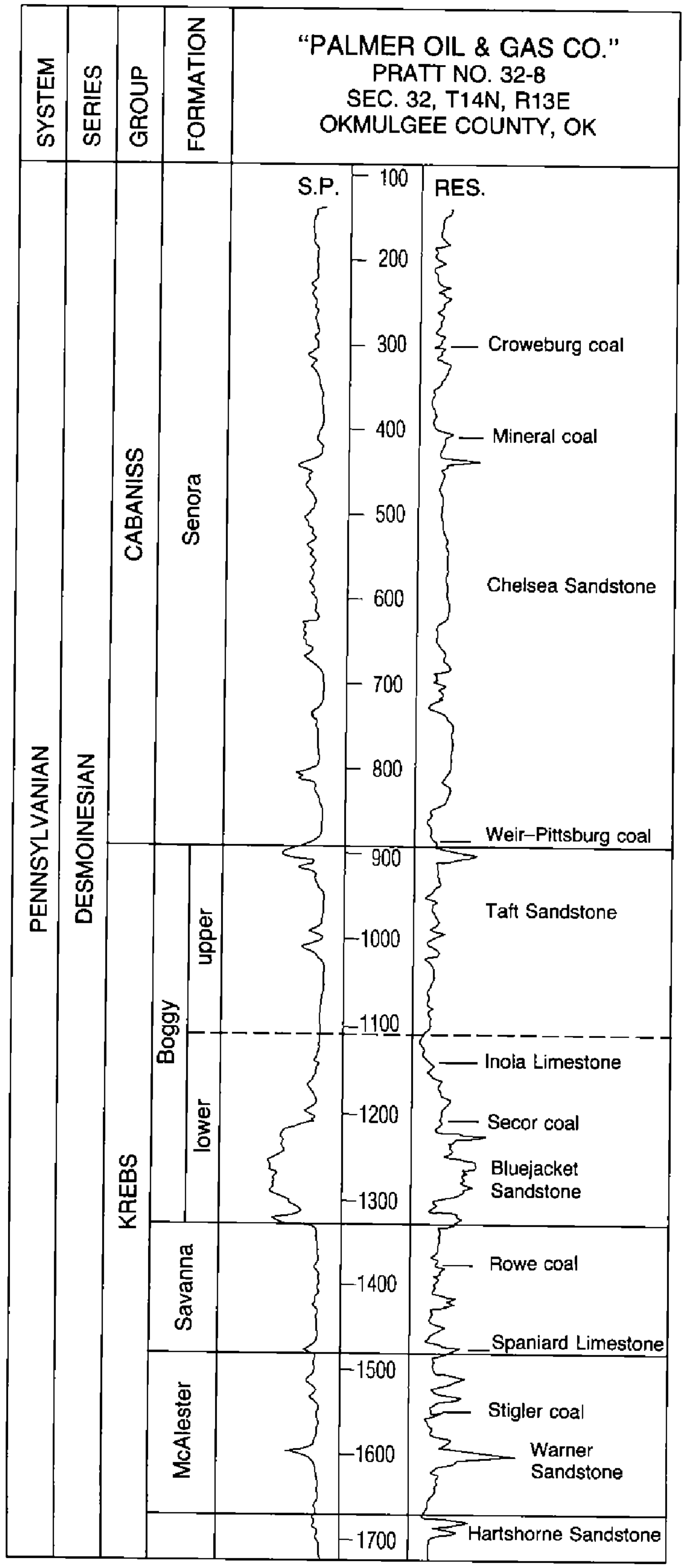

Figure 3. Electric log from a drill hole west of the study area, showing sequence and characteristics of the lower Boggy Formation and associated strata.

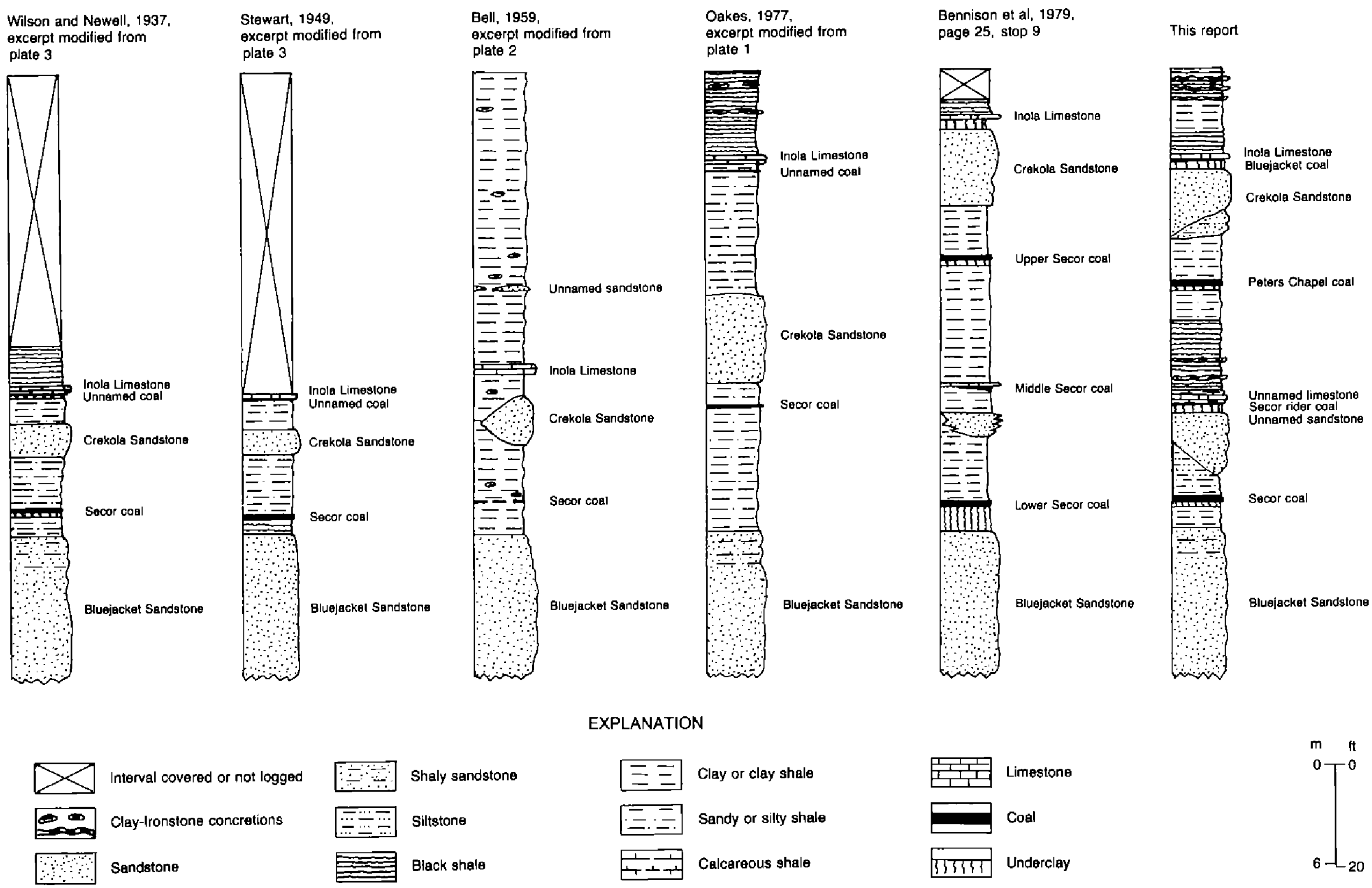

Figure 4. Generalized stratigraphic interpretations of the lower Boggy Formation in T15N, R16–17E, northwestern Muskogee County, according to previous authors, contrasted with the interpretation of the present study.

units in the stratigraphic section from the top of the Bluejacket Sandstone upward to the base of the Taft Sandstone Member.

Wilson and Newell (1937, p. 55) correlated a coal observed near Taft (T15N) and near Porter (T16N) with the Secor coal in the Quinton–Scipio district to the south, where it was mined and named (Oklahoma Geological Survey, 1954, p. 129). According to Wilson and Newell, "Farther north, near Taft, in T. 15 N., the coal appears to rest almost directly on the Bluejacket, and the same situation seems to obtain at Porter in T. 16 N. Wilson classified this coal as the Secor bed." The writer concurs with Wilson and Newell's interpretation.

However, the early investigators underestimated the thickness of the interval between the Bluejacket Sandstone and the Inola Limestone. The errors were probably due to the complex structure in the area (see Oakes, 1977, p. 41–44), to similarity of cyclic sequences, and certainly to misidentification of key beds. The lack of detailed drill logs and the absence of exposures in highwalls of strip mines also must have hindered previous workers to some extent.

Stewart (1949, p. 25) properly identified the Secor coal: "It lies, as nearly as can be determined, about five feet above the Bluejacket." He recognized that other coal beds were present in the area, and commented, "Locally coal occurs between the Bluejacket and Crekola sandstone, but not in the relative stratigraphic position of the Secor coal." Stewart also stated (p. 65), "Several local coals are present at various horizons within the shale above the Bluejacket and below the Inola."

Bell (1959, p. 50–51) identified the Crekola Sandstone Member in T15N, R17E, but mistakenly identified the underlying coal as the Secor. Closely spaced confidential drill logs in the same area show that the Secor coal is stratigraphically ~15 m (~50 ft) lower in the section.

The Crekola Sandstone was named by Wilson (1935, p. 510–511) from the village of Crekola, in sec. 10, T14N, R17E, Muskogee County. In the area where it was named, the Crekola Sandstone is the first sandstone stratigraphically above the Bluejacket Sandstone. The Secor coal occurs in the interval between the Bluejacket Sandstone and the Crekola Sandstone. In secs. 9–11 and 14–18, T15N, R17E, the first sandstone stratigraphically above the Bluejacket Sandstone is not the Crekola Sandstone, but a locally occurring channel-fill deposit. This sandstone occurs between the Secor coal and the Secor rider coal. The log of a core hole drilled by the Oklahoma Geological Survey in the area where the Crekola Sandstone was named shows that this sandstone is not present in that area (Appendix 1). This log and information from six additional coal-company logs of holes drilled in the same vicinity show that the Peters Chapel coal occurs just a few feet below the Crekola Sandstone, and about 30–50 ft above the Secor coal. Knowledge of a second locally occurring sandstone (below the Peters Chapel coal and above the Secor coal) should help to clarify the stratigraphic picture in the study area. Figures 2 and 4 show the stratigraphic position of this unnamed sandstone.

Bell (1959, pl. 2) showed only one coal in the lower part of the Boggy Formation, which he called the Secor. It is unclear whether he observed two coals in the interval between the Bluejacket Sandstone and the Crekola Sandstone (Figs. 2,4) and mapped them as one, but he did state (Bell, 1959, p. 53) that "no coal was found under the Inola in the Muskogee area in this investigation."

Oakes's (1977) interpretation of the stratigraphy in the lower Boggy did not vary greatly from interpretations of previous authors, except for his greater estimate of the thickness of the interval between the top of the Bluejacket Sandstone and the bottom of the Inola Limestone. Measurements made during the present study indicate that he was correct (Fig. 4). However, the outcrop line of the coal bed in sec. 14, T15N, R17E (Oakes, 1977, pl. 1) is not that of the Secor coal, as indicated, but that of the Peters Chapel coal, which is ~14 m (~45 ft) higher in the section.

Bennison and others (1979) presented a composite column of three outcrop sections, showing the Secor coal cycles in sec. 17, T15N, R16E (Fig. 4). The lithologic units in their column agree closely with new data gathered for the present report. Three coals were shown between the top of the Bluejacket Sandstone and the base of the Crekola Sandstone. The three coals were tentatively referred to as the "Lower Secor coal," "Middle Secor coal," and "Upper Secor coal." No coal was shown directly below the Inola Limestone.

It is here proposed that the terminology suggested by Bennison and others (1979, p. 25) be abandoned in order to avoid confusion concerning the Secor coal. It is recommended that the name Secor be retained for the coal occurring a few feet above the Bluejacket Sandstone on the basis of correlations by Wilson and Newell (1937, p. 55). It is further recommended that a formal name *not* be given now to the sandstone that occurs between the Secor coal and the Secor rider coal; too little is known about the areal extent of this unit at present to warrant assignment of a name. This sandstone was not observed north of the Arkansas River in Wagoner County (Fig. 2).

The Peters Chapel coal, about 2–4 m (6–13 ft) below the Crekola Sandstone, often has been confused with the Secor coal in the study area. The writer believes that this bituminous-rank coal should be informally named because (1) it is present on both sides of the Arkansas River (Fig. 2) and to the south in McIntosh County; (2) it is thick enough to have commercial value in Muskogee and McIntosh Counties (reserve and resources statistics as well as stratigraphic correlations are given in Hemish, in prep.); and (3) numerous small strip mines and drift mines have been developed along its outcrop (the coal has been mined extensively under the sandstone bluffs just south of Peters Chapel in the N½ sec. 14, T15N, R17E). The name is derived from Peters Chapel (SW¼SW¼SW¼SE¼ sec. 11, T15N, R17E), Muskogee County, Oklahoma. The measured section nearest to Peters Chapel is at an exposure below a bluff capped by sandstone ~0.4 km (~0.25 mi) southeast of Peters Chapel, in the NW¼SE¼NW¼NE¼ sec. 14, T15N, R17E, Muskogee County, Oklahoma (Fig. 1). The writer's descriptions of this section and two other nearby sections are given in Appendix 2.

In the area of investigation, the Peters Chapel coal is differentiated from the Secor coal on the basis of its stratigraphic position below the Inola Limestone Member. Owing to structural complexity in the region and the similarity of rock sequences overlying the Secor coal and the Peters Chapel coal (Fig. 4), the beds are easily confused in outcrop; however, the two coals can be differentiated on the basis of chemical analysis. In the area of this report, coal analyses consistently show that the Secor coal is a high-quality coal with a low ash content and a sulfur content averaging <1%. By contrast, the Peters Chapel coal has a high ash content (averaging >12%) and a high sulfur content (averaging >5%). Representative analyses of the two coals are shown in Table 1.

The uppermost coal in the lower Boggy Formation occurs just below the Inola Limestone Member. This coal was named the Bluejacket coal in Missouri (Searight and others, 1953, p. 2748) and mapped and identified in Oklahoma counties northeast of the study area. Branson and others (1965, p. 31–32) observed the Bluejacket coal in Craig County, Oklahoma, and stated, "Below the Inola horizon is a sequence of gray to buff shale, a thin, poorly developed coal and underclay, and a gray to buff shale below the underclay. This coal . . . is the Bluejacket coal of the platform classification." The writer has mapped the Bluejacket coal through Craig, Mayes, Rogers, and Wagoner Counties (Hemish, in prep.). The outcrop boundary of the Bluejacket coal has been traced to measured section 9 (Fig. 2).

Black shale containing clay-ironstone layers and concretions overlies the Inola Limestone. A thick unit of gray shales overlies the black shale and separates the lower Boggy Formation from the upper Boggy Formation as defined in this report.

Correlations of key stratigraphic units in the lower Boggy Formation across the Arkansas River show that the interval thins markedly to the north (Fig. 2), where, above the Secor coal, the Crekola Sandstone and Secor rider coal with overlying limestone are absent.

TABLE 1.—REPRESENTATIVE ANALYSES OF THE PETERS CHAPEL AND SECOR COALS FROM SEC. 10, T15N, R17E, MUSKOGEE COUNTY

Analytical parameter	Peters Chapel coal	Secor coal
Proximate analysis (wt. %)		
Moisture	3.12	2.00
Volatile matter	38.95	35.80
Ash	8.20	2.20
Fixed carbon	49.93	60.00
Sulfur, total (wt. %)	5.58	0.50
Heat value (Btu/lb)	13,493	14,590

Note: Analyses on an as-received basis.

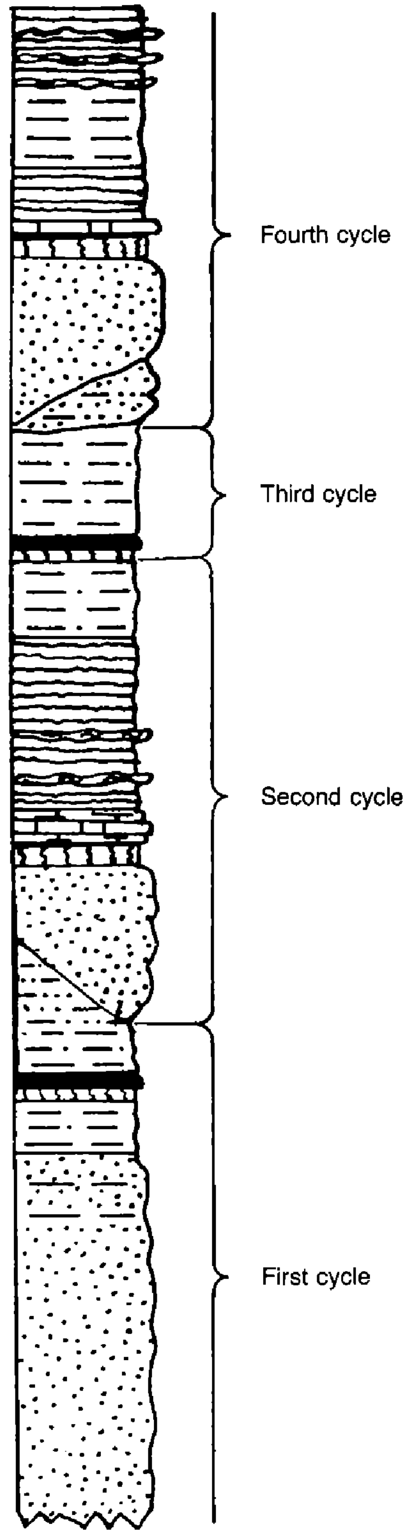

Figure 5. Generalized section of the lower Boggy Formation, showing four cycles of sedimentation.

The northern limit of the Peters Chapel coal is in the vicinity of State Highway 51B (Fig. 2), where it has thinned to 0.03 m (0.1 ft). The Bluejacket coal and overlying Inola Limestone Member are persistent beds. However, it should be noted that the interval between the Bluejacket Sandstone Member and the Inola Limestone Member decreases to only a few feet near the north end of the traverse shown in Figure 2. Govett (1959, appendix A, p. 167) measured only 1.1 m (3.5 ft) of black shale in this same interval 10 km (6 mi) north of measured section 9 (Fig. 2). The Secor coal has not been identified north of T16N; probably it was never deposited there, or it may have been uplifted and removed by erosion.

Sedimentological Interpretations

It has been shown that four coal beds are present in an area where before only two or three coals were thought to be present. Four distinct cycles of sedimentation can be recognized in the study area, but not in adjacent areas. Figure 5 is an interpretation of the writer's generalized section for the study area (Fig. 4), showing the four cycles. Figure 6 (modified from Blatt and others, 1980, p. 620) shows an idealized cycle of sedimentation, and a facies diagram of the environment of deposition.

The writer believes that the lower Boggy Formation is relatively thick in northwestern Muskogee County because deposition occurred in a graben, contemporaneous with faulting and subsidence. The Muskogee fault and the Pecan Creek fault form the southern and southeastern boundaries of the graben. Convergence and wedging out of stratigraphic units between

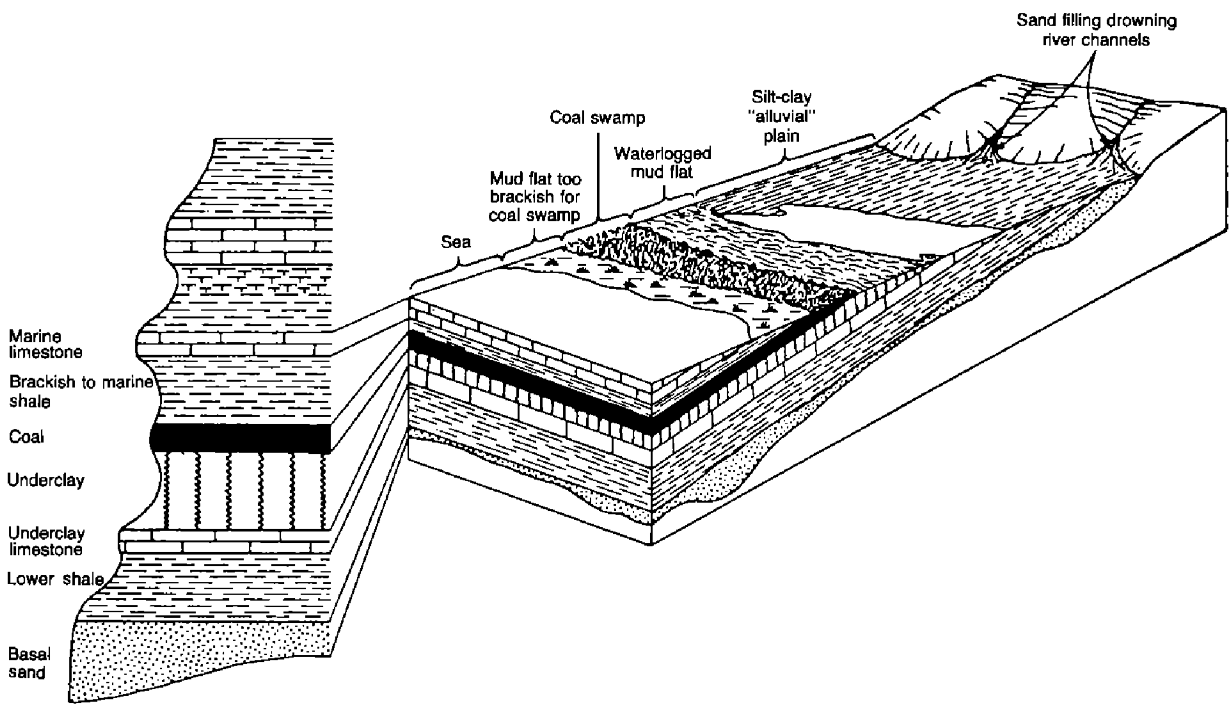

Figure 6. An idealized cycle of sedimentation and an interpretive facies diagram showing depositional environments. Modified from Blatt and others (1980 [after Weller, 1960; from Shaw, 1964]).

the Bluejacket Sandstone Member and the Inola Limestone Member to the north in Wagoner County indicate that the subsiding block was tilted toward the south. Shelton (1968, p. 399–413) discussed the role of contemporaneous faulting during basin subsidence; he stated (p. 399) that "certain relatively small depositional basins are tilted fault-block areas and . . . movement along the bounding, high-angle faults was contemporaneous with deposition." He also noted (p. 399) that "most basins, both large and small, are bounded on at least one side by faults."

Investigations in progress in central Muskogee County indicate that the interval between the Bluejacket Sandstone and Inola Limestone is considerably thinner than in the northwestern part of the county, and that the Secor and Secor rider coals may be absent locally. However, stratigraphic cross sections prepared by Hemish (in prep.) show that correlations can be made between each of the four coals discussed in this report and coals that occur in the Rattlesnake Mountain syncline in east-central McIntosh County to the south.

The presence of additional cyclic units suggests that the Pennsylvanian sea had invaded the subsiding basin north of the Muskogee fault twice while the upthrown area to the south was standing above sea level. The persistence of the Inola Limestone Member indicates that widespread stability prevailed during its deposition.

Wilson and Newell (1937, p. 75) stated that major faults mark the margins of six crustal blocks in Muskogee County. Further investigations are needed south of the present study area to determine whether evidence exists for additional sedimentary cycles associated with the downthrown blocks. If such evidence is found, the writer's suggestions that cyclic deposition was contemporaneous with faulting and subsidence in northeastern Oklahoma will be supported.

Summary and Conclusions

The writer has presented evidence showing the need for additions to and clarification of terminology used in describing the lower Boggy Formation of northwestern Muskogee and southwestern Wagoner Counties, Oklahoma. This clarification provides a firmer basis for further stratigraphic studies in and near the study area, and also provides a framework for other kinds of geologic investigations, such as exploration for coal or other economic resources.

The major results of this study and conclusions in this paper are these:

1) Four coal beds are present in northwestern Muskogee County in the lower Boggy Formation;

2) The lowermost coal bed in this interval can be correlated with the Secor coal;

3) The coal bed ~5.8 m (~19 ft) above the Secor coal can be correlated with the Secor rider coal;

4) The uppermost coal bed in this interval can be correlated with the Bluejacket coal;

5) In order to avoid confusion, the coal bed ~6.1 m (~20 ft) below the Inola Limestone and below the Crekola Sandstone is given a new informal name, the Peters Chapel coal;

6) Where structural complexities hinder identification of coal beds in the study area, the high-sulfur, high-ash Peters Chapel coal can be distinguished from the low-sulfur, low-ash Secor coal by means of chemical analyses;

7) Correlations across the Arkansas River show that most rock units between the Bluejacket Sandstone and Inola Limestone thin or wedge out to the north;

8) Four cycles of sedimentation can be recognized in the lower Boggy Formation in the study area;

9) Deposition of the lower Boggy Formation in the study area probably occurred in a graben, contemporaneous with faulting and subsidence; the downthrown block is bounded on the south and southeast by the Muskogee fault and the Pecan Creek fault; convergence of beds to the north indicates that the block was tilted toward the south during deposition;

10) Further work is needed south of the Muskogee fault to clarify the stratigraphic relationships of units in the lower Boggy Formation in adjacent areas.

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Appendix 1

Log of a Core Hole (C MM 54) Drilled in the Type Area of the Crekola Sandstone

NE¼NW¼SW¼NE¼NE¼ sec. 15, T14N, R17E, 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	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 plannt 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

Appendix 2

Sections Measured in the Area Where the Peters Chapel Coal was Named

1. Section measured at outcrop 0.4 km (0.25 mi) SE of Peters Chapel

NW¼SE¼NW¼NE¼ sec. 14, T15N, R17E, Muskogee County, Oklahoma. Measured at edge of an old, small, abandoned coal mine and shale pit, by LeRoy A. Hemish. Top of measured section is at top of bluff, elevation ~199 m (~652 ft).

	Thickness (m)	(ft)
Krebs Group		
Boggy Formation		
Sandstone, orange-brown, very fine-grained, ferruginous, thick-bedded, noncalcareous, ripple-marked at base; forms resistant ledge jutting out 1.2 m (~4 ft) beyond underlying unit (Crekola Sandstone)	0.58	(1.9)
Siltstone, yellow-brown and yellow-gray, shaly, laminated to thin-bedded, noncalcareous	1.86	(6.1)
Shale, dark-gray, with orange-brown streaks, silty; includes carbonized plant fragments on stratification surfaces	1.98	(6.5)
Shale, black, highly carbonaceous	0.06	(0.2)
Coal, black, with reddish-brown iron-oxide staining on cleat surfaces, bituminous (Peters Chapel coal)	0.27	(0.9)
Underclay, light-gray, with orange streaks and mottling; includes thin coal streaks and carbonized plant compressions	0.30	(1.0)
Total	5.05	(16.6)

Base of measured section is at contact with alluvium in valley.

2. Section measured at outcrop ~1.6 km (~1 mi) NW of Peters Chapel

NE¼NE¼SW¼SE¼ sec. 10, T15N, R17E, Muskogee County, Oklahoma. Measured in ravine adjacent to old, small, abandoned mine, by LeRoy A. Hemish. Top of measured section is at top of hill, elevation ~181 m (~595 ft).

	Thickness (m)	(ft)
Krebs Group		
Boggy Formation		
Sandstone, yellow-brown (weathers reddish-brown), fine-grained, thick- to medium-bedded, thin-bedded and cross-laminated in lower 0.3 m (1 ft), noncalcareous; basal contact sharp; forms resistant ledge at head of ravine; top covered by sandy soil (Crekola Sandstone)	2.13	(7.0)
Shale, light-gray, with orange streaks	0.61	(2.0)
Shale, very dark-gray, flaky; contains some stringers of orange clay-ironstone	0.61	(2.0)
Shale, black, with purplish-brown stains on stratification surfaces, fissile	0.58	(1.9)
Shale, light-gray, with orange streaks, clayey	0.09	(0.3)
Shale, black, soft, coaly	0.03	(0.1)

Coal, black, with reddish-brown staining on cleat surfaces, bituminous (Peters Chapel coal)	0.27	(0.9)
Underclay, light-gray and orange; contains carbonized plant fragments	0.33	(1.1)
Shale, bluish-gray, with orange and purple mottling, silty; weathers to roughly rounded, flattened nodules about 2.5–5.0 cm (~1–2 in.) in diameter in some places	0.46	(1.5)
Shale, very dark-gray to black, fissile; contains discoidal, highly oxidized, orange-red, ferruginous concretions ~15 cm (~6 in.) in diameter and about 2.5–5.0 cm (~1–2 in.) in thickness (base covered)	0.52	(1.7)
Total	5.63	(18.5)

Base of section is at base of cutbank of intermittent stream where alluvium covers bedrock.

3. Section measured in highwall of strip mine ~2 km (~1.25 mi) NW of Peters Chapel

SE¼SW¼SW¼NE¼ sec. 10, T15N, R17E, Muskogee County, Oklahoma. Measured in highwall of active strip pit operated by Turner Brothers, Inc. by LeRoy A. Hemish. Top of measured section is at top of highwall, elevation ~189 m (~621 ft).

	Thickness (m)	(ft)
Krebs Group		
Boggy Formation		
Sandstone, dark reddish-brown to buff, ferruginous, micaceous, very fine-grained to fine-grained, noncalcareous; massive to thin-bedded in lower part and stained by purplish-black mineral deposits (Crekola Sandstone)	3.05	(10.0)
Shale, dark-gray, weathers orange-brown, silty	2.44	(8.0)
Shale, black, highly carbonaceous	0.06	(0.2)
Coal, black, with reddish-brown iron-oxide staining on cleat surfaces, banded (Peters Chapel coal)	0.24	(0.8)
Underclay, light-gray, with orange staining; includes carbonized plant fragments	0.27	(0.9)
Shale, very dark-gray, pyritic in part; includes gray, noncalcareous, sideritic nodules <2.5 cm (<1 in.) in diameter	1.89	(6.2)
Shale, black, stained reddish-brown on joint surfaces, blocky	2.44	(8.0)
Clay-ironstone, black, with banded maroon and reddish-brown rind ~2 cm (~0.75 in.) thick; dense, hard, sparsely fossiliferous; drusy calcite on fracture surfaces	0.09	(0.2)
Shale, black, with reddish-brown banding, fissile, jointed, gypsiferous	0.79	(2.6)
Clay-ironstone, black, with brownish-black rind ~3.2 cm (~1.25 in.) thick; dense, hard, sparsely fossiliferous	0.09	(0.3)
Shale, black, with reddish-brown banding, fissile, jointed, gypsiferous	0.24	(0.8)
Clay-ironstone, purple-brown to hematite-red, highly fractured; selenite crystals on fracture surfaces	0.03	(0.1)

Shale, black, with bright-yellow banding (probably jarosite); carbonaceous, gypsiferous	0.61	(2.0)
Shale, very dark-gray, highly calcareous, unbedded; includes abundant well-preserved marine fossils; selenite crystals fill fracture cavities; at top of unit a 1.3-cm (0.5 in.) colorless and white layer of selenite crystals and powdery gypsum fills or partially fills a continuous, horizontal solution cavity	0.15	(0.5)
Limestone, very dark-gray to dark-purplish-black, impure, muddy, hard; contains abundant marine fossils, mostly brachiopods (unnamed limestone)	0.15	(0.5)
Shale, very dark-gray, highly calcareous, unbedded, gypsiferous; includes abundant marine fossils	0.15	(0.5)
Coal, black, with reddish-brown iron-oxide staining on cleat surfaces (Secor rider coal)	0.03	(0.1)
Underclay, very dark-gray, with orange iron-oxide staining in upper 7.6 cm (3 in.); medium-gray with carbonized plant fragments in lower part; highly carbonaceous	0.61	(2.0)
Sandstone, light-gray with brown streaks along joints and fractures, very fine-grained, massive to thin-bedded, noncalcareous; includes some small-scale cross-bedding (unnamed sandstone)	3.96	(13.0)
Shale, medium gray, silty, hard; contains well-preserved carbonized plant compressions with abundant ferns	1.37	(4.5)
Coal, black, banded; "peacock coal" in part; moderately friable; includes scattered pyrite veinlets and crusts on cleat surfaces (Secor coal)	0.24	(0.8)
Underclay, dark gray, silty; contains very thin coaly streaks and carbonized plant material; pyritic in part (total thickness undetermined)	0.24	(0.8)
Total	19.14	(62.8)

Base of section is at bottom of strip mine.

OGS ISSUES HYDROLOGIC REPORT

A new publication on the *Geohydrology of the Vamoosa–Ada Aquifer, East-Central Oklahoma* was released by the Oklahoma Geological Survey as Circular 87. The 42-page volume is authored by Joseph J. D'Lugosz and Roger G. McClaflin, both of the Water Resources Division of the U.S. Geological Survey in Oklahoma City. Circular 87 describes the geology and water-bearing character of Pennsylvanian-age rocks that extend in the subsurface of east-central Oklahoma from the state's northern border to the Canadian River. A section by Melvin V. Marcher, former chief of the Hydrologic Studies Section of the Water Resources Division, now retired, discusses and presents detailed data on the chemical quality of the water contained in the aquifer, in streams draining the aquifer, and in municipal water supplies in the area.

Records on several hundred wells in Creek, Lincoln, Okfuskee, Osage, Payne, Pottawatomie, Pawnee, and Seminole Counties are shown in tabular form in the report, as are aquifer tests, water usage, and chemical analyses. Three large plates that come folded in an envelope accompanying the book show the geology of the area, sandstone thicknesses, transmissivity, well capacities, and geohydrology.

OGS Circular 87 is available from the OGS at the address given inside the front cover of this issue. The price is $12 for paperbound copies, $16 for hardbound.

NEW THESES IN OU GEOLOGY LIBRARY

The following M.S. theses have been added to the University of Oklahoma Geology and Geophysics Library:

The Lithostratigraphy, Biostratigraphy and Depositional History of the Atokan Series (Middle Pennsylvanian) in the Ardmore Basin, Oklahoma, by William Walter Clopine. 161 p., 15 figs., 3 pls., 1 table, 3 appendixes, 1986.

The Relationship Between Hydrocarbon Migration and Aughigenic Magnetite: Testing the Hypothesis, by Karen Anne Cochran. 90 p., 22 figs., 4 tables, 1986.

Tide and Storm Dominated Bars on a Distal Muddy Shelf: The Pennsylvanian Cottage Sandstone, Northwestern Oklahoma, by David J. Fruit. 83 p., 24 figs., 6 appendixes, 1986.

Subsurface Geology of the Frederick Area, Tillman County, Oklahoma, by Stanley Paul Geurin. 64 p., 17 figs., 9 pls., 1986.

Petrology and Mineral Chemical Studies of the Lawler Peak Granite and Associated Tungsten Mineralization, Yavapai County, Arizona, by Kathleen Stack Goodman. 99 p., 25 figs., 12 tables, 4 appendixes, 1986.

A Study of Small-Scale Deformation Features Associated with the Embudo Fault Zone, North-Central New Mexico, by Daniel Marc Jan Hillman. 79 p., 34 figs., 1986.

The Petroleum Geochemistry of the Pauls Valley Area, Anadarko Basin, Oklahoma, by Peter John Jones. 175 p., 28 figs., 5 tables, 4 appendixes, 1986.

Depositional History of the Upper Morrowan (Pennsylvanian) Strata of the Ardmore Basin, Oklahoma, by Michael Paul Maley. 206 p., 22 figs, 5 pls., 2 appendixes, 1986.

The Nonesuch Formation: Precambrian Sedimentation in an Intracratonic Rift, by Gary John Milavec. 142 p., 16 figs., 1 table, appendix, 1986.

Subsurface Facies Model for a Transgressive Shallow-Water, Transitional Clastic-Carbonate Environment: Martha Brae Delta-Reef Complex, Falmouth, Jamaica, by Stephen M. Roberts. 80 p., 37 figs., 1 table, 3 appendixes, 1986.

The Distribution of Trace Elements in Crude Oils Using Proton Induced X-Ray Emission Analysis and Wavelength-Dispersive X-Ray Fluorescence, by Alice Veronica Ruffel. 132 p., 33 figs., 12 tables, 3 appendixes, 1986.

OGS RELEASES OIL-CORRELATION REPORT

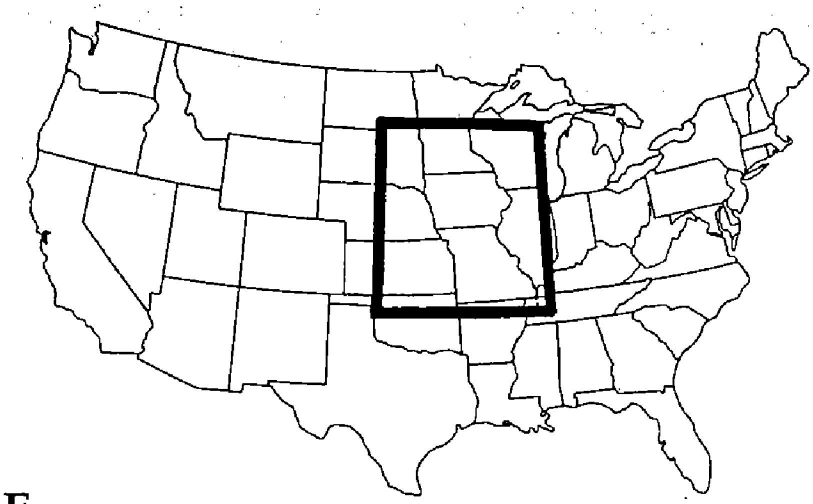
A new publication released by the Oklahoma Geological Survey reviews and analyzes the current state of knowledge of the influence on an oil of its source material, the maturity level of the oil, the extent of degradation, and its possible migration history.

The 51-page volume *Oil-Oil and Oil-Rock Correlations: A Chemist's Perspective,* has been issued as OGS Special Publication 86-1. Author Jane L. Weber, organic chemist with the Survey, states that "Techniques for making oil-oil or oil-rock correlations have evolved considerably since the days when crude oils were classified according to their physical properties and an oil was related to a source rock on the basis of geologic considerations alone."

Although it is most commonly acknowledged that petroleum is generated through the thermal breakdown of finely disseminated organic matter in source beds, other theories have been proposed, including a hot, deep origin; a cool, shallow origin following anaerobic transformations; and even outgassing of primordial hydrocarbons.

Weber explains that based on the conventional theory of petroleum generation each oil presents a separate problem in relating it to another oil and to its source rock and must be examined with this in mind, using every form of chemical analysis available, even down to the molecular level. She describes various geochemical parameters that can be used in such correlations and provides detailed information on techniques now in use for such studies. She gives specific examples of the use of these analyses on oils from many localities in the world and provides numerous references to studies of other workers in this field.

Oklahoma Geological Survey Special Publication 86-1 can be obtained from the address given inside the front cover of this issue. The price is $3.



DRILL-HOLE MAP AVAILABLE

The U.S. Geological Survey, in cooperation with the Oklahoma Geological Survey and other state survey organizations, recently published *Miscellaneous Field Studies Map* MF-1835A, showing availability of data for selected deep drill holes in the northern Midcontinent of the United States. The scale of the map is 1:1,000,000, or 1 in. = ~16 mi. The map encompasses the region bounded by 36° and 46° north latitude, and by 88° and 100° west longitude, so that it includes all of the states of Missouri and Iowa, most of Illinois, and substantial parts of Wisconsin, Minnesota, South Dakota, Nebraska, Kansas, and Oklahoma. It also includes small parts of Arkansas, Tennessee, and Kentucky (see index map). The map covers approximately the northern one-third of Oklahoma east of the panhandle.

More than 3,000 deep drill holes are plotted on the map. For each, the following information is provided: (a) bottom-hole elevation relative to mean sea level, (b) geologic age of deepest rocks penetrated, and (c) whether cuttings and/or core are available for part of the section penetrated by the well.

The small-scale map shows counties, but not township and range. However, the wells can be located approximately by estimation if one has another base map with township and range. The map is especially useful for locating well cuttings and cores of deep wells for subsurface study. For Oklahoma, the map can be used in conjunction with OGS Special Publication 84-2, *Core-Collection Catalog*, 1984. The catalog describes each well by location (township, range, and section), as well as operator and lease names, and indicates the gross cored interval and formation name for which core is available.

The map is available from the U.S. Geological Survey, Branch of Distribution, Box 25286, Federal Center, Denver, CO 80225; (303) 236-7477. The price is $1.50 plus $1 for postage and handling for orders under $10.

The *Core-Collection Catalog* is available from OGS. The cost is $4, postage paid within the U.S., from the address given inside the front cover of this issue.

EARTHQUAKE ACTIVITY DOWN DURING FIRST HALF OF 1986

The world's earthquake activity was down during the first half of 1986 after rising sharply in 1985, according to the U.S. Geological Survey.

Through June 30, 1986, 21 significant earthquakes were recorded, a number less than one-third of the 67 that occurred during all of 1985, said Waverly Person, chief of the USGS National Earthquake Information Service in Golden, Colorado.

Person said 47 significant earthquakes occurred during all of 1984, the lowest total since 1977. He defined a significant earthquake as one that registers at least 6.5 magnitude, or a tremor with a smaller magnitude that causes casualties or considerable damage.

Three of the 21 significant 1986 earthquakes occurred in the the United States, including a major shock with a magnitude of 7.7 in the Aleutian Islands May 7—the strongest earthquake in the world so far this year. The Aleutian earthquake caused damage on Adak and Atka islands and generated a small tsunami (seismic sea wave) that swept across the Pacific Ocean.

The other two significant U.S. earthquakes in 1986 were a magnitude-6.5 aftershock May 17 in the same area of the Aleutian Islands as the May 7 earthquake, and a magnitude-5.0 tremor January 31 in Ohio, northeast of Cleveland. The Ohio tremor injured 17 people and caused some damage in the Painesville–Mentor area and nearby regions of Ohio and Pennsylvania, and was felt in parts of 11 other states.

Only two of the 67 significant earthquakes in 1985 were in the United States.

There were fewer fatalities in the first half of 1986. Person said that through June, 41 persons had been reported killed in earthquakes in 1986, compared with 9,844 in all of the previous year, most of them in a great 8.1 magnitude earthquake in Mexico. The earthquake death toll of 77 in 1984 was the lowest since at least the 1940s. An average of about 10,000 people die annually in earthquakes.

The most deadly 1986 earthquake through June was a magnitude-5.2 tremor April 5 in Peru that killed at least 16 people, injured 170 others, and destroyed about 2,000 houses in the Cuzco area. The second most deadly earthquake was a magnitude-5.9 tremor May 5 in Turkey that killed at least 15 people, injured about 100 others, and damaged 4,000 houses.

UPCOMING MEETINGS

GSA, Northeastern Section, Annual Meeting, March 4–7, 1987, Pittsburgh, Pennsylvania. Information: GSA, Meetings Department, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020.

GSA, Southeastern Section, Annual Meeting, March 26–27, 1987, Norfolk, Virginia. Information: GSA, Meetings Department, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020.

GSA, South-Central Section, Annual Meeting, March 30–31, 1987, Waco, Texas. Information: GSA, Meetings Department, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020.

GSA, North-Central Section, Annual Meeting, April 30–May 1, 1987, St. Paul, Minnesota. Information: GSA, Meetings Department, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020.

GSA, Rocky Mountain Section, Annual Meeting, May 2–3, 1987, Boulder, Colorado. Information: GSA, Meetings Department, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020.

AAPG Research Conference, "Analysis of Naturally Fractured Reservoirs," May 4–8, 1987, Snowbird, Utah. Information: Jane Rider, AAPG, Education Department, P.O. Box 979, Tulsa, OK 74101; (918) 584-2555.

Mid-America Oil and Gas Show, May 19–21, 1987, Great Bend, Kansas. Information: Marilyn Norton, MAOGS Coordinator, P.O. Box 400, Great Bend, KS 67530; (316) 792-2401.

GSA, Cordilleran Section, Annual Meeting, May 20–22, 1987, Hilo, Hawaii. Information: GSA, Meetings Department, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020.

AAPG Annual Meeting (with Divisions: SEPM, EMD, and DPA), June 7–10, 1987, Los Angeles, California. Information: Eugene F. Reid, Sunburst Exploration, Inc., 1224 Coast Village Circle, Suite 24, Santa Barbara, CA 93108.

AAPG Research Conference, "Prediction of Reservoir Quality Through Chemical Modeling," June 21–26, 1987, Park City, Utah. Information: Jane Rider, AAPG, Education Department, P.O. Box 979, Tulsa, OK 74101; (918) 584-2555.

SEPM, Fourth Annual Midyear Meeting, August 20–23, 1987, Austin, Texas. Information: Robert A. Morton, Bureau of Economic Geology, University of Texas at Austin, University Station, Box X, Austin, TX 78712; (512) 471-1534.

AAPG, Rocky Mountain Section, Annual Meeting, September 13–16, 1987, Boise, Idaho. Information: Iva Brimmer, AAPG, Convention Department, P.O. Box 979, Tulsa, OK 74101; (918) 584-2555.

AAPG, Mid-Continent Section, Annual Meeting, September 27–29, 1987, Tulsa, Oklahoma. Information: George Bole, Amoco Production Co., P.O. Box 591, Tulsa, OK 74102; (918) 581-3161.

AAPG Research Conference, "Secular Variations in the Geochemistry of the Rock Record," October 5–9, 1987, Fort Burgwin, New Mexico. Information: Jane Rider, AAPG, Education Department, P.O. Box 979, Tulsa, OK 74101; (918) 584-2555.

AAPG, Eastern Section, Annual Meeting, October 7–10, 1987, Columbus, Ohio. Information: William Rike, P.O. Box 763, Worthington, OH 43085; (614) 888-6745.

Geological Society of America, Annual Meeting, October 26–29, 1987, Phoenix, Arizona. Information: GSA, Meetings Department, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020.

AAPG, Gulf Coast Section, Annual Meeting, October 28–31, 1987, San Antonio, Texas. Information: Don F. Tobin, 1530 Milam Building, San Antonio, TX 78205; (512) 227-9740.

FIRST DNAG VOLUME EXAMINES GEOLOGISTS AND IDEAS

Volume I of the Geological Society of America's suite of publications for the Decade of North American Geology (DNAG) project is titled *Geologists and Ideas: A History of North American Geology.* This book is one of four special-topic volumes being issued along with the DNAG series (see *Oklahoma Geology Notes*, vol. 46, no. 3, p. 108).

The 525-page collection of 33 scholarly papers is divided into sections on "The Evolution of Significant Ideas," "Contributions of Individuals," "Contributions of Organized Groups," and "Application of Significant Ideas." The papers were written by both geologists and historians of the earth sciences. Their work takes readers from an early-day field trip, as seen through the eyes of a college student helping with the pack mules, to the emerging world of geology from space, as seen through the "eyes" of modern satellites.

The book examines the people as well as the ideas that have played key roles in the development of North American geology. It traces James Hall's discovery of the craton and discusses the anticlinal theory of oil and gas accumulation, as well as that theory's part in the inception of the oil and gas industries.

An abundance of quality photographs, maps, and illustrations is included along with the text. The case-bound, 8 ½" × 11" book is bound in and printed on pH-neutral material designed to last several hundred years without significant deterioration under normal library use and storage conditions.

Centennial Special Volume I is available from The Geological Society of America, Publication Sales, P.O. Box 9140, Boulder CO 80301 (call toll free 1-800-GSA-1988). GSA members can get information about a discount by calling the toll-free number.

The Decade of North American Geology DNAG

OKLAHOMAN SERVES ON COMMITTEE TO ASSESS NATION'S RESOURCES

Oklahoman T. S. Ary of the Kerr McGee Corporation in Oklahoma City is serving on The National Strategic Materials and Minerals Program Advisory Committee that recently released an assessment of the nation's resources posture. NSMMPAC expresses in the report concerns about U.S. capabilities to reduce the current high degree of import dependence on materials and minerals vital to maintaining a strong national security and to preserving the nation's industrial base. The report was prepared by the group for Interior Secretary Don Hodel.

"The committee has worked vigorously to examine a broad range of policy issues concerning U.S. import vulnerabilities, domestic minerals production and stockpile matters," retired Admiral William C. Mott, committee chairman, said. "We have attempted to identify specific national minerals and materials needs and we have addressed specific problem areas. As a result, 11 recommendations were made and accepted by former Secretary William Clark; those recommendations and four additional ones have been endorsed by Secretary Hodel."

The chairman indicated that the committee was encouraged with progress by the Reagan Administration toward vitalizing a national resources policy and hoped that this assessment would focus attention on problem areas. Findings of the committee include:

- The most immediate resources problem concerns how and under what estimates the stockpile is to be maintained.
- Minerals education must become a basic part of our educational system if the U.S. is to reestablish a shared value about resources development.
- Public-lands issues concerning domestic minerals recovery are in a legislative-regulation-litigation gridlock.
- A stable legal framework must be structured to encourage meaningful strategic minerals exploration in the Exclusive Economic Zone, proclaimed in 1983 by President Reagan to establish U.S. sovereign rights extending 200 miles offshore from U.S. states and territories.
- Industrial-base erosion is a serious and growing national problem that has already limited our capability to assure adequate raw materials processing in times of emergency.

Secretary Hodel recently extended the charter of the NSMMPAC for an 18-month period, and has asked Admiral Mott to continue in the role of chairman for that time. Ary also was named to the extended term.

"We must be sensitive to those policies and programs which could have adverse consequences to the critical and strategic capability of the Nation, which impact the health of our domestic minerals industry and which limit our ability to stay abreast of advances in technology," Hodel said. "When one solution is not workable, we must continue to seek alternative remedies that have a chance of succeeding."

AIRBORNE-RADAR IMAGERY AVAILABLE FOR OKLAHOMA

The U.S. Geological Survey, EROS Data Center, has announced that side-looking airborne radar (SLAR) imagery is now completed and available for about two-thirds of Oklahoma. The following two-degree quadrangles (analogous to the USGS 1:250,000 map series) which encompass parts of Oklahoma and adjacent areas are now available: Amarillo (Texas), Perryton (Oklahoma and Texas), Lawton (Oklahoma and Texas), Clinton (Oklahoma), Oklahoma City (Oklahoma), Ardmore (Oklahoma), Fort Smith (Oklahoma and Arkansas), and McAlester (Oklahoma and Arkansas).

Six quadrangles covering parts of Oklahoma remain to be acquired. These are: Woodward and Enid (Oklahoma), Dalhart (Texas, New Mexico, and Oklahoma), Tulsa (Oklahoma, Arkansas, and Missouri), Sherman (Texas and Oklahoma), and Texarkana (Texas, Arkansas, and Oklahoma). None of these are planned for acquisition in the near future by the USGS.

Radar imagery is produced from high-frequency energy which is reflected from the Earth's surface at an oblique angle. This form of imagery is especially useful in the study of subtle geologic structure, or any geologic problem to which structure may contribute significantly, such as petroleum exploration.

Radar imagery is available as mosaics at two scales, or in strips of individual images that have not been compiled into a mosaic. Scales and prices are provided below. For additional information, and to order radar imagery, contact: U.S. Geological Survey, EROS Data Center, User Services Section, Sioux Falls, SD 57198; (605) 659-6151.

Mosaics are available at 1:250,000 scale and 1:100,000 scale and are priced, respectively, at $85 and $60 for a paper print; $100 and $85 for a film positive; and also $100 and $85 for a film negative. Strips are available at $30 for a paper print, $35 for a film positive or a film negative.

NOTES ON NEW PUBLICATIONS

Effects of Climate, Vegetation, and Soils on Consumptive Water Use and Ground-Water Recharge to the Central Midwest Regional Aquifer System, Mid-Continent United States

Written by J. T. Dugan and J. M. Peckenpaugh, this USGS water resources investigations report contains 78 pages.

Order WRI 85-4236 from: U.S. Geological Survey, Books and Open-File Reports, Federal Center, Bldg. 41, Box 25425, Denver, CO 80225. The price is $4 for microfiche and $13 for a paper copy; add 25% to the price for shipment outside North America.

HOUSTON HOSTS INTERNATIONAL EVENTS

Houston will be the site of two major oil-industry events in April 1987 when the Offshore Technology Conference and the World Petroleum Congress are staged there concurrently.

More than 30,000 oil industry and government leaders are expected for the two events. The 19th Annual Offshore Technology Conference (OTC) will be held Monday through Thursday, April 27–30. OTC combines a major technical program and exhibition at Houston's massive Astrodomain complex. The 12th World Petroleum Congress (WPC) will be staged at the downtown Houston Civic Center from Sunday, April 26, through Friday, May 1.

WPC and OTC had been scheduled originally for a two-week period in late April and early May. The change to concurrent dates in late April was made to benefit the thousands of engineers, scientists, managers, and government officials expected to converge on Houston for the conferences.

The World Petroleum Congress is held every four years. While Houston has hosted OTC annually since 1969, only one other United States site (New York City in 1959) has served as host for WPC since its beginning in 1933. Nine leaders of industry and government from around the world will be keynote speakers in plenary sessions held during the six-day event, and 110 papers will be presented in concurrent technical sessions. WPC registration has ranged from 2,500 to 6,000. OTC primarily serves offshore industry engineers and managers from around the world who participate in the four-day technical program and exhibition. The OTC program features 250 papers presented in concurrent sessions that cover technology and management techniques developed within the 11 scientific and engineering disciplines represented by the OTC sponsoring organizations. OTC in 1986 had some 27,000 registrants.

WPC organizers, immediately after the 1983 Congress in London (which marked its 50th anniversary), scheduled the 1987 Congress in Houston to precede OTC as a convenience to delegates to both events. While the petroleum industry had begun to restructure at the time, WPC organizers then could not foresee the extent of today's depressed industry conditions. The move to coordinate OTC and WPC dates in late April is a direct response to the impact of the "free fall" in oil prices that began in mid-January. Organizers are confident that the consolidated dates, plus other cooperative efforts, will maximize attendance at both events. Organizers point out that those interested now can attend both meetings in one week instead of two in Houston.

For more information, contact: Offshore Technology Conference, P.O. Box 833868, Richardson, TX 75083-3868; (214) 669-0072.

OKLAHOMA ABSTRACTS

American Association of Petroleum Geologists

The following abstracts are reprinted as published in the *Bulletin* of the American Association of Petroleum Geologists. Volume and page numbers are given in brackets below the abstracts. Permission of the authors and of the AAPG to reproduce the abstracts is gratefully acknowledged.

Role of Small Oil and Gas Fields in the United States

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With the maturation of oil and gas production operations in a province or country, fields found by new-field wildcats diminish in size. The actual economic size cutoff is a function of such factors as depth, water depth offshore, and accessibility to transportation infrastructure. Because of the constraint of resource availability, price is now the principal force driving drilling activity. The proportion of new-field wildcats to other exploratory wells has fallen in recent years, but success in new-field wildcats has risen to about 20%. However, only very small fields, less than 1 million BOE, are being found in large numbers. The 200 largest companies, based on lease revenues, drill 30% of all wells and 44% of the footage, and they make 83% of drilling expenditures. The 20 largest companies alone find 60% of the large fields and 20% of the small ones. Through 1979, almost 93% of known gas fields and 94.5% of known oil fields were small, yet they contain only 14.5% of the ultimately recoverable gas and 12.5% of the oil. However, small fields are less capital intensive than equivalent-capacity synthetic-fuel plants, they are extremely numerous, and they are relatively easy and inexpensive to find and put on production. [v. 69, p. 1950]

OKLAHOMA ABSTRACTS is intended to present abstracts of recent papers relating to the geology of Oklahoma and adjacent areas of interest. The editors are therefore interested in obtaining abstracts of formally presented or approved documents, such as dissertations, theses, and papers presented at professional meetings.

Relationships Among Vitrinite Reflectance, Illite Crystallinity, and Organic Geochemistry in Carboniferous Strata, Ouachita Mountains, Oklahoma and Arkansas

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The Ouachita Mountains contain a thick section of Carboniferous strata that display an extreme range in thermal maturity as determined by vitrinite reflectance. Clay mineralogy, illite crystallinity, and organic geochemistry of shales from those strata are systematically related to thermal maturity.

Shales of the Stanley, Jackfork, and Atoka formations are predominantly composed of illite and chlorite with minor occurrences of mixed-layer clays (restricted to samples characterized by mean vitrinite reflectance less than 1.5%) and pyrophyllite (restricted to samples characterized by mean vitrinite reflectance greater than 2.7%). Illite crystallinity is significantly related to vitrinite reflectance (R_o). Weaver's illite sharpness ratio (SR) increases with increasing R_o: $\log (SR) = 0.28 + 0.08 (R_o)$; whereas Kubler's illite crystallinity index (CI) decreases with increasing R_o: $\log (CI) = 1.01 - 0.07 (R_o)$.

Plots of bitumen ratio (bitumen/total organic carbon) vs. vitrinite reflectance, Weaver's illite sharpness ratio, and Kubler's crystallinity index all reveal hydrocarbon generation-preservation curves that define submature, mature, and supermature zones with regard to a liquid hydrocarbon window.

These results suggest that, in the absence of vitrinite, illite crystallinity can be used quantitatively to estimate levels of thermal maturity and cautiously to approximate hydrocarbon generation-preservation stages of potential source rocks. [v. 70, p. 26]

Interpretation of Crustal Structure from Regional Gravity Anomalies, Ouachita Mountains Area and Adjacent Gulf Coastal Plain

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A gravity data base from more than 35,000 stations was used to generate a series of regional gravity maps of the Ouachita Mountains area including adjacent parts of the craton and the Gulf coastal plain. These maps were used in conjunction with information from 96 wells, data from preexisting geophysical and geological investigations, and computer models to interpret four gravity profiles that transect the study area (approximately lat. 30–37°N, long. 91.5–99°W). These models, gravity maps, and previous investigations were then used to analyze various regional gravity anomalies

and to interpret the gross crustal structure of the region and its tectonic implications.

These data suggest that variably attenuated continental crust lies beneath the Gulf coastal plain, south of the Ouachita system gravity gradient, as opposed to "typical" continental crust of the craton north of this gradient. This variation in crustal structure probably reflects the complexity of Eocambrian and early Mesozoic rifting in the area. The Arkoma basin gravity minima may result from the combined effect of a late Paleozoic foreland basin and an Eocambrian northwest-trending, rift-related basin. The Ouachita system interior zone gravity maximum varies along strike of this orogenic belt. This anomaly appears to be a good indicator of the position of the Eocambrian continental margin and associated rift zone. Gravity anomalies in the Gulf coastal plain appear to be a combined effect of variable crustal attenuation, basins and uplifts, and mafic intrusions. Gravity maxima in the southern Oklahoma aulacogen result from uplifts and deep-seated mafic intrusions; gravity minima result from deep sedimentary basins. [v. 70, p. 667]

Queen's University of Belfast

The following abstract is from a Ph.D. thesis.

Transpression: An Application to the Slick Hills, SW Oklahoma

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"Transpression" is used to denote deformation within a zone which can be factorised into components of simple shear along the zone, and pure shear across it. Using this concept, computer modelling demonstrates how transpression can account for en echelon folds oriented at anomalously low angles to the strike of a wrench zone. To assess the applicability of the concept, the model is tested against deformation within the Slick Hills, SW Oklahoma.

The area of study forms part of the Frontal Fault System, an intensely faulted tectonic province within the S Oklahoma Aulacogen. The tectonic evolution of the system fits closely with the model for aulacogen development as outlined by Milanovsky (1981). The Slick Hills consists of Cambro–Ordovician limestones resting unconformably upon thick rhyolitic extrusions. The hills are fault bounded and are divided into a "graben" and "horst" block. Deformation took place during the late Pennsylvanian and is attributed to a continental collision along the line of the present day Ouachita foldbelt.

Within the Frontal Fault System inversion of the basin gave rise to a series of high angle reverse faults, on which the Cambrian basement and the Cambro–Ordovician sediments are thrust up towards the NE. These major faults trend WNW/ESE, and are linked by a second set trending NNW/SSE. Both sets are thought to have developed as extensional faults during the initial stage of rifting (Prec-Camb), but were later reactivated as contractional faults during the late Pennsylvanian. Deformation within the Slick Hills, largely confined to the graben block, is dominated by left-handed en echelon folds which are inclined at low angles to the bounding faults. The faults show evidence for oblique-slip reverse movement and are interpreted as part of a deep-seated flower structure, formed under a transpressive regime.

A series of deformation experiments using wax models are carried out to test many of the rules of simple shear; and to link the theoretical speculation and the fieldwork, by modelling features characteristic of transpressive deformation.