Oklahoma GEOLOGY Notes

OKLAHOMA GEOLOGICAL SURVEY VOL. 48, NO. 3 JUNE 1988

On the cover—

Panoramic View of the Potato Hills

View of the Potato Hills, looking south from Buffalo Mountain, with Kiamichi Mountain on the horizon. The Potato Hills are composed of tightly folded early to middle Paleozoic cherts, siliceous shales, and dark shales in the core of a major anticline along the north edge of the central zone of the Ouachita Mountains. Broad valleys to the north and south of the Potato Hills are underlain by Mississippian volcaniclastic flysch (Stanley Shale). The Stanley is overlain by thick-bedded quartzose sandstones of the Pennsylvanian Jackfork Group, which form the crests of Buffalo Mountain and Kiamichi Mountain.

Charles A. Ferguson

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Oklahoma GEOLOGY *Notes*

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OKLAHOMA GEOLOGICAL SURVEY VOL. 48, NO. 3 JUNE 1988

COALESCENCE OF THE SECOR AND SECOR RIDER COAL BEDS IN THE SHADY GROVE CREEK AREA, NORTHEASTERN McINTOSH COUNTY, OKLAHOMA, WITH INTERPRETATIONS CONCERNING DEPOSITIONAL ENVIRONMENTS

LeRoy A. Hemish[1]

Abstract

The Secor coal bed and the stratigraphically higher Secor rider coal bed coalesce to form a single coal bed ~2 ft thick in an area of ~4 mi^2, approximately 5 mi northeast of Checotah, Oklahoma, in T. 11 N., R. 18 E.; T. 12 N., R. 17 E.; and T. 12 N., R. 18 E. The two coal beds generally are separated by a gray shale or silty sandstone that is 12–18 ft thick in McIntosh County, and 35–50 ft thick in Pittsburg County to the south.

In the area where the two coal beds coalesce, averaged chemical analyses of eight samples show that the coal has a high ash content (>16%) and a high sulfur content (>6%). In the area where the coal beds are separated, the quality of the Secor rider coal is consistently similar to the quality of the coalesced coal beds (high-ash, high-sulfur). However, the lower split (Secor coal) in McIntosh County is generally a high-quality, low- to medium-sulfur (~1.3%), low-ash (~7.1%) coal.

The contrast in coal quality is probably due to varying rates of sediment influx into the peat-forming environment in a deltaic-plain or coastal-plain setting during the initial stages of coal formation. Rapid burial of the lower split owing to high influx of detritus effectively protected the swamp peat from the ingress of sulfate-rich seawater, thus cutting off the pyrite-producing process. Transgression of seawater over the Secor rider peat swamp prior to deep burial is evident. Thin, fossiliferous, marine limestones or fossil-rich shales occur in many places 1–2 ft above the Secor rider coal, as well as above the coalesced coals. This evident invasion of marine waters probably accounts for the high sulfur content of these coals.

Introduction

The purpose of this report is to show that two named coal beds, the Secor and Secor rider (Hemish, 1987, p. 99,105), coalesce to form one bed in northeastern McIntosh County, Oklahoma (Fig. 1), where it has been extensively strip-mined at various times during the past 50 years. Two cross sections were constructed to graphically portray the convergence of the beds from west to east and from south

[1]Oklahoma Geological Survey.

to north (Figs. 1,2). A study of lithologic units associated with the coals and the variations in ash and sulfur contents of the coals was undertaken to understand the interrelations between environmental patterns and physical and chemical attributes of the coals.

One hundred five logs of coal test holes and two measured sections within the study area were examined. Although most of the data are from holes drilled by coal companies, additional data came from 10 core holes drilled by the Oklahoma Geological Survey (OGS) (core descriptions are included in Friedman, 1978, and Hemish, 1988). Company logs and measured sections are on file at the OGS offices in Norman.

Also, logs of 210 drill holes and 22 measured sections were examined in T. 11 N., R. 16–18 E., and T. 12 N., R. 17–18 E., areas west of the study area proper (Fig. 1).

Eight analyses of coal samples were evaluated from the area of coalesced coals. Another 41 analyses of the Secor coal and eight analyses of the Secor rider coal were evaluated from the adjacent areas described above.

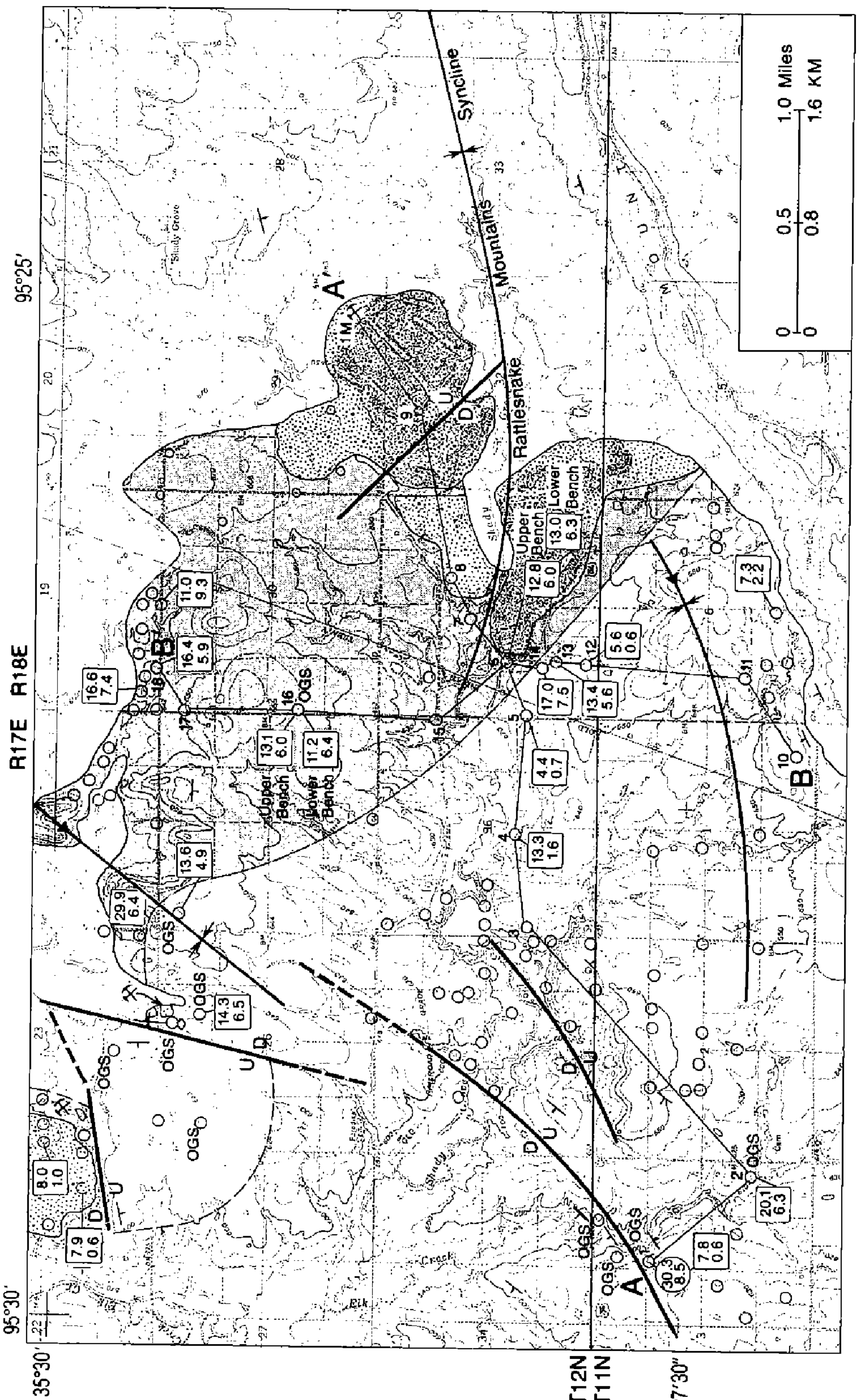
Chemical analyses were performed by the OGS Laboratories, Mines and Minerals Laboratory, Standard Laboratories, Inc., and Williams Brothers Laboratories. The Oklahoma Geological Survey is grateful for these data and also for drilling records supplied by Alpine Construction Co., W. H. Burdett, Inter-Chem, Kay Kay and Associate Engineers, Midwest Geotech, Inc., Mintech, Inc., and Turner Brothers, Inc.

Stratigraphy

The indurated rocks at the surface in the study area are all of Pennsylvanian (Desmoinesian) age. They are all in the lower part of the Boggy Formation (Fig. 3). The oldest member of the Boggy Formation, the Bluejacket Sandstone, is exposed in secs. 5 and 6, T. 11 N., R. 18 E., and in secs. 19, 20, 21, 28, 29, and 33, T. 12 N., R. 18 E. (Oakes and Koontz, 1967, pl. 1). The youngest units of the Boggy Formation exposed in the study area are the Inola Limestone Member and an overlying unnamed shale; these units crop out in sec. 3, T. 11 N., R. 17 E., and sec. 34, T. 12 N., R. 17 E. (Oakes and Koontz, 1967, pl. 1). The Secor coal occurs almost immediately above the Bluejacket Sandstone or above an unnamed shale interval of varying thickness that overlies the Bluejacket Sandstone (Fig. 2). The Secor rider coal occurs ~17 ft to <1 ft above the Secor coal, and ~90 ft below the Inola Limestone (Fig. 2).

A discontinuous, thin, unnamed, impure, fossiliferous marine limestone or calcareous shale closely overlies the Secor rider coal (holes 1, 2, 4, and 5, Fig. 2a) in the study area and beyond. This same unit also discontinuously overlies the coal in the area of coalescence (Fig. 1), although it was not recorded in any of the drill hole logs used in this study. Miners have reported the occurrence of a fossiliferous, impure limestone above the coal, and the writer has observed fragments of the limestone in the spoil piles of the abandoned strip mines in sec. 6, T. 11 N., R. 18 E.

The cumulative thickness of the rocks of the lower part of the Boggy Formation exposed in the outcrop belt in the study area is ~300 ft.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95°25'
R17E
R18E
35°30'
T12N
T11N
35°27'30"
A
A'
B
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Rattlesnake Mountains Syncline
Upper Bench
Lower Bench
OGS
0 0.5 1.0 Miles
0 0.8 1.6 KM

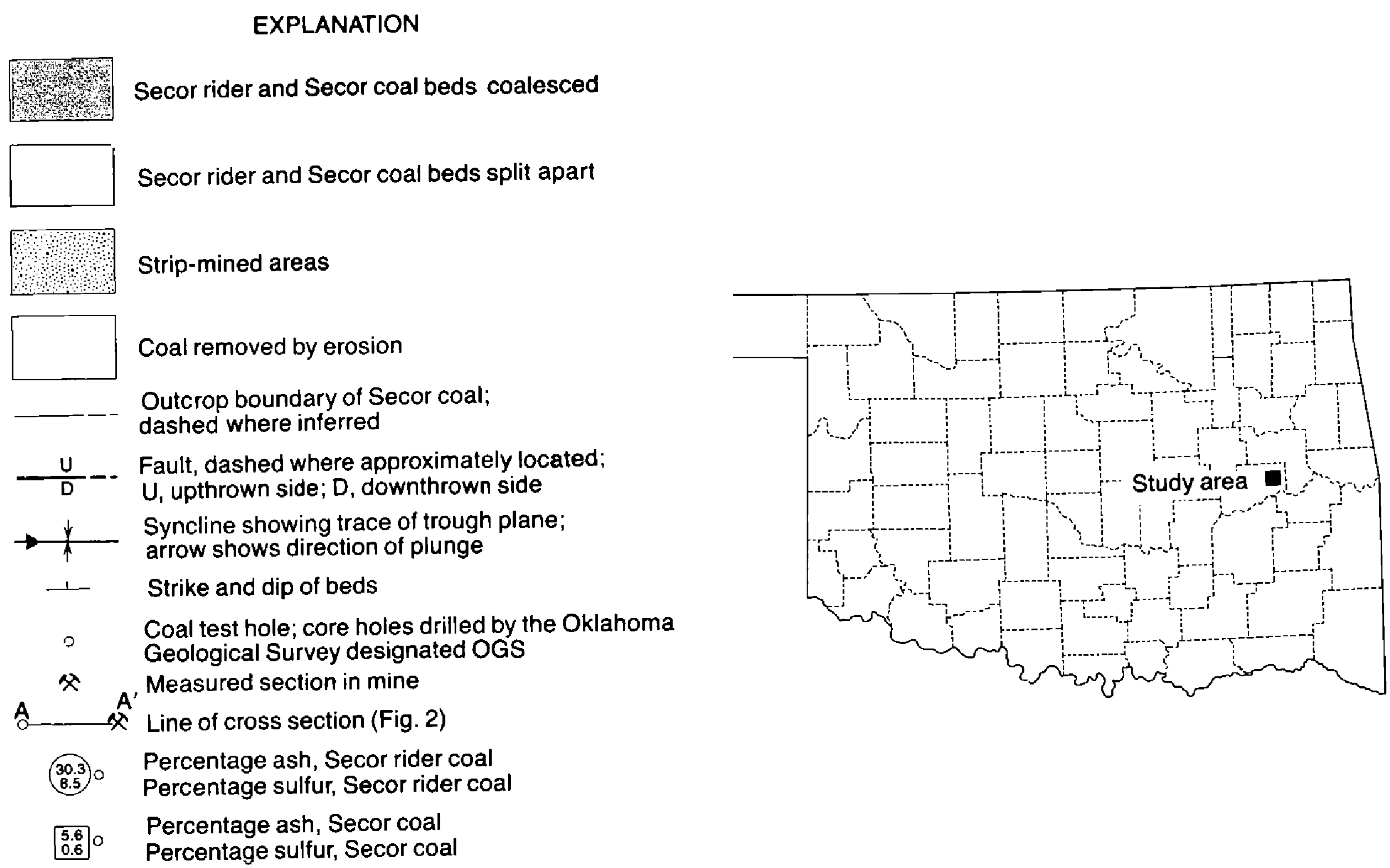


Figure 1. Map of Shady Grove Creek area, McIntosh County, Oklahoma, showing coal geology.

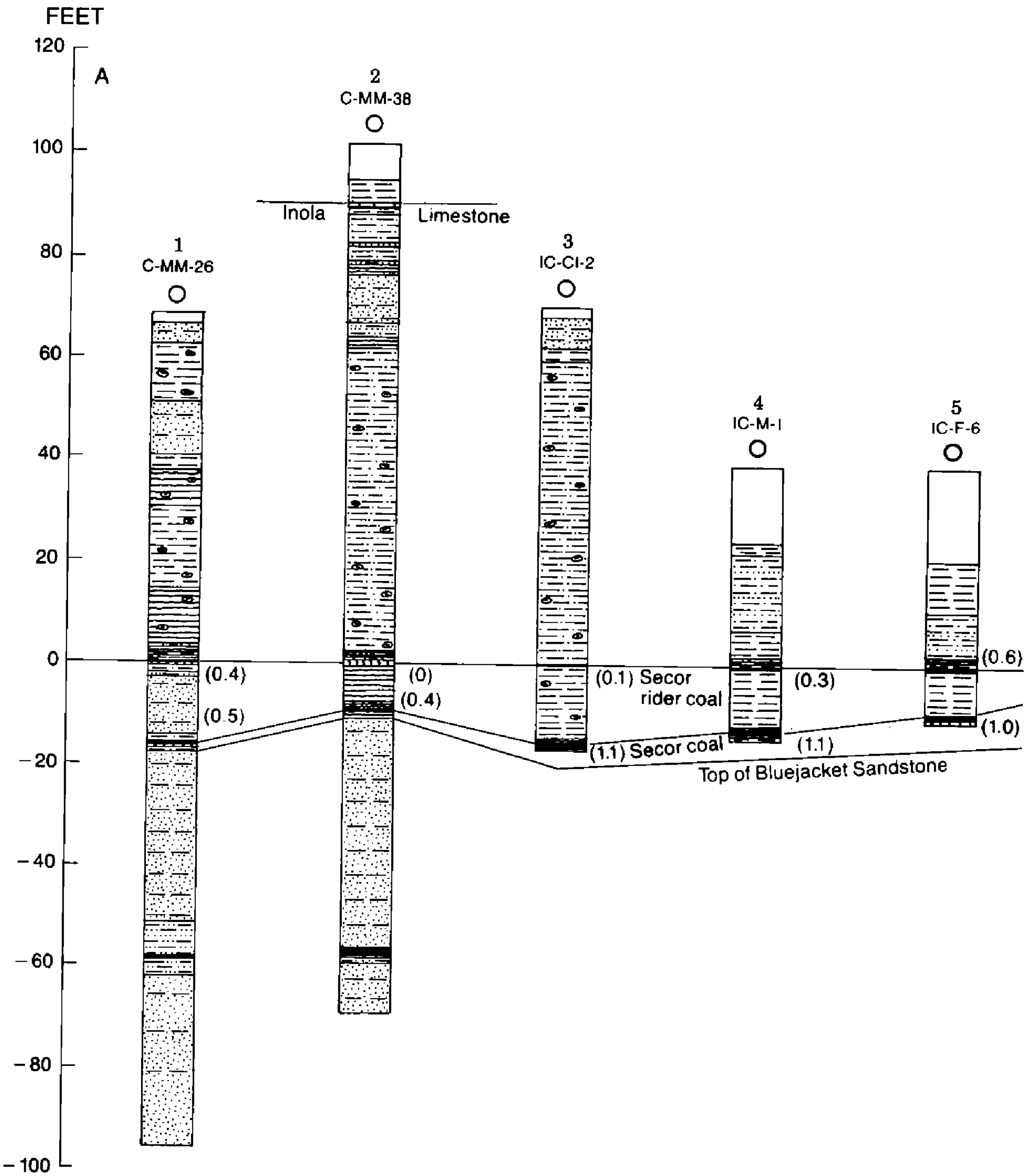
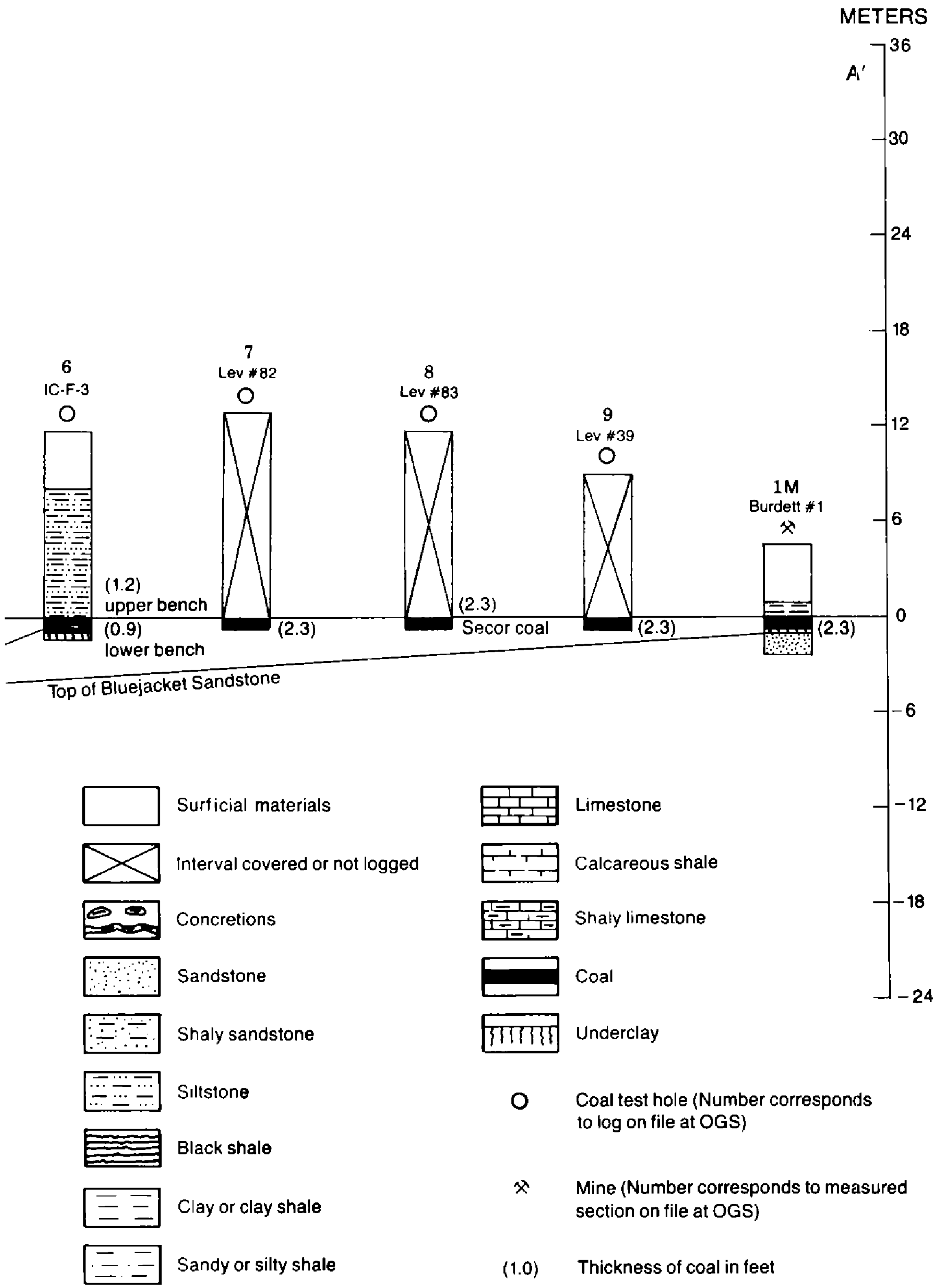


Figure 2*A*. Cross section showing coalescence of Secor rider and Secor coal beds from west to east in Shady Grove Creek area. No horizontal scale. Line of cross section shown in Figure 1.


METERS
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8
Lev #83
9
Lev #39
1M
Burdett #1
(1.2)
upper bench
(0.9)
lower bench
(2.3)
(2.3)
Secor coal
(2.3)
(2.3)
Top of Bluejacket Sandstone
Surficial materials
Interval covered or not logged
Concretions
Sandstone
Shaly sandstone
Siltstone
Black shale
Clay or clay shale
Sandy or silty shale
Limestone
Calcareous shale
Shaly limestone
Coal
Underclay
Coal test hole (Number corresponds to log on file at OGS)
Mine (Number corresponds to measured section on file at OGS)
(1.0) Thickness of coal in feet

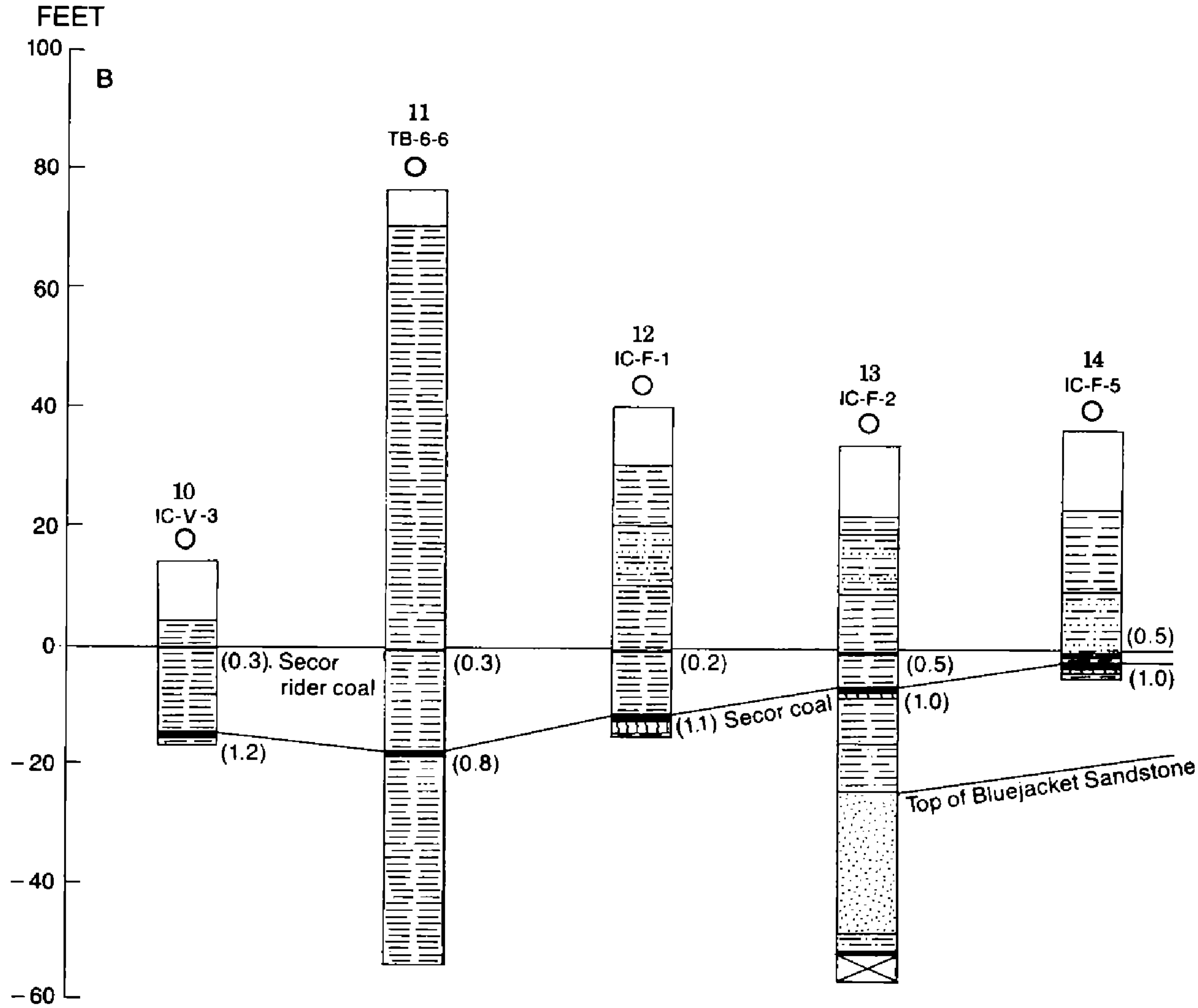
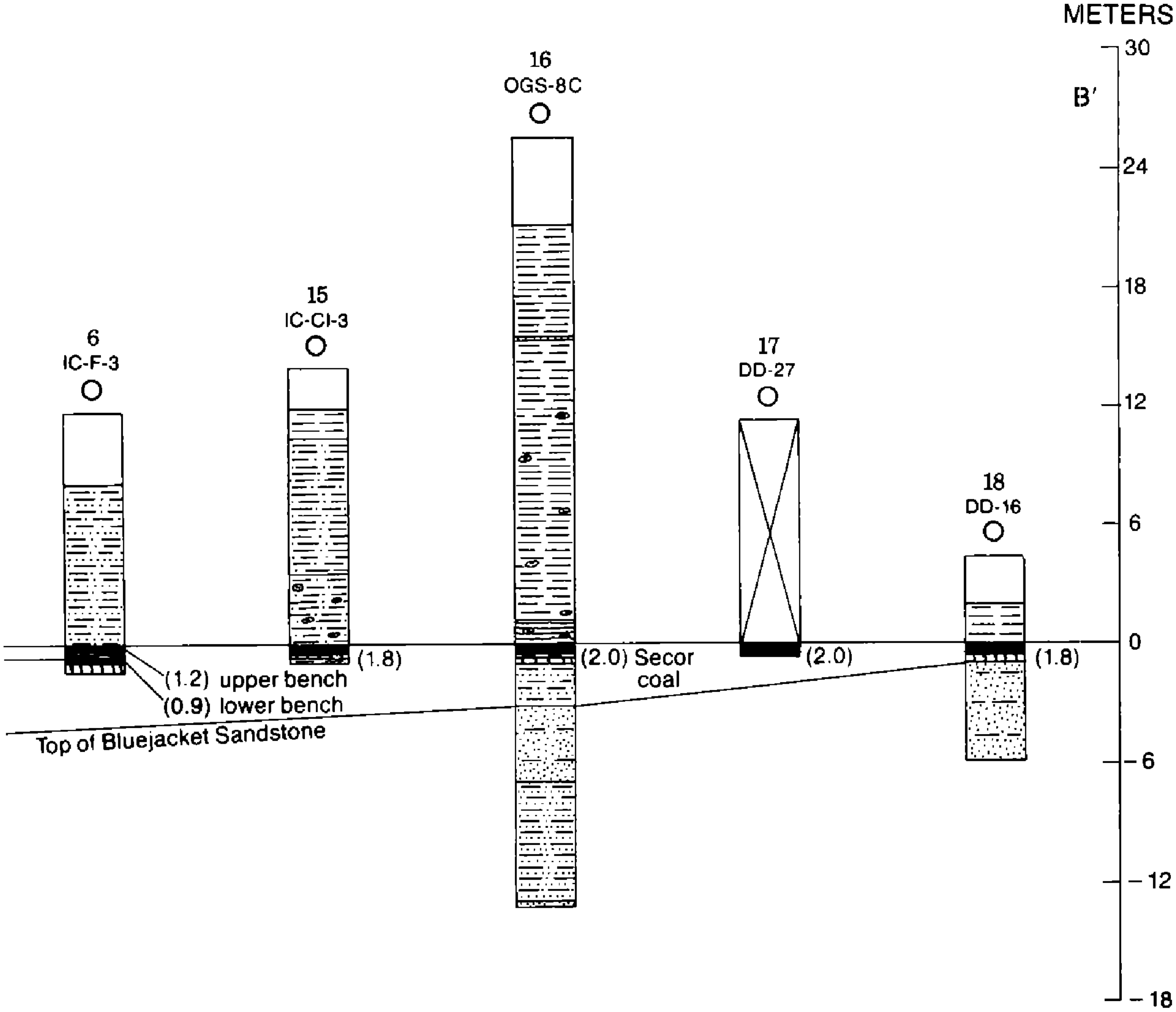


Figure 2*B*. Cross section showing coalescence of Secor and Secor rider coal beds from south to north in Shady Grove Creek area. No horizontal scale. Line of cross section shown in Figure 1.

Structure

It was not the purpose of this study to make a detailed investigation of the surface structure of the rocks in the Shady Grove Creek area. However, the previously mapped and newly observed structural features shown in Figure 1 are here discussed briefly.

The Rattlesnake Mountains syncline was first mapped by Wilson and Newell (1937, p. 84, pl. 1). The axis extends from the east in Muskogee County into the study area in McIntosh County to the southwestern part of T. 12 N., R. 15 E. The syncline is somewhat asymmetric; outcrops on the south limb dip NW at rates of as much as 90 ft/mi, and outcrops on the north limb dip SW at ~50 ft/mi (Oakes



and Koontz, 1967, p. 46). The configuration of the mined-out area and the outcrop boundary of the Secor coal in the eastern part of the study area reflects this asymmetry (Fig. 1).

Oakes and Koontz (1967, p. 45) presented evidence to show that McIntosh County and adjacent areas were tectonically active throughout most of Boggy time. Accumulation of peat contemporaneous with downwarping in the Rattlesnake Mountains syncline may explain the increased thickness of the bed in secs. 29, 30, 31, and 32, T. 12 N., R. 18 E. (Fig. 1). Pre-mining exploration records show that the coal bed reached a maximum thickness of 30 in. in sec. 32. Ward (1984, p. 166) stated that coal beds tend to increase in thickness over synclinal axes.

The fault shown in secs. 29, 30, and 32, T. 12 N., R. 18 E., is from Oakes and Koontz (1967, pl. 1). Two other faults shown in secs. 2 and 3, T. 11 N., R. 17 E., and secs. 26, 34, and 35, T. 12 N., R. 17 E., have been modified somewhat from Oakes and Koontz (1967, pl. 1), based on new drilling and recent field observations by the writer.

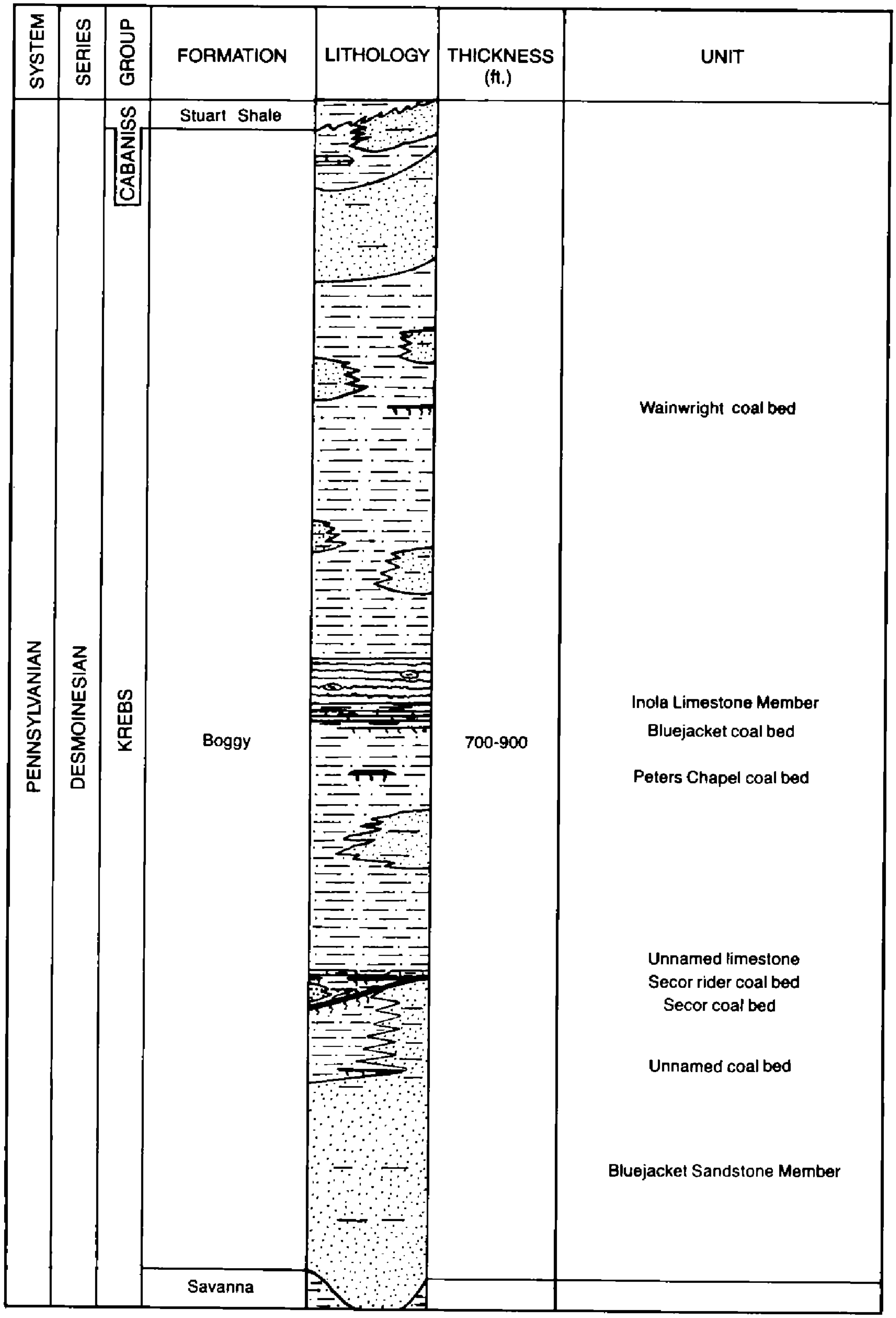


Figure 3. Generalized geologic column showing the Boggy Formation and associated strata in northern McIntosh County, Oklahoma.

New drilling information in secs. 22, 23, and 26, T. 12 N., R. 17 E., has shown that the Secor rider and Secor coals are both absent south of the escarpment along the west-flowing tributary of Elk Creek in secs. 22 and 23, as well as in the NW¼ sec. 26. Although the absence of the coal could be explained by nondeposition, or possibly by a channel cutout, the writer's interpretation is that the coal has been eroded from the upthrown wedge shown between two newly mapped faults (Fig. 1). This explanation is preferred because of the presence of the high escarpment along the south side of the tributary stream, and the sharp reversal in dips on the outcropping rocks on either side of the fault shown in secs. 23 and 26. The Secor and Secor rider coals crop out in the NW¼SE¼ sec. 26, T. 12 N., R. 17 E., where they apparently have been dragged up on the east side of the fault. The coal has been strip-mined along the fault on a small scale in the past, as evidenced by abandoned pits on both sides of the county road in this vicinity (Fig. 1).

New drilling also shows that a plunging syncline is present in secs. 1 and 2, T. 11 N., R. 17 E., and sec. 6, T. 11 N., R. 18 E. Another previously unmapped syncline, plunging to the southwest in secs. 23, 24, 25, and 26, T. 12 N., R. 17 E., has been revealed by new drilling (Fig. 1). The topographic expression of resistant sandstones in sec. 24, T. 11 N., R. 17 E., delineates the axis of the syncline.

It seems probable that other small, secondary structural features are present in the Shady Grove Creek area (the outcrop boundary of the Secor coal in secs. 19, 20, 29, and 30, T. 12 N., R. 18 E., suggests folding, but density of data is insufficient to verify the hypothesis).

In the extreme western part of the Shady Grove Creek area, and to the west, the outcropping rocks generally dip WNW at a rate of ~1°. In a few localities (NW¼NW¼NE¼ sec. 3, T. 11 N., R. 17 E., and S½ sec. 34, T. 12 N., R. 17 E.) the dips are as great as 6°.

Coalescence of the Coals

Closely spaced exploration drilling in T. 12 N., R. 17 E., and T. 12 N., R. 18 E., McIntosh County, Oklahoma, shows that the Secor coal bed and the stratigraphically higher Secor rider coal bed coalesce to form a single coal bed ~2 ft thick in an area of ~4 mi^2, ~5 mi northeast of Checotah (Fig. 1). This coal has traditionally been called the Secor by miners and authors of technical reports (Wilson and Newell, 1937, p. 91,92,94; Oakes and Koontz, 1967, p. 26; Friedman, 1974, p. 31, 1978, p. 19–24; Friedman and Woods, 1982, pl. 2).

In some places within the 4-mi^2 area, the coalesced beds contain one or more shale partings (Friedman, 1978, p. 22–23; W. H. Burdett, 1986, personal communication; Fig. 2, drill holes 6 and 16).

Wood and others (1983, p. 15), in their glossary of coal terms, define a parting as "a layer or stratum of non-coal material in a coal bed which does not exceed the thickness of coal in either the directly underlying or overlying benches" of coal. Where the non-coal material exceeds the thickness of either the underlying or overlying parts of the coal bed, the coal bed is considered to have split into two coal beds (Wood and others, 1983, p. 36).

Cross section A–A′ (Fig. 2a) shows that the two coals converge from west to east over a distance of ~2.5 mi, from a maximum separation of 16 ft (hole 1) to

0.7 ft (hole 6). By definition, the coals are considered to be one bed at this point, because the parting of non-coal material is less than the thickness of either the underlying or overlying parts of the coal bed (0.9 ft and 1.2 ft, respectively). Similarly, cross section B–B′ (Fig. 2b) shows that the two coals converge from south to north over a distance of ~1 mi, from a maximum separation of 17 ft (hole 11) to 0.7 ft (hole 6). Hole 14 (cross section B–B′) occurs just at the boundary where the two coals coalesce, but at this point the two beds must still be considered separate, because the non-coal parting is thicker (0.9 ft) than the overlying Secor rider coal (0.5 ft).

Approximation of the dividing line between split and coalesced beds (Fig. 1) was based on data from drill-hole and core-hole logs—specifically, coal thickness and absence of the Secor rider coal bed. Future drilling in sec. 25, T. 12 N., R. 17 E., may necessitate some revision of the dividing line.

Drill-hole, mine, and outcrop data indicate that much of the area west and southwest of the present study area (T. 11–12 N., R. 16–17 E.) is underlain by both the Secor and Secor rider coal beds. Locally, one coal or the other, or both, may be absent owing to nondeposition or channel cutout. However, there is no evidence to suggest that the beds have converged if only one bed is present—rather, the interval between the two beds becomes greater southwestward. Friedman (1978, p. 23) reported that the Secor rider coal occurs ~35 ft above the Secor coal to the south of McIntosh County in central and northern Pittsburg County. Additional data on file at OGS show that the Secor rider occurs as much as 50 ft above the Secor coal in other parts of Pittsburg County.

To the northwest, the Secor and Secor rider coals are both present in northwestern Muskogee County (Hemish, 1986), where the interval separating the two beds is variable (1–19 ft). No evidence was found for convergence of the Secor and Secor rider coals into one bed north of the study area. The Secor coal has not been identified north of T. 16 N. in the vicinity of Porter in Wagoner County, and the Secor rider coal pinches out at the northern boundary of Muskogee County (Hemish, 1986, p. 178,180).

Analytical Properties of the Coals

Table 1 shows that samples of coal from the area where the Secor and Secor rider coal beds coalesce (Fig. 1) contain a high percentage of ash (16.2%) and a high percentage of sulfur (6.8%). Wood and others (1983, p. 10) define high-ash coal as coal containing >15% total ash. They further define low-ash coal as coal containing <8% total ash, and medium-ash coal as coal containing 8–15% total ash—all on an as-received basis. They define high-sulfur coal as coal containing ≥3% total sulfur; medium-sulfur coal as coal containing >1% and <3% total sulfur; and low-sulfur coal as coal containing ≤1% total sulfur—all on an as-received basis.

Where the Secor and Secor rider coals are split apart, in the remainder of McIntosh County, the Secor coal is a low-ash (7.1%), medium-sulfur (1.3%) coal, and the Secor rider is a high-ash (21.4%), high-sulfur (7.9%) coal. In most of this area, the Secor coal is a low-sulfur coal. Of the 41 samples averaged in Table 1, 29 contained ≤1% total sulfur. Three notable exceptions to the 1.3% average

TABLE 1.—AVERAGED ANALYSES OF THE COALESCED SECOR AND SECOR RIDER COALS VERSUS AVERAGED ANALYSES OF THE INDIVIDUAL SECOR AND SECOR RIDER COALS IN MCINTOSH COUNTY[a]

Area	Analytical parameter[b]	Secor rider coal	No. of samples	Secor coal	No. of samples
Parts of T. 11–12 N., R. 17–18 E. (coals coalesced)[d]	Proximate analysis (wt.%)				
	Moisture	N/A[c]		1.4	8
	Volatile matter	N/A		27.7	3
	Ash	N/A		16.2	8
	Fixed carbon	N/A		56.1	3
	Sulfur, total (wt.%)	N/A		6.8	8
	Heat value (Btu/lb)	N/A		12,628	8
Parts of T. 11–12 N., R. 16–18 E. (coals split apart)	Proximate analysis (wt.%)				
	Moisture	3.1	8	3.2	41
	Volatile matter	31.3	8	32.5	38
	Ash	21.4	8	7.1	41
	Fixed carbon	44.2	8	57.2	38
	Sulfur, total (wt.%)	7.9	8	1.3	41
	Heat value (Btu/lb)	10,951	8	13,613	41

[a]Weighted whole-bed averages are used where benched samples of one coal bed have been separately analyzed.
[b]Analyses on an as-received basis.
[c]Not applicable.
[d]Includes two samples from transition area near the center of the SW¼, T. 12 N., R. 18 E.

sulfur content of the Secor coal in the area where the coals are split apart are shown in Figure 1 (SE¼ sec. 3, T. 11 N., R. 17 E.; NW¼ sec. 25, T. 12 N., R. 17 E.; NE¼ sec. 26, T. 12 N., R. 17 E). These anomalous high-sulfur, high-ash occurrences are attributed to a particular depositional environment (see below) as is the similarity of the high ash and sulfur contents of the Secor rider coal and the coalesced Secor rider and Secor coals.

Depositional Environments

Coal beds originate from peat deposited in swamps. The following basic requirements are necessary in the formation of a peat swamp (Ward, 1984, p. 161): (1) substantial growth of vegetation with at least some woody or fibrous components, (2) sufficient standing water around the accumulated vegetable material to exclude oxidation or bacterial destruction of the organic components, (3) the absence of inorganic sediment during peat accumulation.

Modern-day peat accumulates in a variety of sedimentary environments, including river flood plains, deltas, and coastal areas. Such areas probably are similar to the environments in which Oklahoma's bituminous coal beds accumulated during Pennsylvanian time. The Dismal Swamp, Florida Everglades, and the Mississippi Delta provide useful modern comparisons (Dott and Batten, 1971, p. 311). The coal beds of the interior part of the United States were formed when the continents were more submerged than they are now, and when wide coastal plains bordered shallow epicontinental seas. During the Pennsylvanian the central part of the United States was a vast, level plain, generally a little above or a little below sea level. Large rivers flowed southwestward from eastern Canada, building deltaic and alluvial plains as they debouched into the epeiric sea (Wanless and others, 1963,1969, p. 111; Dott and Batten, 1971, p. 315,317).

Figure 4 shows the course of the large alluvial–deltaic system that deposited the Bluejacket Sandstone during a time when the continental shelf was uplifted above sea level. Deltaic deposits associated with this large alluvial system covered an extensive area in central Oklahoma prior to deposition of the Secor coal (Fig. 5). The writer believes that distribution of the Secor and Secor rider coals was controlled by the development and evolution of this widespread delta complex.

The Shady Grove Creek area and adjacent areas are interpreted as part of a lower delta plain that existed immediately after deposition of the Bluejacket Formation. This interpretation is based on the nature of splitting of the coal beds, the lithologic characteristics of the sedimentary sequence, and the distribution of ash and sulfur in the coals. Shelton (1973, fig. 12-7), in his paleogeographic map of the Bluejacket Sandstone complex, showed the study area to be part of a widespread deltaic plain.

Frazier and Osanik (1979, p. 351) stated that "peat-forming environments are related directly to development of delta lobes." Delta platforms are built when rivers deposit their load at the distributary mouth. Delta-front facies prograde over delta deposits, creating a delta platform. The shoreline advances during continued progradation, and the delta plain develops. Vegetation becomes established as the delta plain enlarges. Thick accumulations of peat develop in the areas between distributary channels. Splits in the peat may develop in areas where the rate of subsidence due to continued compaction of the underlying clays exceeds the rate of aggradation (Frazier and Osanik, 1979, p. 351).

Britten and others (1975, p. 235–236) described two types of coal-bed splitting, multidirectional (zig-zag) splitting and unidirectional (progressive) splitting (Fig. 6).

Multidirectional splitting indicates rapid and frequent oscillation between the accumulation of organic peat and accumulation of inorganic detritus. Sediments were deposited in channels, and from overbank floods from these channels that switched back and forth across the peat swamps.

In unidirectional splitting the splits diverge progressively in one direction towards a zone which is subsiding more rapidly than peat accumulates (Britten and others, 1975, p. 236). Both types of splitting are indicative of rapid accumulation and burial of the peat. Figure 2 shows that the splitting in the study area is unidirectional. Divergence of the Secor rider and Secor coals is progressively greater in a southerly direction, toward the axis of the Arkoma basin, which was apparently subsiding more rapidly than the study area. Smith (1968, p. 32) stated that seam splitting tends to increase toward the center of subsiding basins, where the total thicknesses of sediments are at a maximum.

Gradual abandonment of a delta lobe occurs when the main stream of the distributary system shifts into another course that has a steeper gradient and can

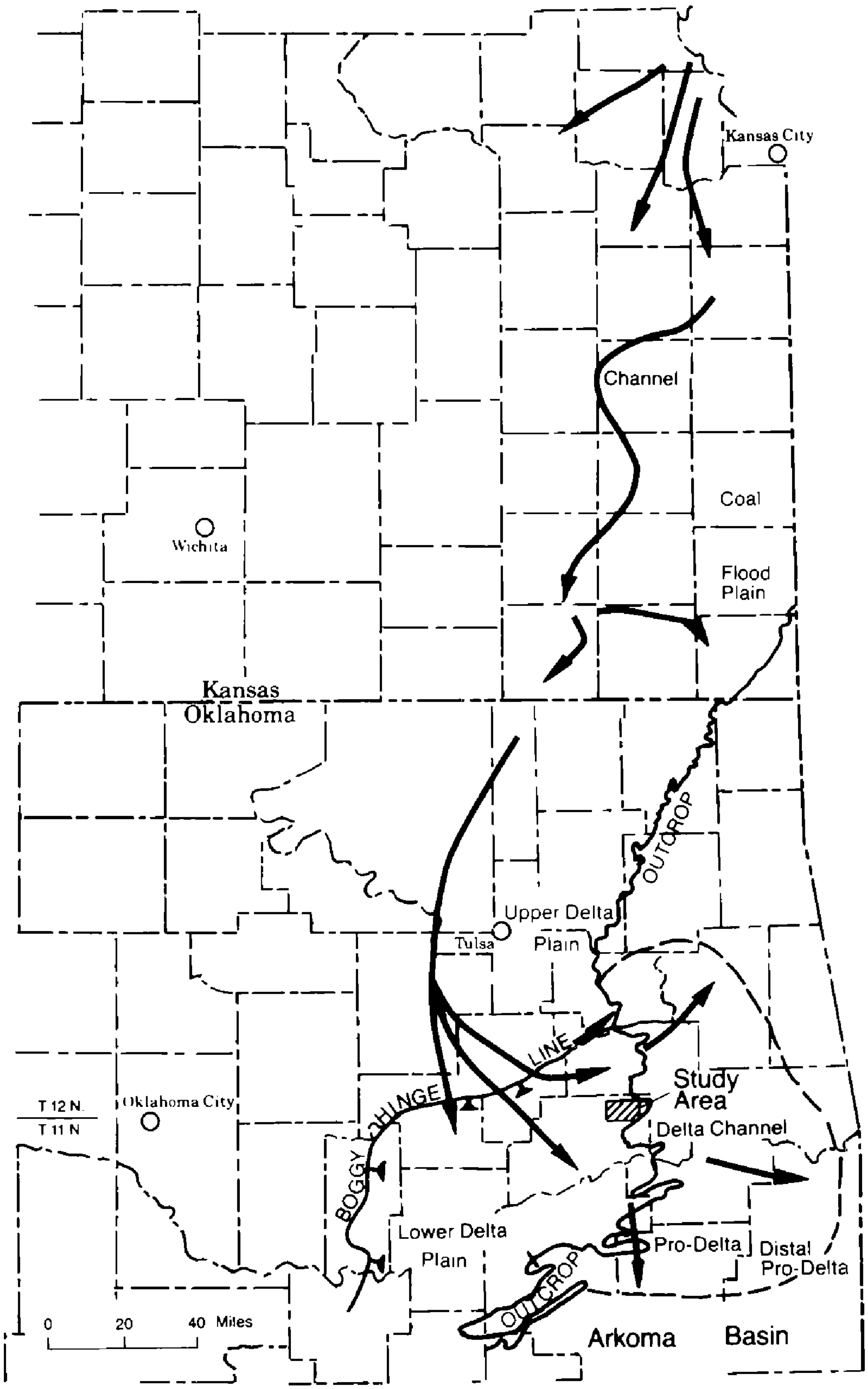


Figure 4. Map showing direction of transport of sediments of the Bluejacket (Bartlesville) complex in Kansas and Oklahoma, and the outcrop limit of the complex. Modified from Visher (1968, fig. 1 [adapted from Weirich, 1953]).

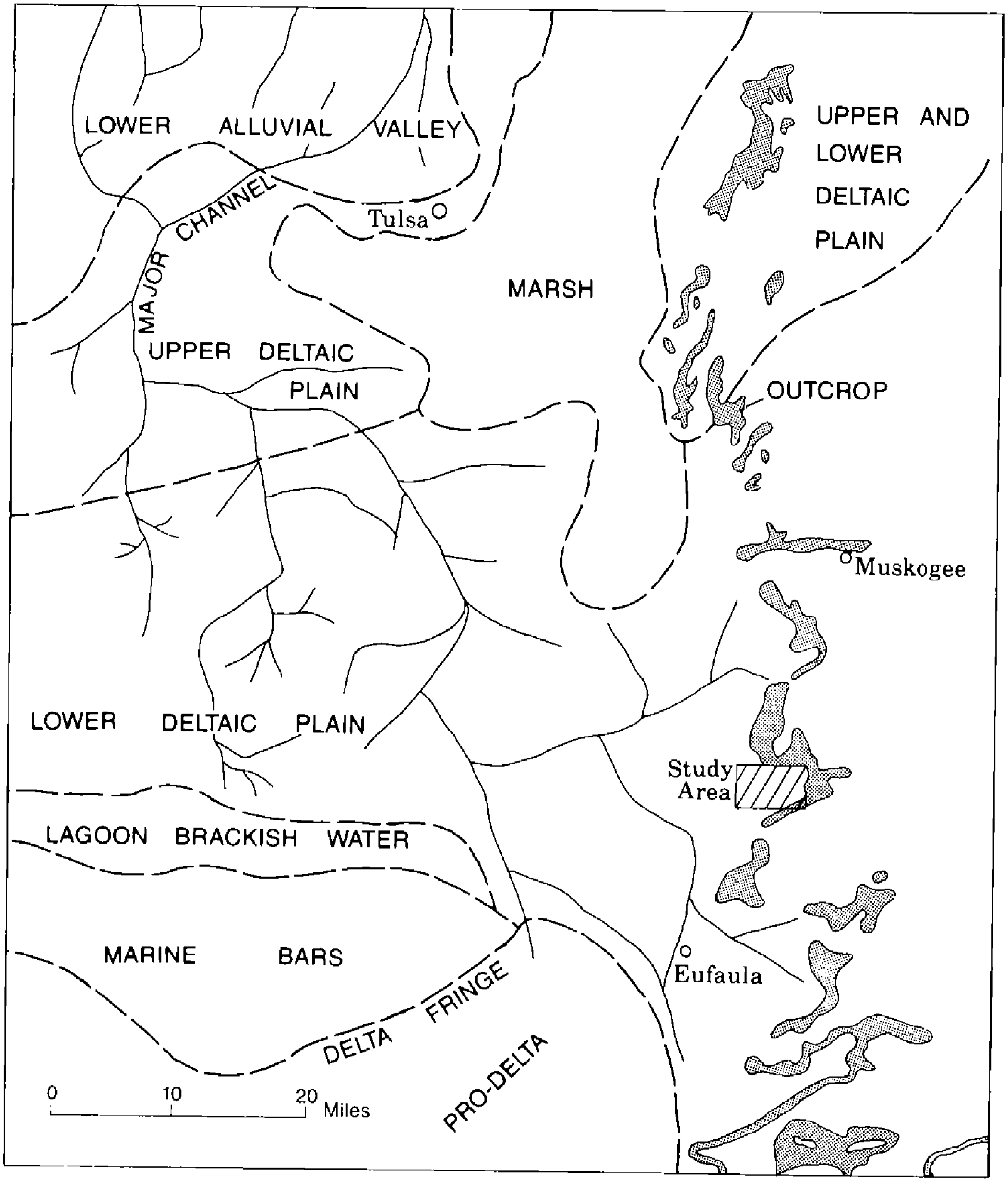


Figure 5. Map showing depositional environments associated with the Bluejacket Sandstone alluvial–deltaic system in east-central Oklahoma. Modified from Saitta and Visher (1968, fig. 5).

offer a shorter course to the sea. This shift may occur far upstream on the alluvial plain. As flow is lessened, the entire distributary network is totally abandoned. When subsidence exceeds aggradation, inundation of the delta margin begins (Frazier and Osanik, 1979, p. 353).

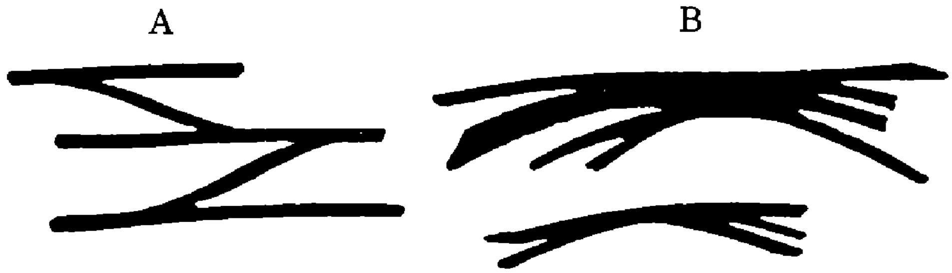


Figure 6. ***A***—**Multidirectional (zig-zag) coal-seam splitting.** ***B***—**Unidirectional (progressive) coal-seam splitting. Modified from Britten and others (1975, fig. 18.3).**

During the time of accumulation of the Secor rider peat, subsidence was taking place slowly and uniformly throughout a broad, tranquil area that probably had low relief. The environmental setting was like that which existed just after abandonment of the distributary network. Transgression of the sea over this area is indicated by the marine strata above the Secor rider coal.

A thin impure limestone or calcareous shale occurs discontinuously in association with black, carbonaceous shales immediately above the Secor rider coal (Fig. 2). The calcareous units contain marine and brackish-water fossils, indicating inundation of the former swamp owing to a small rise of sea level or sinking of the land. The sediments observed in cores in the interval between the Secor coal and the Secor rider coal appear to be terrestrial. They are mostly unfossiliferous silty shales and silty sandstones (Fig. 2)—typical crevasse splay deposits (Ward, 1984, p. 175). They probably were deposited by distributary channels flowing across the delta plain and rapidly burying the peat that was to become the high-quality Secor coal. Not all of the sediments observed in cores in the interval between the Secor coal and the Secor rider coal are terrestrial; for example, the thin limestone, containing marine fossils, overlying the Secor coal in a hole drilled in the SE¼ sec. 3, T. 11 N., R. 17 E. (Fig. 2, drill hole 2; see Fig. 7 for an explanation of this exception). Analysis of a core sample of the coal at this location showed that it contained 6.3% sulfur, which is greatly different from the average sulfur content (~1%) of the Secor coal where overlain by sediments interpreted as terrestrial. Detailed descriptions of all stratigraphic units cored by OGS in the Shady Creek area are given by Hemish (1988).

Marine- and brackish-water conditions in peat swamps are known to have a strong influence on the sulfur content of coals (White and Thiessen, 1913, p. 58; Stach and others, 1975, p. 29–31; Reidenouer and others, 1979, p. 88; Williams and Keith, 1979, p. 109; Ward, 1984, p. 175). The formation of pyrite in coal by bacterial reduction of sulfate takes place most readily in coals associated with marine strata. Sulfur-reducing bacteria thrive best in neutral to weakly alkaline media. Stach and others (1975, p. 29) have shown that peats formed in areas not subjected to marine conditions typically have high acidity. The more acid the peat, the poorer in bacteria it will be. Marine- and brackish-water environments not only provide a good supply of sulfate, but also strongly reduce acidity, thus

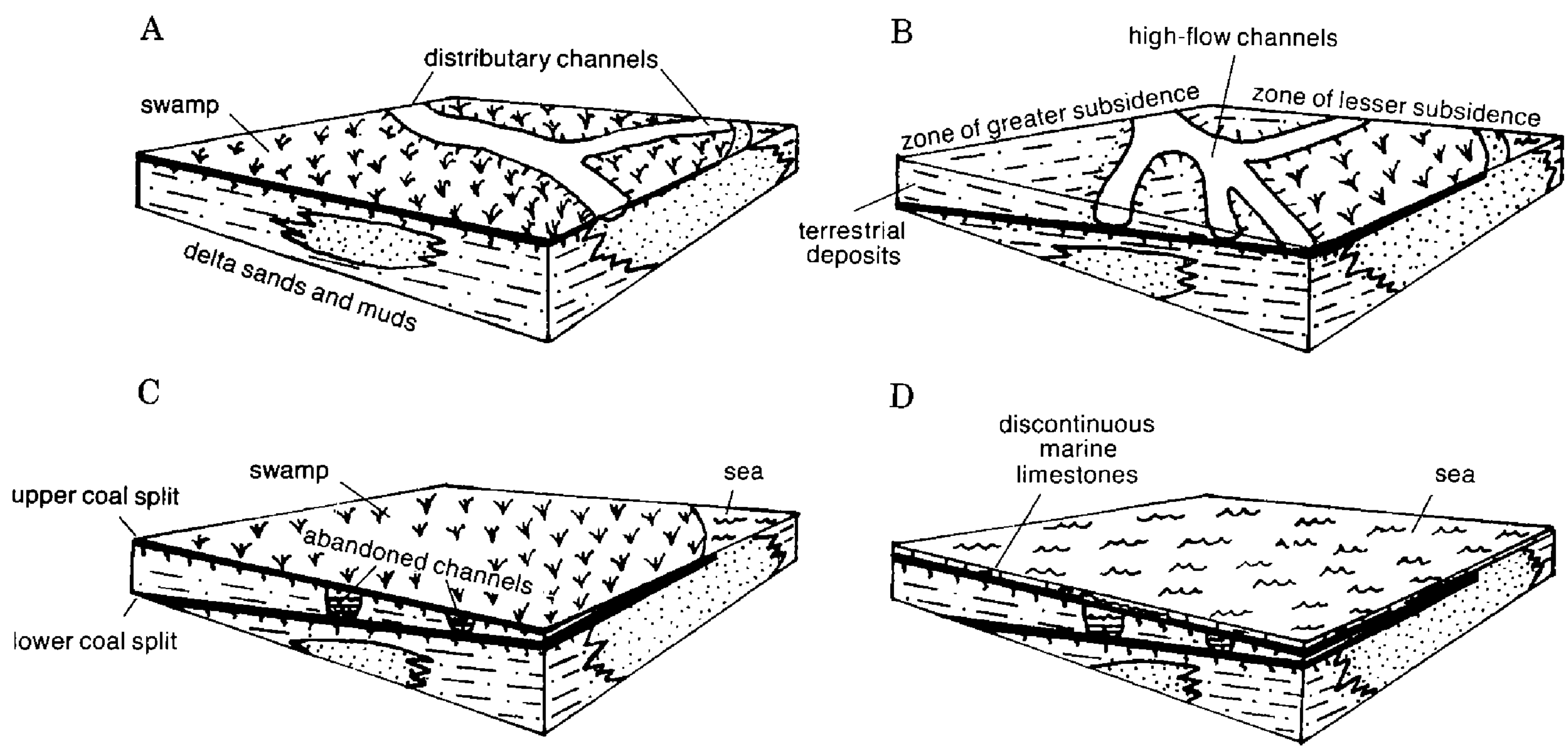


Figure 7. Diagrams showing depositional environments that existed during accumulation of the Secor and Secor rider peats. *A*—Peat accumulates in interchannel areas on lower deltaic plain. *B*—Rapid influx of sediments buries Secor peat in zone of greater subsidence; high-flow channel currents erode down to top of peat; swamp vegetation persists in zone of lesser subsidence. *C*—Delta lobe abandoned by its distributary system; marine waters invade initially unfilled channels and deposit fossiliferous, muddy limestones; swamp vegetation becomes established as area is leveled and peat again accumulates on coastal plain. *D*—Entire delta lobe gradually subsides; sea transgresses across area, drowning peat swamp; black shales and impure marine limestones deposited above peat.

permitting the sulfur-reducing bacteria to thrive (Stach and others, 1975, p. 31; Ward, 1984, p. 175).

Interpretations

The writer believes that a sufficient thickness of sediment was deposited above the low-sulfur Secor coal early enough to shield it from the effects of marine transgression. The anomalous high-sulfur occurrences of the Secor coal in the Shady Grove Creek area can be explained by channeling in the protective cover of sediments subsequent to their deposition on the delta lobe. When the delta lobe was abandoned by its distributary system, the initially unfilled channels eventually would have become estuaries as subsidence and compaction of soft deltaic muds occurred. Through a reversal in the direction of currents (Fisk, 1947), the estuaries would have carried marine waters into contact with the Secor peat. It is believed that the pre-existing distributary channels had eroded down to the level of the peat during high-flow channel conditions. The influence of estuarine brackish waters would explain the high sulfur content of the lower split of coal in limited areas.

At the time of accumulation of the Secor rider peat, the abandoned delta lobe was probably only slightly above sea level. The coastal swamp would have been subjected to intermittent flooding during storms or high tides, and as a result peat would have been contaminated by silt from suspension. This interpretation accounts for both the high sulfur and high ash contents of the coal. Ultimately, the delta lobe submerged, and the peat swamp was drowned by the sea.

Figure 7 shows the sequence of geologic events during accumulation of the Secor and Secor rider coals, as interpreted by the writer.

Conclusions

Most of the information used to make the environmental interpretations concerning deposition of the Secor and Secor rider coal beds in the Shady Grove Creek area and adjacent areas came from moderately spaced subsurface data. The drill-hole data, along with analytical data for the coal, suggest that the swamps in which the coals originated were situated on the platform of a delta lobe that was part of the Bluejacket Sandstone deltaic–alluvial complex. The split in the coals and the superior quality of the lower split are believed to be due to differential subsidence and rapid burial of that portion of the delta lobe where the Secor and Secor rider coals are not coalesced. The lower split was effectively shielded from the sulfur-reducing effects of marine waters by the influx of terrestrial detritus. Subsequently, the swamp which produced the Secor rider peat extended over a broad area of low relief adjacent to the sea. Transgression of the sea eventually drowned the peat swamps. Ingress of sulfate-rich seawater accounts for the high sulfur content of the coalesced coals and the Secor rider coal.

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OGS HOSTS SECOND ANNUAL OUACHITA MOUNTAINS COGEOMAP WORKSHOP

Neil H. Suneson[1]

From April 7 through 9, the Oklahoma Geological Survey hosted the second annual Ouachita Mountains COGEOMAP workshop and field trip. OGS Associate Director Kenneth Johnson organized the workshop, which included geologists from the OGS, the Arkansas Geological Commission, and the U.S. Geological Survey. Following the meeting, held at the Oklahoma Center for Continuing Education on the OU campus in Norman, Boyd Haley and Charles Stone, geologists with the AGC, led a field trip to examine the Devonian through Pennsylvanian stratigraphy of western Arkansas near Mena. Neil Suneson and Charles Ferguson of the OGS led a brief trip through the frontal belt north of Talihina, Oklahoma, and LeRoy Hemish of the OGS followed with a trip showing some of the Pennsylvanian coal-bearing strata he has been mapping in the Arkoma basin near Wilburton, Oklahoma.

The Ouachita Mountains in Oklahoma and Arkansas are the target of the COGEOMAP effort because they are one of the least-understood of the major tectonic provinces in the central part of the United States. The geologic and tectonic history of the Ouachitas is not well understood, the stratigraphic and biostratigraphic relationships of the sparsely fossiliferous rock units are not well established, and the amount of compiled and released geophysical data on the region is inadequate for proper geologic interpretations. Since initiating the COGEOMAP program, the OGS and AGC geologists have established a data base for the mapping portion of the project, mapped large parts of the Arkansas Ouachitas, and started detailed geologic mapping in the frontal thrust belt of the Oklahoma Ouachita Mountains. Plans call for continuing several aspects of the project, particularly biostratigraphy and seismic reflection, and accelerating the mapping phase of the work.

The purposes and social benefits of the Ouachita COGEOMAP program are multiple. The Ouachita Mountains produce moderate amounts of oil and gas and are an active exploration target, particularly in Arbuckle strata beneath the thick Pennsylvanian turbidites. Some industry geologists consider parts of the Ouachitas to be the largest untested anticlinal structure in the continental United States. Many metallic and nonmetallic minerals are known to be present in the region. Certain thick shale beds are prone to landslides that are a significant hazard to highway maintenance and other development. The quality and quantity of groundwater supplies are dependent on the subsurface geology and are highly variable throughout the region.

The academic contributions are also great. Understanding the geologic and

[1]Oklahoma Geological Survey.

tectonic history of the Ouachitas would help greatly in unraveling the evolution of basins and the history of plate tectonics along the southern edge of the North American craton.

At the meeting, Neil Suneson summarized the present status of OGS mapping in the Oklahoma Ouachita Mountains frontal belt. To date, three 7.5′ quadrangles (Higgins, Damon, Baker Mountain) and parts of two others south of the Choctaw fault (Wilburton, Panola) have been completed. The Talihina Quadrangle has been started, and completion of a strip of 7.5′ quadrangles across the frontal belt to the Arkansas state line is planned. All the Oklahoma mapping will be compiled at a scale of 1:24,000. The final products will constitute the most-detailed available geologic maps of the area.

Charles Ferguson presented the results of a detailed analysis of paleocurrent data collected from the Atoka Formation in the frontal belt in the area of detailed mapping and from a reconnaissance survey to the southwest as far as the town of Atoka. This analysis shows that Atoka Formation flysch accumulated in several sub-basins parallel to and landward of the principal, deep Ouachita trough. These sub-basins were formed by south-side-down, basement-involved, listric growth faults that were activated during the initial stages of the Ouachita orogeny. The northernmost basins contain sandstone beds that were deposited by northeast-directed paleocurrents, suggesting an Arbuckle Mountains source area. This contrasts with the west-directed, time-equivalent paleocurrents to the south. The steplike geometry of the growth-fault blocks is believed to have influenced the development of thrust faults during the later stages of the Ouachita orogeny.

LeRoy Hemish described the results of his mapping in the Arkoma basin immediately north of the Choctaw fault. He has mapped the Atoka, Hartshorne, McAlester, Savanna (subdivided into several unnamed shale units and seven informal but mappable sandstone members), and Boggy Formations. Of particular interest to workers in the area is his recognition of north-directed paleocurrents; this contrasts with the generally accepted idea of a source terrain to the north for the Desmoinesian strata in the Arkoma basin.

Neil Suneson and Dorothy Smith then briefly described OGS efforts at subsurface mapping in the Arkoma basin. The cross sections will tie in with those by Suneson and Ferguson to the south in the Ouachita Mountains and with the surface geology being mapped by Hemish. Jim Chaplin of the OGS brought the workshop up to date on his bio- and chronostratigraphic data compilation for the entire Ouachita Mountains. The results of his efforts will be published at the end of the year.

Joe Whiteside, a graduate student working with Dr. Robert Grayson at Baylor University, then spoke about his Mississippian–Pennsylvanian conodont work in the frontal Ouachitas in Oklahoma. Whiteside is working closely with the OGS field geologists to better define some of the similar-looking shales that occur throughout the stratigraphic section; he is particularly interested in the conodont biostratigraphy of the Mississippian–Pennsylvanian boundary and the Lower Pennsylvanian.

Jane Weber, organic geochemist with the OGS, briefly spoke about her source-rock work in the Ouachitas and her plans to collect and analyze oils from producing wells throughout the mountains. This work is under way. Michelle Summers then described the OGS/Natural Resources Information Systems well file for the Ouachita Mountains and Arkoma basin.

Following the Oklahoma Geological Survey presentations, Boyd Haley, geologist with the Arkansas Geological Commission, presented the results of his and Charles Stone's mapping throughout the Ouachita Mountains in Arkansas. Of particular interest is their discovery of a major NE-trending lineament separating a terrain characterized by broad, open synclines of Pennsylvanian strata to the west (the "central belt" of the Oklahoma Ouachitas) and one characterized by tightly folded, faulted, and detached Mississippian and older rocks to the east. This lineament is particularly evident on aerial photographs and recently acquired SLAR imagery, and has been mapped by Haley and Stone.

Bob Kosanke from the U.S. Geological Survey in Denver then spoke about his work with the palynomorphs in the Stanley, Johns Valley, Atoka, and Hartshorne Formations in the Ouachitas frontal belt and southern part of the Arkoma basin. While age assignments for the samples are not available yet, many of the samples are productive and should enable comparisons with reference sections. Wayne Newell, Office of Regional Geology, USGS, Reston, Virginia, then described future funding possibilities for the USGS COGEOMAP program and the Ouachita COGEOMAP program in particular.

After the workshop meetings in Norman, many of the participants drove to Mena, Arkansas, to look at the geology in the western part of the Arkansas Ouachitas. The first stop was a classic locality of the Johns Valley Formation from which middle Morrowan ammonoids have been collected and in which olistoliths of lower Morrowan Prairie Grove sandstone (Hale Formation), St. Clair Limestone (Silurian), Fernvale and Plattin Limestones (Upper Ordovician), and Cotter Dolomite (Lower Ordovician) are present. The middle part of the Jackfork sandstone was examined near Y City, and an excellent exposure of chert conglomerate within the Hot Springs sandstone member of the Stanley Shale was examined at Potter Junction. Also at this outcrop was the contact between the Arkansas Novaculite and the Stanley Shale, representing the transition from early, thin, starved-basin deposits (novaculite) to thick flysch deposits (Stanley). The field trip then visited an outcrop of complexly folded Stanley Formation near the lineament that separates the broadly folded central belt from the tightly folded strata to the south. At the end of the first day, the field-trip participants examined excellent exposures of Jackfork turbidites on the east end of Rich Mountain, the Wildhorse Mountain Member of the Jackfork along the crest of Rich Mountain, and the Stanley–Jackfork contact at the west end of Rich Mountain along Talimena Drive.

On the second day of the field trip, participants were led by OGS geologists Neil Suneson, Charles Ferguson, and LeRoy Hemish through the Ouachita Mountains frontal belt north of Talihina and the Sans Bois Mountains north of Panola and Wilburton. An exposure of Johns Valley shale was examined in a road cut near an area where slumping has occurred along Highway 82. West of Bengal, the origin of some lower Atoka turbidite sandstones with opposing current-direction indicators was discussed. Hemish then led the field trip into the Sans Bois Mountains to look at outcrops of the Savanna Formation, featuring almost-continuous exposures of alternating shales and sandstones along an eroded gas-well road ditch. Sedimentary structures in the sandstone unit that contains Robbers Cave were particularly interesting. The basal part of the Boggy Formation was observed in Robbers Cave State Park. Well-preserved plant impressions at the top of the Bluejacket Sandstone Member were viewed at a gas-well pad southwest of Lake Wayne Wallace (see cover photo, *Oklahoma Geology Notes*, v. 48, no. 2). The trip ended at Robbers Cave, where massive blocks of sandstone have separated along joints and slid downslope to form the protected recess or "cave."

The meeting participants agreed that the COGEOMAP workshops are a useful way to exchange new information and ideas. Next spring, the Arkansas Geological Commission will host the third workshop in Little Rock.

Participants of the COGEOMAP field trip pause to rest on an outcrop of Jackfork sandstone atop Rich Mountain just east of the Arkansas–Oklahoma state line, April 8, 1988. Top row, left to right: Charles Stone, Bill Perry, Wayne Newell. Middle row: Harry Tourtelot, Ken Johnson, Neil Suneson, Ken Luza, LeRoy Hemish. Bottom row: Robert Kosanke, Michelle Summers, Boyd Haley, Charles Ferguson.

ANADARKO BASIN RESEARCH HIGHLIGHTED

The Anadarko basin symposium, held April 5–6 at the University of Oklahoma, was highly successful. About 250 people from throughout the United States attended the meeting at the Oklahoma Center for Continuing Education in Norman. The Oklahoma Geological Survey and the U.S. Geological Survey were cosponsors of the symposium. Kenneth S. Johnson, associate director of the OGS, was general chairman for the symposium.

The meeting was an opportunity to highlight recent research activities in one of the major petroleum basins of the United States. Twenty-one papers were presented on a wide range of petroleum-related subjects, including basin evolution and petroleum exploration (2 papers); thermal maturity (2); geochemistry of oils and gases (3); structure and tectonics (5); sedimentology, mineralogy, biostratigraphy (7); paleohydrology (1); and information systems (1). In addition to the 21 formal papers, 18 more reports were given in an informal poster session that was available to participants during the entire two-day program.

Of the 250 attendees, about 70% were from industry or were consultants, about 20% represented state or federal agencies, and about 10% were university faculty or students. This attendance shows that the program clearly met some of the needs of industry in this time of revitalization, but also provided a good balance of government and academic input.

The proceedings of the symposium are to be published by the OGS as a bulletin late in 1988 or early in 1989. In addition to the formal papers, it is hoped that abstracts or extended abstracts will also be submitted by most of those involved in the poster session.

Kenneth S. Johnson

UPDATED CATALOG OF THESES AVAILABLE

The Oklahoma Geological Survey has recently released Special Publication 88-1, *Catalog of Theses and Dissertations Granted by the University of Oklahoma in Geology, Geophysics, and Selected Titles from Geological and Petroleum Engineering, 1904–1986*, compiled by Claren M. Kidd, OU Geology and Geophysics Library librarian.

Author's preface:

> Although classes began at the University of Oklahoma in 1892, no instruction in geology was offered until the arrival of Charles Newton Gould in 1900. In the early years, requirements for the Bachelor of Arts degree in geology included preparation of a written thesis. The first to earn this degree was Charles T. Kirk, who was awarded his diploma in 1904. Only a few of these B.A. theses were written, but since that 1904 beginning, approximately 900 theses and dissertations have been accepted as partial requirement for degrees in geology and geophysics. These are listed herein.
>
> Theses from the College of Engineering believed to be of interest to petroleum

geologists and geophysicists have been included in this list. Subjects include reservoir properties, exploration techniques, and energy-resources evaluation.

Theses and dissertations are listed by author and by date and are indexed according to localities covered. For convenience of reference, an outline map showing counties in Oklahoma is included at the back of the catalog.

Copies of most of the theses are available for inspection in Bizzell Memorial Library of the University of Oklahoma, and in the Geology and Geophysics Library in Gould Hall on campus. The selected engineering theses can be found in Bizzell Memorial Library and in the campus Engineering Library in Felgar Hall. Theses and dissertations can be obtained through Interlibrary Loan on request through any official library. The request should be addressed to the Interlibrary Loan Office, University of Oklahoma, Bizzell Memorial Library, 401 W. Brooks, Norman, Oklahoma 73019. Also, dissertations accepted since 1955 can be purchased from University Microfilm, 300 North Zeeb Road, Ann Arbor, Michigan 48106, either in microfilm or hard copy.

Special Publication 88-1 may be purchased over the counter or postpaid from the Oklahoma Geological Survey at the address given inside the front cover of this issue. The price is $7.

OGS ISSUES REPORT OF CORE-DRILLING IN THE NORTHEASTERN OKLAHOMA COAL BELT

Report of Core-Drilling by the Oklahoma Geological Survey in Pennsylvanian Rocks of the Northeastern Oklahoma Coal Belt, 1983–86, by LeRoy A. Hemish, has recently been issued by the Survey as Special Publication 88-2.

Excerpts from author's text:

> The Oklahoma Geological Survey completed several core-drilling projects in the northeastern Oklahoma coal belt during 1983–86. The purpose of the projects was to gather information on geologic characteristics of various coal beds and associated strata, and to examine strata where accuracy of existing interpretations of stratigraphy and structure were questionable.
>
> Detailed descriptions of lithologic units cored in 85 holes, as well as stratigraphic interpretations, are presented in this report.
>
> The purpose of the core-drilling studies conducted by the OGS in the northeastern Oklahoma coal belt was to gather information concerning the geologic characteristics of the coal beds and associated strata. The data were then used (along with data from other sources) to determine the areal extent, amounts, and chemical characteristics of the coal deposits. The results are being published by the OGS in a series of county reports evaluating the coal resources and reserves of Oklahoma.
>
> A second purpose was to examine strata in parts of the Oklahoma coal belt where accuracy of interpretations of stratigraphy and structure were questionable. Revisions of geologic mapping in some areas in McIntosh, Muskogee, and Okfuskee Counties are in progress.

Special Publication 88-2 is available over the counter or postpaid from the Oklahoma Geological Survey at the address given inside the front cover of this issue. Copies are $7 each.

OIL AND GAS INFORMATION: CONFERENCE PROCEEDINGS RELEASED

Proceedings of the First Conference on Oil and Gas Information and Data-Base Management, coordinated by Michelle J. Summers, was released recently by the Oklahoma Geological Survey as Special Publication 88-3. The 266-page report is a compilation of 19 papers presented at the conference, sponsored jointly by the Bartlesville Project Office of the U.S. Department of Energy and the Oklahoma Geological Survey. The conference, held in Norman, Oklahoma, October 20–21, 1987, brought together representatives from 14 states, the U.S. Department of Energy, and the U.S. Geological Survey.

Excerpts from the preface, by Charles J. Mankin:

> The theme of the conference was to develop a better understanding and appreciation of the magnitude and diversity of information available on oil-and-gas activities from state and federal agencies. The rationale for this theme is based on the recognition that future domestic hydrocarbon production, at least on-shore in the lower 48 states, must come increasingly from additional recovery from prior discoveries. Thus, a broad range of geological, reservoir-engineering, and production-history information on currently producing as well as abandoned fields is expected to become more important in such future developments.
>
> Presentations by state representatives, the U.S. Department of Energy, and the U.S. Geological Survey provided a good view of the diversity and complexity of hydrocarbon information available in the public sector. Not only does the type of information collected vary substantially from state to state, but the systems employed to collect, store, and use that information cover an equally broad spectrum.
>
> This conference therefore achieved its objective—namely, to examine the diversity of philosophies, methodologies, and procedures used in the collection, management, and utilization of hydrocarbon information by public-sector agencies. The conference provided also a better understanding among the participants of the reasons for this diversity. Hopefully, the papers contained in these proceedings will convey to the reader some of this same understanding and appreciation. If so, perhaps this conference will have served as an important first step in the eventual establishment of a nationally compatible system of hydrocarbon information.

Special Publication 88-3 is available over the counter or postpaid from the Oklahoma Geological Survey at the address given inside the front cover of this issue. The price is $9.

Lucy Finnerty
(1905–1988)

In Memoriam

LUCY HART FINNERTY

Former Geology Librarian

Lucy Finnerty died March 5 in Norman Regional Hospital at the age of 82. She had served for 23 years—from September 1944 to 1956 and from August 1960 to July 1971—as librarian for the University of Oklahoma's geology library, where she worked jointly with the Oklahoma Geological Survey and the School of Geology and Geophysics to provide and maintain a comprehensive and up-to-date source of printed material on all phases of the earth sciences from all parts of the world.

Lucy was born to Charles E. and Anna Thomas Hart on September 26, 1905, in Muskogee, when that part of Oklahoma was still Indian Territory. She attended the University of Oklahoma, earning a Bachelor of Arts degree in 1926 and working as a student assistant in the University Library. She worked in the circulation department of the library from 1926–29, then took a year off to complete work toward a B.S. in library science at the University of Illinois, which was awarded in 1930. She then returned to OU and to the University Library, where she became head of the periodicals department. She worked for the main library during 1930–32 and again from 1940–43.

Lucy took time off again at this point, this time to give birth to her son, Tom, who arrived on Christmas Eve, 1943. (I don't have to check the records for this bit of information, because Lucy's son and our oldest son were born one month apart and grew up together.)

In 1944, Lucy became the librarian for our geology library, although according to Claren Kidd (1975a,b), who has headed the library since July 1973, V. E. Monnett, who was at that time director of the School of Geology, "was skeptical about having a woman librarian." He was skeptical about women in general in his geology school, for that matter, but it was wartime, and the men had gone to the service, and the library needed a librarian. Fortunately, Monnett saw the light and recognized Lucy Finnerty as the valuable acquisition she was.

At any rate, Lucy Finnerty came to the Oklahoma Geological Survey and to the School of Geology in 1944 and remained until 1956—one of the busiest periods for the geology library, when enrollment in geology increased dramatically, when the science both expanded its scope and became more specialized, when the complement and variety of teaching staff increased correspondingly, when the need for printed material for library research rose accordingly. Lucy in turn rose to fill the need.

By her own reckoning, the library in 1945 contained 20,531 "bound and accessioned" books (Finnerty, 1945). Good, but not good enough. As she herself said, "The library is always on the alert to secure all available material in the field of geology." So she arranged for acquisitions of books, journals and other periodicals—foreign and domestic—maps, guidebooks, whatever was needed and attainable with funds available or through exchange. She filled in the gaps in the collection of Corporation Commission well logs, this by hand typing because there were no Xerox machines for this purpose. She filled in the gaps in the map collection, in the collection of scout tickets. She chose all these additions with care and with understanding of what was needed. She handled donated materials also with care and with concern for donors. With the help of advice from knowledgeable members from the profession, she built our geology library into one of the outstanding such collections extant, as it remains today under Claren Kidd.

In 1956, Lucy left the library for four years. She had pioneer open-heart surgery for replacement of a valve in her heart. She opened a gift shop on Norman's Campus Corner together with a friend. She took care of her mother, her son, friends.

She resumed her position at the geology library in the late summer of 1960, remaining until the summer of 1971, by which time the collection of cataloged volumes had increased to some 75,800 volumes — a lot of books for one departmental library—plus all those thousands of maps and scout tickets, and the hundreds of thousands of Corporation Commission well logs. That was a lot of literature for one lady to supervise, and she could tell you just about where everything in that library was or point you toward finding it. Having filled in the gaps, she took good care of the literature.

But her care, her service didn't stop there. She filled in the gaps in a lot of lives, too. She was always taking care of someone. Lucy spent a lifetime in service, not only to her profession but to people, her family, her church, her sorority, her community, to humanity—a remarkable, wonderful woman.

She was a member of the American Library Association, the Oklahoma Library Association, Beta Phi Mu (honorary librarian), the Oklahoma Heart Association, Alpha Phi social sorority and their alumnae association, P.E.O., and the First Baptist

Church of Norman. She served on committees and boards for all those organizations. She chaired or conducted Heart Fund drives year after year. She was named an assistant professor at OU, the only departmental librarian to that time to have been given faculty rank at OU.

Lucy is survived by her son, Tom, of Dallas, who is in management with American Airlines; by three cousins; and by many friends and associates. She will be deeply missed by all who have known her.

References

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Oklahoma Geology Notes, 1971, Two staff members to retire this summer: Oklahoma Geology Notes, v. 31, p. 56.

The Sooner Geologist, 1970, Been to a good library lately? Or, research for fun and profit: The Sooner Geologist, v. 4, no. 1, p. 3–8.

——— 1971, Lucy Finnerty retires: The Sooner Geologist, v. 4, no. 2, p. 11–13.

Elizabeth A. Ham

Services were held March 8 in Mayes Chapel of Remembrance in Norman with Dr. Lavonn Brown of the First Baptist Church of Norman officiating. Burial was in Sunnylane Cemetery. Memorial contributions in her name may be sent to the Alpha Phi Foundation Heart Memorial, 1930 Sherman Ave., Evanston, Illinois 60201.

SEPM INSTALLS NEW OFFICERS

Officers in the Society of Economic Paleontologists and Mineralogists for the 1988–89 term are:

President: PETER A. SCHOLLE, Southern Methodist University
President-Elect: RAYMOND L. ETHINGTON, University of Missouri at Columbia
Vice-President: EDWARD D. PITTMAN, Amoco Research Center, Tulsa
Secretary-Treasurer: RICHARD A. DAVIS, JR., University of South Florida
Paleontology Councilor: ALAN A. EKDALE, University of Utah
Sedimentology Councilor: ARNOLD H. BOUMA, Louisiana State University
Editor, *Journal of Sedimentary Petrology*: NORMAN D. SMITH, University of Illinois at Chicago
Editor, *PALAIOS*: LEO F. LAPORTE, University of California at Santa Cruz
Editor, Special Publications: BARBARA H. LIDZ, U.S. Geological Survey

SEPM ANNUAL MIDYEAR MEETING
Columbus, Ohio, August 21–24, 1988

Hosted by the Ohio State University at Columbus, the Society of Economic Paleontologists and Mineralogists Fifth Annual Midyear Meeting will feature the following meetings and field trips:

Symposia and Technical Sessions

August 22

Carbonate Diagenesis I
Paleobiology of Benthic Invertebrates
Late Paleozoic Deltaic Systems
Limnology of the Great Lakes

August 23

Carbonate Diagenesis II
Siliciclastic Depositional Systems I and II
Paleocommunity Temporal Dynamics: Patterns and Processes of Long-Term Community Development I and II (Paleontological Society)
Carbonate Depositional Systems I
General Geology

August 24

Carbonate Depositional Systems II
Diagenetic Interactions in Siliciclastic Sediments I and II
Mixed Carbonate/Siliciclastic Depositional Systems I and II
Facies Models and Ice Dynamics at the Margin of a Midcontinental Ice Sheet
New Approaches in Biostratigraphy

Field Trips

Lower and Middle Silurian of the Eastern Flank of the Cincinnati Arch and the Appalachian Basin Margin, Ohio, *August 21*
Lithofacies and Ichnofossils of Selected Ordovician and Upper Devonian Units Along the Cincinnati Arch in Kentucky, *August 21*
An Upper Devonian–Lower Mississippian Transgressive–Regressive Clastic Sequence in Central Ohio, *August 21*

Pennsylvanian (Conemaugh) Fluvio-Deltaic and Marine Depositional Systems During Mild Alleghenian Tectonism near Huntington, West Virginia, *August 21*
Sedimentology, Stratigraphy, and Paleontology of Upper Ordovician Rocks in Southwestern Ohio, *August 25*
A Lower Mississippian Deltaic Shallow-Marine Complex in Central Ohio, *August 25*
Depositional Facies of Wisconsinan Ice-Sheet Materials of the Scioto Glacial Lobe, *August 25*
Geologic Setting and Coastal Processes Along the Shore of Lake Erie, North-Central Ohio, *August 25*

For further information about the meeting, contact SEPM, Meetings and Educational Programs, P.O. Box 4756, Tulsa, OK 74159-0756; (918) 743-9765. The preregistration deadline is July 21.

UPCOMING MEETINGS

Fifth International Symposium on the Ordovician System, August 9–12, 1988, St. John's, Newfoundland. Information: Chris R. Barnes, ISOS, Dept. of Earth Sciences, Memorial University, St. John's, Newfoundland A1B 3X5, Canada; (709) 737-8143.

GSA Penrose Conference, "Marine Evaporites: Genesis, Alteration, Associated Deposits," August 28–September 2, 1988, Detroit, Michigan, and Windsor, Ontario. Deadline for applications is June 30. Information: Peter Sonnenfeld, Dept. of Geology, University of Windsor, Windsor, Ontario N9B 3P4, Canada; (313) 963-6112 or 6113, ext. 2490.

Geographic Information Symposium, September 26–30, 1988, Denver, Colorado. Information: Thomas Usselman, GIS Symposium, National Academy of Sciences, 2101 Constitution Ave., Washington, DC 20418.

American Institute of Professional Geologists, National Convention, September 28–30, 1988, Tulsa, Oklahoma. Information: James E. O'Brien, General Chairman, P.O. Box 916, Mannford, OK 74044; (918) 865-4490.

Society of Economic Paleontologists and Mineralogists, Midcontinent Section, Annual Meeting, October 8–9, 1988, Knoxville, Tennessee. Information: David Houseknecht, Dept. of Geology, University of Missouri, Columbia, MO 65211; (314) 882-6785.

Association of Engineering Geologists, 31st Annual Meeting, October 16–21, 1988, Kansas City, Missouri. Information: William Bryson, Kansas Corporation Commission, 4th Floor, State Office Bldg., Topeka, KS 66612; (913) 296-5113.

Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Restoration, November 9–11, 1988, Houston, Texas. Information: National Water Well Association, Education Dept., 6375 Riverside Dr., Dublin, OH 43017; (614) 761-1711.

NOTES ON NEW PUBLICATIONS

Hydrologic Data for Selected Streams in the Coal Area of Southeastern Oklahoma, July 1978 to September 1982

Data collected in four counties during an investigation of the effects of coal surface mining on the hydrology in the southeastern Oklahoma coal resource area is presented in this 337-page USGS open-file report by Stephen P. Blumer and Lee Ann Alf. The study was conducted to determine the characteristics of the regional hydrologic system and to detect and document changes in the system that may occur as the result of coal surface mining.

Order OF 86-319 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 $51.25 for a paper copy; add 25% to the price for shipment outside North America.

Ground-Water Quality Assessment of the Central Oklahoma Aquifer, Oklahoma: Project Description

The Central Oklahoma aquifer project is part of the National Water-Quality Assessment (NAWQA) program, a pilot program began by the USGS to assess the quality of the nation's water resources. The Central Oklahoma aquifer was selected for study by the NAWQA program because it is a major source for water supplies in central Oklahoma and because it has several known or suspected water-quality problems. The project is described by Scott C. Christenson and David L. Parkhurst in this 30-page open-file report.

Order OF 87-235 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 $5.25 for a paper copy; add 25% to the price for foreign shipment.

Chemical Analyses of Water Samples from the Picher Mining Area, Northeast Oklahoma and Southeast Kansas

Chemical analyses of water samples collected during a study of the Picher mining area and Tar Creek are presented in this 43-page USGS open-file report. The study was undertaken to determine the chemical evolution of mine water and the effects of mine-water discharge on the chemistry of surface water. In this report, author David L. Parkhurst includes only interpretations related to the methods and accuracy of chemical analyses. No interpretations of the data are made in terms of geochemical reactions.

Order OF 87-453 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 $7 for a paper copy; add 25% to the price for mailing to countries outside North America.

Innovative Approaches to Mined Land Reclamation

Edited by C. L. Carlson and J. H. Swisher, this book contains collected papers.

Order from: Southern Illinois University Press, P.O. Box 3697, Carbondale, IL 62902-3697. The price is $50 plus $1.50 postage; Illinois residents must add 6.25% sales tax.

OKLAHOMA ABSTRACTS

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

Hunton and Sycamore Reservoirs in Golden Trend Field, Garvin County, Oklahoma

R. P. SORENSON, F. W. WHITE, and C. N. CLARK, Anadarko Petroleum Corp., Oklahoma City, OK

During the 1980s, significant reserves have been developed from Hunton and Sycamore reservoirs subcropping beneath the basal Desmoinesian unconformity, on the east flank of the Anadarko basin in T2, 3N, R2, 3W. Earlier oil production from the giant Golden Trend field has been largely from several overlapping Pennsylvanian stratigraphic traps, with only a minor contribution from pre-Pennsylvanian reservoirs within the study area. Approximately 200 Hunton/Sycamore producers have been drilled since 1982 in a program that continues to be active and competitive, despite the general industry downturn.

The economic success of this play is the result of seven major factors: (1) establishment of a large productive area with a nearly 100% success rate; (2) knowledge that the Hunton is primarily a fractured reservoir and does not require matrix porosity in the Bois D'Arc and Chimneyhill formations, as assumed by earlier operators; (3) recognition that the Haragan and Henryhouse Formations of the Hunton Group are productive, despite unimpressive log characteristics; (4) discovery that not only the local clean limestones, but also the widespread shaly, dolomitic siltstones of the Sycamore are productive, added an important second reservoir; (5) application of large-volume, high-rate, water fracs without proppant that lowered costs without sacrificing productivity; (6) penetration of Pennsylvanian Hart and Gibson sandstones added important behind-pipe reserves; and (7) high initial flow rates provided rates of return that compensate for the relatively high finding costs per barrel.

Reprinted as published in the American Association of Petroleum Geologists *Bulletin*, v. 71, p. 997.

Prediction of Pressure Depletion from Wireline and Mud Logs, Golden Trend Field, Garvin County, Oklahoma

R. P. SORENSON, F. W. WHITE, Anadarko Petroleum Corp., Oklahoma City, OK; and J. C. STRUCKEL, Geosearch Logging, Inc., Edmond, OK

The Golden Trend, a giant oil field encompassing several overlapping Pennsylvanian stratigraphic traps on the eastern flank of the Anadarko basin, has undergone a resurgence in the 1980s with deeper drilling for pre-Pennsylvanian targets.

Approximately 200 new wells in and near the Antioch Southwest, Panther Creek, and Elmore Northeast waterflood units (T2, 3N, R2, 3W) have encountered evidence of undrained reserves in both established and new pay intervals of Pennsylvanian Hart and Gibson sandstones. Although all porous Hart and Gibson sandstones in the study area were originally oil bearing, evaluation of the state of depletion is necessary for planning future recompletions to these reservoirs.

In general, wireline and mud logs over intervals with known production histories exhibit characteristics suggestive of pressure depletion, even in areas of old waterfloods. The most consistent parameters correlating to low reservoir pressure are lost circulation, lack of an increase in penetration rate when drilling porous sandstone, excessive "gas effect" on neutron-density logs, and low methane and total gas levels on the mud logs. The resistivity invasion profile also reflects lower pressure, but is subtle. The SP curve and gas composition on the mud log do not vary substantially as a function of pressure. Visual sample shows are slightly weaker in depleted sandstones, but are less reliable, owing to dependence on reservoir quality and variations between geologists on oral descriptions of show quality.

Reprinted as published in the American Association of Petroleum Geologists *Bulletin*, v. 71, p. 997.

Geophysical Case History of South Centrahoma Prospect, Coal County, Oklahoma

FRANK X. SCHLOEDER, FXS Seismic Services, Tulsa, OK

The South Centrahoma prospect is an example of the successful use of aeromagnetic data in locating basement-controlled structures in mature exploration areas. Although commercial hydrocarbons were not found, the test well did confirm a positive structure that had been undetected during 50 years of development of the adjacent Centrahoma field.

In late 1983, Clyde Petroleum commissioned Borehole Exploration Corporation to acquire, process, and interpret 430 line-mi of "high-resolution" aeromagnetic data in Coal County, Oklahoma. From this survey, nine prospective leads were identified. The South Centrahoma prospect, due south of the Centrahoma field, is on the downthrown side of a major left-lateral strike-slip fault system that is expressed on aeromagnetic data. The adjacent Centrahoma field, in the Franks graben of Coal County, Oklahoma, has produced 3.4 million bbl of oil and 93.5 bcf of gas from six different reservoirs, ranging from the Ordovician Oil Creek through the Pennsylvanian Booch. This field is a cross-faulted anticline that is expressed as a surface structure, and for this reason probably attracted the Carter Oil Company to drill in 1937.

Clyde Petroleum pursued a typical evaluation process for the prospect, including the purchasing and reprocessing of both Singlefold (100%) and modern CDP seismic data. These purchased data hinted at a prospect where the original aeromagnetic data had suggested, but were inconclusive. Two detail seismic lines were acquired. These modern data confirmed a positive high-relief structure similar to that shown on the aeromagnetic data. Closure ranged from 100 ft at the shallow Gilcrease sandstone to 250 ft at the Hunton Limestone.

Clyde Petroleum drilled the Goss 1–3 in NW¼NW¼, Sec. 1, T1N, R9E, to a depth of 8,500 ft. The Goss well confirmed the structure, but found no commercial hydrocarbons. Some expected porosity zones were not present, some were wet, and the deeper zones were complexly faulted. Perhaps this faulting explains the lack of a trapping mechanism.

Reprinted as published in the American Association of Petroleum Geologists *Bulletin*, v. 71, p. 996–997.

Variation of Oil Composition in Vicinity of Arbuckle Mountains, Oklahoma

I. ZEMMELS and C. C. WALTERS, Sun Exploration & Production Co., Dallas, TX

Fifteen oils in an 8-county area in the vicinity of the Arbuckle Mountains were classified into 6 oil types: stable platform type, reservoired in the Simpson Group (Seminole and Cleveland Counties); Mill Creek syncline type, in Simpson Group, Arbuckle Group, and Deese Formation (Garvin, Murray, Carter, and Marshall Counties); Joiner City field type, in Woodford and Bois d'Arc formations (Carter and Jefferson Counties); *Gloeocapsamorpha* type, in Viola Limestone (Love County); Hoover field A-type in Arbuckle Group (Garvin County); and Fitts field type, in McAllister Formation (Pennsylvanian) (Pontotoc County).

The stable platform, Mill Creek syncline, and Joiner City field types have a common element (diminished C_{32} hopane) and are thought to be derived from distinctly different facies of the Woodford Formation.

Reprinted as published in the American Association of Petroleum Geologists *Bulletin*, v. 71, p. 998.

Unconformities: Key to Hydrocarbon Migration and Entrapment

GLENN S. VISHER, Geological Services & Ventures, Inc., Tulsa, OK

Analysis of hydrocarbon distribution in the Mid-Continent area and throughout the world indicates that unconformities control the depositional history, the reservoir development pattern, migration pathways, and hydrocarbon-seal development. Anticlinal and fault traps are most commonly the site for accumulation of hydrocarbons, but many structures either do not contain hydrocarbons or contain only minor accumulations. Traps not closely associated with an unconformity surface cannot segregate hydrocarbons from the many thousands of pore volumes of fluid that migrate along the unconformity surface from the compacting source rocks in the basin center.

Unconformities caused by periodic changes in sea level are readily observed from seismic and log sections and facies models. Unconformities below the Simpson, Woodford, Morrowan, and the Wolfcampian granite wash are the controls for the accumulation of hydrocarbons. Patterns of truncation, onlap, topography, and structural history of these surfaces is the key to discovering new hydrocarbon accumulations in the Mid-Continent.

Location of subtle traps associated with these unconformities has not been widely used in the Mid-Continent. Detecting hydrocarbon accumulations requires isopach mapping of intervals between event markers, both below and above the unconformity surface. These isopach maps provide information on timing and pattern of the structural history, topographic control for onlapping reservoir units, points for fluid migration into overlying onlapping sequences, and truncation of underlying reservoir units. Study of these maps indicates areas for hydrocarbon accumulations in various stratigraphic units, including the Simpson, Hunton, Misener, Mississippian carbonates, Morrowan, and a succession of onlapping Atokan and Desmoinesian rocks and in Wolfcampian granite wash.

Reprinted as published in the American Association of Petroleum Geologists *Bulletin*, v. 71, p. 998.

1340–1480 Ma Anorogenic Granite and Rhyolite of the Midcontinent: Age, Distribution, Chemical, and Petrographic Characteristics

M. E. BICKFORD, W. R. VAN SCHMUS, and D. S. COLEMAN, Dept. of Geology, University of Kansas, Lawrence, KS

Middle Proterozoic rocks of the midcontinent region are characterized by anorogenic granitic plutons and extensive rhyolite fields. These rocks were formed during two episodes of igneous activity: 1450–1480 Ma in the eastern midcontinent and 1340–1400 Ma in the southwestern midcontinent. Apparently isolated coeval plutons occur to the north, where they characteristically display sharp, circular magnetic anomalies on the order of 1000 gammas above regional background, suggesting that the rhyolite may have extended farther north than the present, pre-late Cambrian subcrop.

These rocks are variable both mineralogically and petrographically, but many are characterized by high abundances of magnetite, sphene, apatite, and zircon, and all contain perthitic alkali feldspars. Many are granophyric and some have rapakivi textures. Chemically, they are subalkalic and metaluminous; many are Fe-rich. All are relatively enriched in incompatible elements such as Zr, Nb, Y, Rb, Sr, and Ba and plot in the within-plate granite fields on the tectonic discrimination diagrams of Pearce et al. (1984). The Nd isotopic data of Nelson and DePaolo (1985) indicate mantle separation ages of about 1800 Ma regardless of crystallization age, indicating that these rocks were derived from anatexis of pre-existing continental crust. They probably form a veneer that lies upon the older crust from which they were derived.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1987*, v. 19, no. 7, p. 588–589.

Occurrence of Filter-Feeding Pelecypods in a Middle Ordovician (Blackriveran) Intra-Cratonic Basin, Criner Hills, Oklahoma

ROBERT C. FREY, Dept. of Geology, Centenary College, Shreveport, LA

The Middle Ordovician Pooleville Member of the Bromide Formation (Blackriveran) exposed in the Criner Hills, Oklahoma, represents a low energy, subtidal facies deposited as a fine-grained carbonate sequence within an intra-cratonic tectonic basin, the South Oklahoma Aulacogen. Upper Pooleville facies in the

Criner Hills include 4–13 cm thick lime mudstone and wackestone beds representing subtidal deposition along the axis of the basin at depths below fair-weather wave base. These strata contain a fauna dominated by small modiomorphid pelecypods associated with large linguloid and epifaunal discinid and siphonotretatid inarticulates, cyclomyan, monoplacophorans, endocerid nautiloids, trilobites, cryptostomes, and strophomenid, and orthid brachiopods.

This Bromide assemblage contains elements in common with younger communities occurring in Late Ordovician siliclastic mud-bottom facies in the Ohio valley. These shared elements include modiomorphid pelecypods, large linguloid and epifaunal trematid inarticulates, cyclomyan monoplacophorans, nautiloids, and trilobites. Articulate brachiopods and cryptostomes are absent from these later mud-bottom communities.

These Bromide assemblages indicate that modiomorphid pelecypods were constituents of Ordovician "offshore" shelf facies early in their geologic history. This is in contrast to current models of Ordovician benthic community evolution that suggest that modiomorphid and other filter-feeding pelecypods evolved in and were largely restricted to "nearshore" marginal shelf environments in the Early Paleozoic.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1987*, v. 19, no. 7, p. 668.

Trace Element Geochemistry and Origin of Early Cambrian A-Type Granites from the Southern Oklahoma Aulacogen

BARRY L. WEAVER and M. CAMERON, School of Geology and Geophysics, University of Oklahoma, Norman, OK; and M. CHARLES GILBERT, Dept. of Geology, Texas A&M University, College Station, TX

Laterally extensive granite sheets and rhyolite flows comprise one end-member of a bimodal igneous suite in the Eocambrian Southern Oklahoma Aulacogen. Intrusion and extrusion of silicic magmas postdated mafic igneous activity in the aulacogen, with the exception of a minor suite of diabase dykes.

Granites have 71.0–77.6% SiO_2, low Al_2O_3 and CaO contents (11.6–13.0% and >1.5% respectively) and Na_2O/K_2O ratios of 0.67–0.91. Trace element abundances vary widely in the granites (e.g., Rb = 104–232 ppm, Sr = 4–112 ppm), as do abundance ratios (e.g., Rb/Sr = 1.18–33.1). REE patterns show moderate LREE enrichment (Ce_N/Yb_N ratios = 3.0–6.2), with variable negative Eu anomalies (Eu/Eu* = 0.07–0.56).

Overall, the rhyolites have geochemical characteristics similar to the granites, but differ in some critical respects, e.g., Zr contents of the rhyolites are consistently higher (617–759 ppm) than those of the granites (176–591 ppm). On this basis, it seems unlikely that the rhyolites are the direct extrusive equivalents of the granites.

The granites and rhyolites have entirely "within-plate" trace element characteristics. The silicic rocks show little relative depletion in Nb compared to other incompatible trace elements, as would be expected in melts derived from typical calc-alkaline crustal material. However, as the chemical nature of Proterozoic basement granitoids is poorly known, such a source cannot be rigorously precluded. The trace element characteristics of the least evolved granites are comparable to those of the transitional "within-plate" mafic rocks of the aulacogen (e.g., both have similar La/Nb [0.9–1.1] and Rb/Nb [0.7–1.5]), suggesting that the granites and rhyolites may dominantly be derived from mafic parental magmas.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1987*, v. 19, no. 7, p. 884.

Seismic Hazard Assessment in the Central United States

ARCH C. JOHNSTON, Center for Earthquake Research, Memphis State University, Memphis, TN

The seismicity and approaches to seismic hazard estimation in the mid-continent of the United States are reviewed and evaluated. Particular uncertainties exist in this zone as compared to the western U.S. both because of the lack of identifiable seismogenic faults and because the low seismic activity rate forces an estimation of recurrence intervals of large earthquakes from an historical record that is a small fraction of the repeat times of these quakes.

The seismotectonic regime of the central U.S. is dominated by the Reelfoot rift complex and the associated New Madrid seismic zone. However, earthquakes capable of damaging ground motion ($m_b \geq 5.0$) have occurred elsewhere in the region in Ohio, Indiana, Illinois, Oklahoma, Texas, Kansas, Nebraska, Kentucky, and Missouri. Major tectonic structures include the Reelfoot rift complex, the Nemaha ridge/mid-continent rift and the Wichita–Ouachita orogenic belt. Widely varying opinions have been published as to the best way to delineate seismic source zones for these and less conspicuous features.

Detailed paleoseismic or neotectonic data that could usefully constrain hazard assessments are extremely sparse in the central U.S. The Meers fault scarp, with its evidence for Holocene displacement and lack of background seismicity, creates a new set of assessment problems. Development of site-specific probabilistic hazard curves are further hampered by the lack of strong ground motion data. Despite these difficulties, an overall characterization of the seismic hazard of the central U.S. is presented. The greatest contributions to uncertainty arise from specification of source zone boundaries and maximum possible earthquake.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1987*, v. 19, no. 7, p. 719.

Late Holocene Evidence Pertaining to the Seismogenic Style and Timing of Movement Along the Meers Fault, Southwestern Oklahoma

GREGORY A. KIENTOP, Dept. of Geology, Texas A&M University, College Station, TX

The Meers Fault, between the Wichita Mountains and the Anadarko Basin in southwestern Oklahoma, displays Late Holocene movement along its 26 km length in the form of a 5 m high fault scarp in an area with no historical seismicity. Due to its mid-continental tectonic setting, the Meers Fault has seen recent activity in

reassessment of its potential for generating hazardous earthquakes, the descriptions of its morphologies, and in the regional Quaternary stratigraphy. Little effort has been spent in direct investigations for evidence of the seismogenic style and timing of movement(s).

Three excavations were made at widely separated points along the fault scarp. The first excavation was cut through an alluvial fan created by an arroyo crossing the fault scarp which preserved a 2.33 m thick buried soil horizon continuous to bedrock (Post Oak Conglomerate–Permian). A second excavation was made in a stream cut through Hennessey Shale (Permian) in which the fault zone seems to be constrained to a 4 cm wide clay-rich alteration zone which displays continuous bilateral color changes from its respective parent materials. The third type of excavation was made in local cave sediments in an area of 25 miles radius to the fault. The unconsolidated cave sediments in six caves were studied for their geomorphic and paleoseismological characteristics.

The interpretations from these excavations revealed evidence that the Meers Fault has seen only one period of movement in the last 14,000 years at approximately 1,350 years BP. Some possibly seismically collapsed stream terrace deposits near the fault scarp and remnant topographic features in the Wichitas indicate that this reactivated fault may indeed be in a seismically hazardous zone in the mid-continent as presently described.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1987*, v. 19, no. 7., p. 727.

Deformation and Seismicity Along the Meers Fault, Oklahoma

NORMAN R. TILFORD, Dept. of Geology, Texas A&M University, College Station, TX

In some regions, most crustal deformation occurs through viscoelastic processes. It is premature to associate paleoseismicity with the Meers scarp.

Along the Meers fault, in the time since Permian rocks now exposed were lithified, some movements have taken place which were dominantly lateral. Other movements have been down to the north, and still others up on the north; a complex history of deformation. The most recent surface deformations demonstrating Holocene movement along the Meers fault take the form of a mix of folding and reverse displacements in Permian shales, limestones, and unconsolidated Quaternary sediments. Maximum reverse displacement of surfaces on Permian units, amounting to 2.6 meters underlying Quaternary to Holocene sediments, has been measured thus far. Displacement of surfaces developed on Permian units at other locations along the 27-kilometer-long continuous topographic scarp vary down to a few centimeters or none. In those instances, folding accounts for the total topographic deformation. The folding has produced stream reorientation and numerous tension and ramp features which do not display lateral offset. All positive folding documented to date occurs on the upthrust north block of the scarp suggesting that the up block is the side experiencing absolute movement.

Most, if not all, large and great earthquakes create evidence of strong shaking in unconsolidated sediments in the region where the event occurs, particularly those sediments which are saturated and weak. Landslides, debris flows, and other surface phenomena commonly accompany such seismicity. Thus far, recently initiated investigations have not brought such evidence to light in the Meers region. The Meers fault is vertical through the observable range, and being straight, offers no discernible asperities to reverse motion along clay dominated gouge zones.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1987*, v. 19, no. 7, p. 869.

Implications of the Meers Fault on Seismic Potential of Active Faults in the Central U.S.

ALAN R. RAMELLI and D. BURTON SLEMMONS, Center for Neotectonic Studies, Mackay School of Mines, University of Nevada, Reno, NV

The recent recognition of a number of active faults in the central U.S. indicates that the general lack of known surface faults is largely due to insufficient geologic study. These faults may have extensions or regional connections with other active structures. Successes of recent studies suggest that methods used in more active regions can provide a solid basis for seismic hazard assessments in midcontinent regions.

The 1811–1812 New Madrid and 1886 Charleston earthquakes demonstrate the vast destruction that would result from a large central/eastern U.S. event. Extensive damage, relative to more active areas, is largely due to lower seismic wave attenuation. However, certain relationships for large (i.e., surface rupturing) intraplate events have suggested this may be also due to greater source energy release. About 1,200 years ago, the Meers fault ruptured the surface with displacement of several meters and a length of about 40 km. Such displacements are quite large and may result from high stress drop. Most studies of scaling relations of small to moderate ($M<6$) central/eastern U.S. earthquakes have shown no such effect. This may indicate that events rupturing the entire seismogenic zone do not have the same scaling relations as smaller events. Relationships of "intraplate" earthquakes are usually derived from areas with higher rates of activity. Since this is a "mid-plate" setting, such comparisons may not be fully appropriate.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1987*, v. 19, no. 7, p. 812.

Ouachita Mountains Frontal Belt, Oklahoma

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New information on the stratigraphy of the Atoka Formation and structure of parts of the central Ouachita Mountains frontal belt is the result of 1:24,000 geologic mapping and well log analysis. The three major thrust sheets are, from north to south, the Choctaw, Pine Mountain, and Ti Valley. More basinward facies of Morrowan strata are present from north to south between individual sheets. Shelf-edge Wapanucka Limestone underlies Atoka Formation in the Choctaw

sheet. Johns Valley Shale (olistostrome) underlies Atoka in the Ti Valley sheet. Shelf-edge rocks are not present or have been cut off by thrusting in the Pine Mountain sheet. Olistostromes are present in the Pine Mountain sheet either in the lower Atoka or Johns Valley. The size of exotic blocks in the olistostromes varies from less than 1 m to over 300 m. Despite these differences, the basal Atoka "Spiro" sandstone or its lithostratigraphic equivalent is present in the Choctaw and Ti Valley sheets. The basal 1700 m of Atoka Formation in the Choctaw sheet were derived from the west; basinward, equivalent strata are easterly derived.

Detailed mapping of facing direction of Atoka sandstones indicates intra-sheet structural thickening is by folding rather than by repeated thrust faulting as previously interpreted. Large variations in the amount of dip may result from downslope creep.

Autochthonous strata are 3500 m deep beneath the trace of the Choctaw fault and 4500 m deep beneath the trace of the Ti Valley fault. Imbricate thrusts splay off the basal Choctaw fault. A transverse fault off of or overridden by the Pine Mountain fault cuts faults related to the Choctaw fault, supporting evidence that hindward thrust fault propagation has locally occurred within the frontal belt.

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Composition, Origin, and Source of Natural Gases in the Anadarko Basin, Kansas, Oklahoma, and Texas

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Natural gas production in the Anadarko Basin is from three geographically separated areas that can be differentiated by age of reservoir and by inferred nature of thermogenic origin. In the central basin, nonassociated gases are produced from Pennsylvanian sandstones. Gases become isotopically heavier ($\delta^{13}C_1$: -49.2 to -33.2 ‰, $\delta^{13}C_2$: -38.3 to -30.7 ‰, δD_1: -162 to -131 ‰) and chemically drier (C_1/C_{1-4}: 0.74 to 0.99) with increased depth of burial (as great as 6.6 km). Gases were generated mainly from interbedded shales with Type III organic matter at intermediate and late stages of thermal maturity. Deviations from trend are due to mixing of gases generated at different levels of thermal maturity over the past 250 m.y.

In the giant Hugoton field on the west flank, nonassociated gases are produced from Permian carbonates at depths less than 1 km. Gases display little compositional variation ($\delta^{13}C_1$: -44 to -42 ‰, $\delta^{13}C_2$: -34.3 to -32.2 ‰, δD_1: -196 to -154 ‰, C_1/C_{1-5}: 0.69 to 0.84). Because organic-rich, mature source rocks are not present at Hugoton field, gases probably were generated in the central basin from Pennsylvanian and older source rocks at intermediate stages of thermal maturity. This implies gas migration of distances of up to 300 km.

In the Sooner trend on the east flank, associated gases are produced from Mississippian carbonates at depths as great as 3 km and were generated from marine (Type II) organic matter at intermediate stages of thermal maturity. Associated oil correlates with extracts of upper Devonian–Lower Mississippian

Woodford Shale. Gases are isotopically lighter ($\delta^{13}C_1$: −47.3 to −41.7 ‰, $\delta^{13}C_2$: −38.1 to −31 ‰) and chemically wetter (C_1/C_{1-5}: 0.67 to 0.93) than those derived from Type III organic matter at the equivalent level of thermal maturity.

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Magnetic Pyrrhotite Related to Hydrocarbon Seepage at Cement Oil Field, Oklahoma—Implications for the Magnetic Detection of Oil Fields

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Ferrimagnetic pyrrhotite (po; Fe_7S_8), typically intergrown with more abundant, non-magnetic FeS_2, formed as a result of hydrocarbon seepage through Permian strata at the Cement field (Anadarko basin, OK). The po is confined to beds above oil and gas reservoirs. These beds, which lack detrital organic matter, contain higher sulfide and lower sulfate S (1.7 and 0.1 wt %, respectively) than correlative beds off the field (0.2 and 1.1 wt %, respectively). In the field, the isotopic ratios of sulfide S show a systematic decrease upward through the Permian section from positive values (maximum, + 12 per mil at 610–760 m depth) to negative values (− 1 to − 11 per mil at 32–230 m; − 26 to − 30 per mil at the surface). The geochemical results, together with time-temperature data derived from burial curves, point to two major sources of sulfide in the FeS minerals: (1) isotopically heavy sulfide that was derived from thermal cleavage of organic sulfur in petroleum; and (2) isotopically light bacteriogenic sulfide that, toward the surface, mixed with the heavy sulfide. The sulfate-reducing bacteria derived metabolic energy from leaking hydrocarbons and associated organic compounds. Po is the only possible natural source for reported aeromagnetic anomalies at Cement. Magnetite, found in well cuttings from Cement and considered previously by others to be the source of the anomalies, is contamination from drilling. Abiologic and biologic mechanisms in sulfidic seepage plumes are capable of generating magnetic sulfide minerals. At present, concentrations of secondary magnetite that are engendered by seepage and that produce aeromagnetic anomalies have not been documented.

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Late Mississippian Thrombolite Bioherms from the Pitkin Formation of Northern Arkansas

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Two types of bioherms occur in the Pitkin Formation (Chesterian) of northern Arkansas. They are composed of a complex series of ovoid thrombolite heads intergrown with various other algal and bryozoan biolithites and are distinguished from each other on the basis of geometry and faunal and floral content. Type I

mounds have sharp lateral margins and interfinger with horizontally bedded, contemporaneous, flanking strata owing to having expanded and contracted in size during upward accretion. They are interpreted as having had synoptic relief of 3 m or less during growth. Type II mounds occur slightly higher stratigraphically, to the east of type I mounds, and formed in deeper water, farther out on the Ozark shelf. They are interpreted as having had synoptic relief of 6 m or more during growth. Their margins are similar to those in type I mounds, but owing to higher synoptic relief, they interfinger with sediments derived from erosion higher on the mound.

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