OKLAHOMA GEOLOGY

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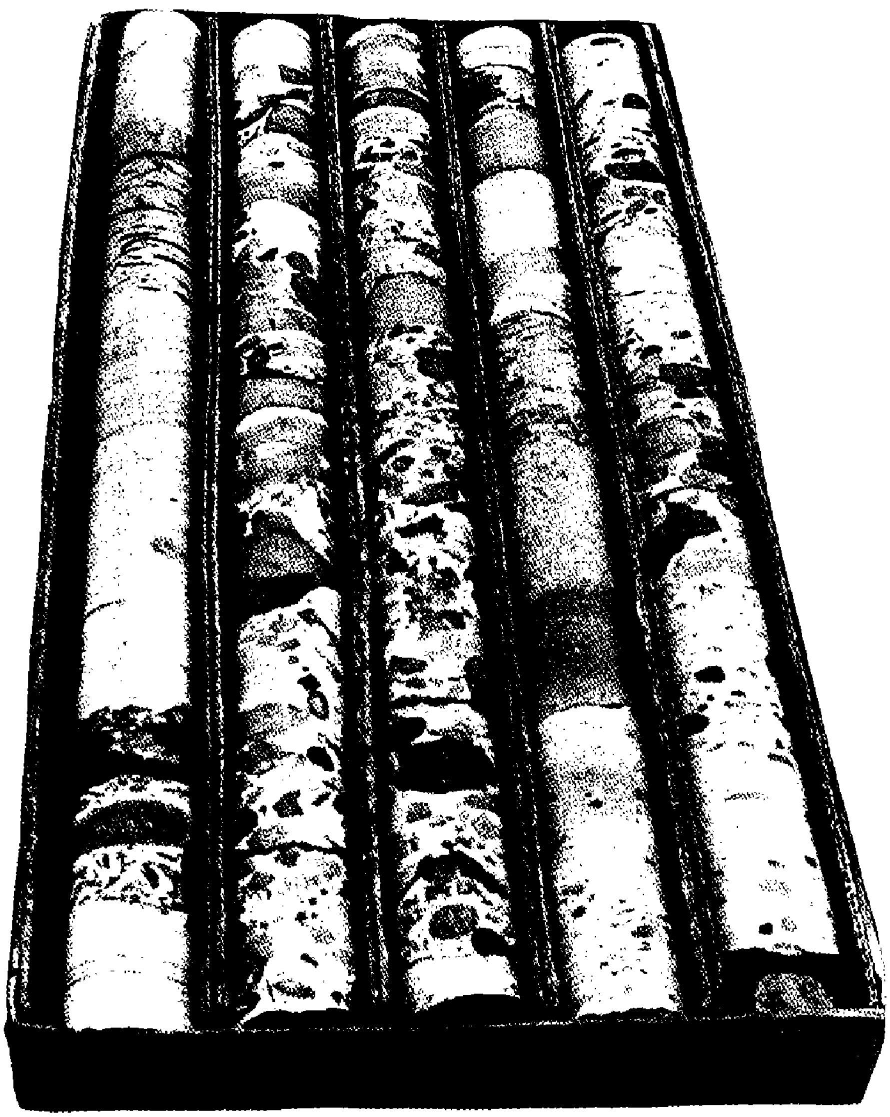

On the cover—

Core from the Bluejacket Sandstone in Its Type Area

A box containing 2-in.-diameter core samples of the Bluejacket Sandstone Member of the Boggy Formation is shown on the cover. The box contains five 2-ft lengths of core cut from rocks at a depth range of 28–38 ft below the ground surface. The core-drilling was done by the Oklahoma Geological Survey drilling rig in the NW¼NE¼NE¼NE¼ sec. 24, T. 27 N., R. 20 E., Craig County, Oklahoma, in the type area of the Bluejacket Sandstone. All core from this test hole is stored at the OGS Core and Sample Library in Norman, and is available for study by the public.

The Bluejacket Sandstone is a key Desmoinesian stratigraphic unit and is also an important source of abundant shallow petroleum production in northeastern Oklahoma and southeastern Kansas. The base of the member marks the contact between the Savanna Formation (below) and the Boggy Formation (above).

Information on this core and the Bluejacket Sandstone is given in a paper in this issue.

LeRoy A. Hemish

OKLAHOMA GEOLOGICAL SURVEY

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OKLAHOMA GEOLOGY NOTES

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OKLAHOMA GEOLOGICAL SURVEY

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BLUEJACKET (BARTLESVILLE) SANDSTONE MEMBER OF THE BOGGY FORMATION (PENNSYLVANIAN) IN ITS TYPE AREA

LeRoy A. Hemish[1]

Abstract

Two core holes drilled in the type area of the Bluejacket (Bartlesville) Member of the Boggy Formation are herein designated as reference wells for stratigraphic purposes. Variability of the lithology of the Bluejacket Sandstone, as well as the need for detailed descriptions of the overlying and underlying strata, necessitated the establishment of the reference wells. Within 1 mile laterally on opposite sides of the type section the lithology of the Bluejacket Sandstone varies from medium-grained sandstone with coarse conglomerate at the base of the unit to comparatively thin, fine-grained sandstone and silty shale.

Interpretations of the depositional environments are (1) that the conglomeratic deposits originated as flood deposits in a distributary channel in a deltaic setting, and (2) that the fine-grained deposits probably originated as crevasse-splay and overbank deposits on an interchannel deltaic plain. The two environments represent different parts of a large delta distributary system.

Introduction

The primary purpose of this article is to report the results of core-drilling by the Oklahoma Geological Survey (OGS) in the type area of the Bluejacket (Bartlesville) Member of the Boggy Formation (Fig. 1). Studies by Ebanks and others (1977), and more recently by Harris (1987), suggest that the stratigraphic relationships of the Bluejacket Sandstone and its associated beds in Oklahoma, Kansas, and Missouri differ from long-accepted interpretations.

Therefore, to provide further insight into the stratigraphic relationships of the strata underlying and overlying the Bluejacket Sandstone in its type area, two core holes were drilled. Figure 2 shows the OGS drilling rig. Locations of the two core-hole sites (CH1, CH2) are shown in Figure 1. Detailed descriptions of the core show the variability of the Bluejacket Sandstone Member within a mile in opposite directions from the type section (see logs in Appendix). This probably explains why, in some areas, correlations have been difficult, and errors of interpretation have been made. This short paper provides additional detailed information concerning the sequence, lithology, thickness, and stratigraphic relationships of the beds associated with the Bluejacket Sandstone in its type area. Figure 3 is a generalized columnar section for Craig County, showing the stratigraphic interval from the base of the Pennsylvanian to the lower part of the Senora Formation.

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[1]Oklahoma Geological Survey.

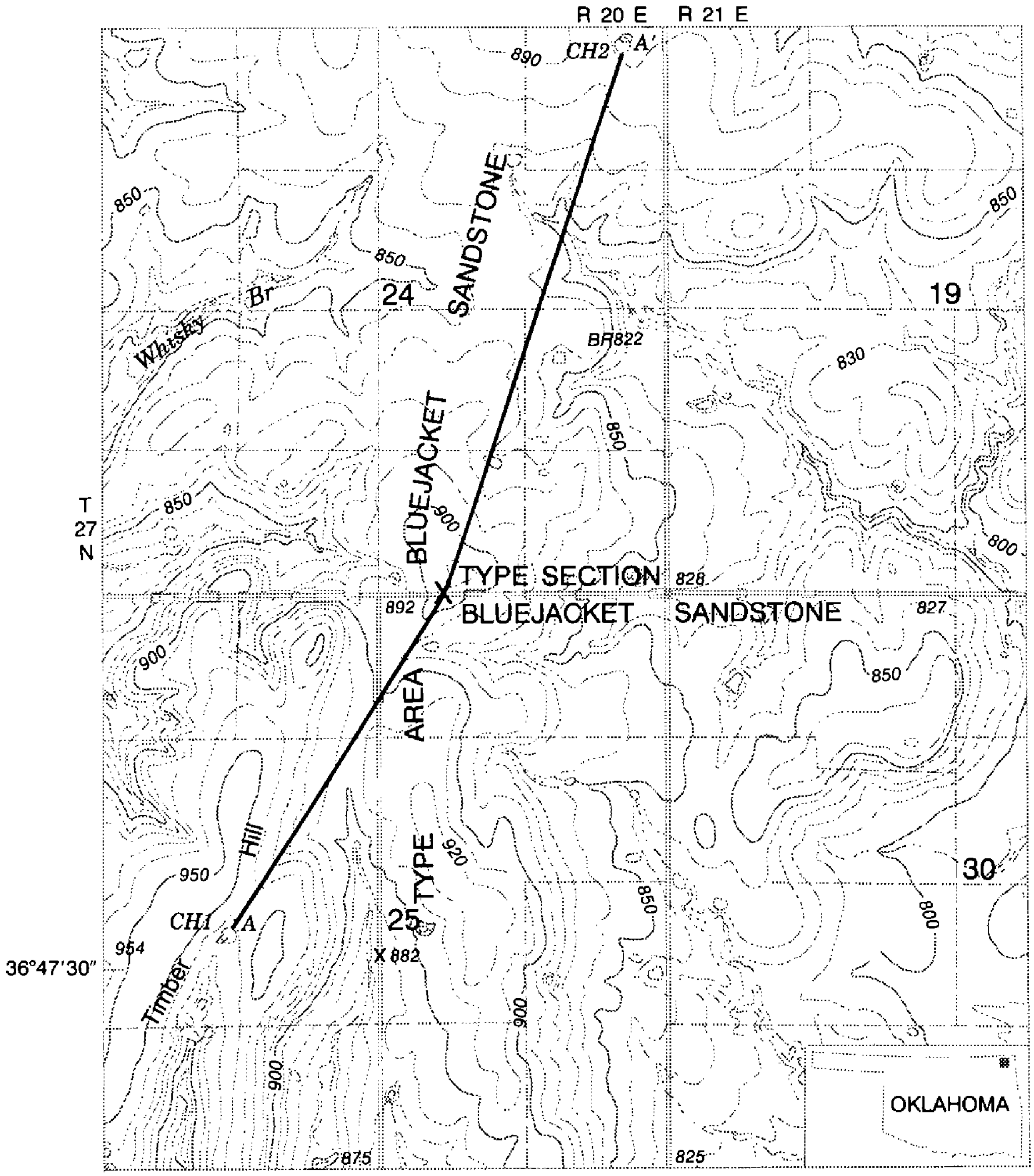

Figure 1. Map locating type section and reference wells for the Bluejacket (Bartlesville) Sandstone Member of the Boggy Formation in northeastern Craig County, Oklahoma.

Previous Investigations

The Bluejacket Sandstone was named by Ohern (1914, p. 28), for the town of Bluejacket, Craig County, Oklahoma. He stated that its base lies ~150 ft above the top of the Little Cabin (Warner) Sandstone. He said that "its typical development is found in the hills west of the town [Bluejacket] from which it is proposed to name it the Bluejacket Sandstone Member." He also said that "in places its total

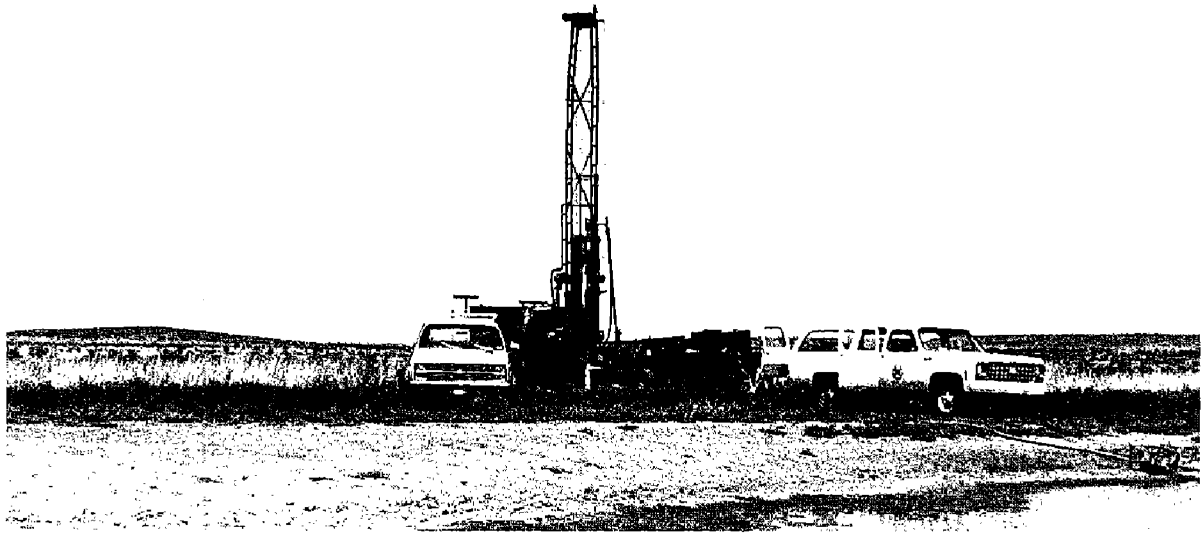

Figure 2. The Oklahoma Geological Survey drill rig, drilling a core hole in Craig County, Oklahoma.

thickness of 50 to 60 ft is a solid mass of sandstone, but usually it is broken into several beds by intervening shales."

Howe (1951, p. 2088) observed that the type section of the Bluejacket Sandstone was not adequately defined, because it included several other sandstone beds, and the actual unit called Bluejacket was not clearly differentiated. Figure 4 shows Howe's (fig. 1, p. 2089) generalized graphic section of the sequence of beds exposed in the "hills west of Bluejacket, Oklahoma," in which he redefines the Bluejacket Sandstone. Howe did not include a measured section, but he did provide a location for the type section. He stated that the Bluejacket Sandstone is "typically exposed in the NE¼, NE¼ of sec. 25, T. 27 N., R. 20 E., along the road from Bluejacket west to Pyramid Corners, in the east slope of Timbered Hill, on Oklahoma Highway 25, in Craig County, Oklahoma." Unfortunately, either through mislocation or typographical error, the location of the sandstone shown as Bluejacket in his graphic section (Fig. 4), has been inaccurately placed in the NE¼NE¼ sec. 25, T. 27 N., R. 20 E. It is correctly located in the NW¼NE¼ sec. 25, T. 27 N., R. 20 E. The sandstone that crops out in the NE¼NE¼ sec. 25, T. 27 N., R. 20 E. is the Dickson Sandstone, named by Branson and others (1965, p. 27, pl. 1).

Chrisman (1951, p. 18; appendix, 15) measured a section at the type section of the Bluejacket Sandstone, reproduced below:

15—Sec. 25, T. 27 N., R. 20 E. Measured from the NW¼NE¼NE¼ of the section, west along road up the hill.

8 Bluejacket Sandstone, tan, fine to medium-grained massively cross-bedded, micaceous	48.7
7 Shale, black	3.0
6 Coal	0.2
5 Underclay	2.5
4 Covered interval	6.8

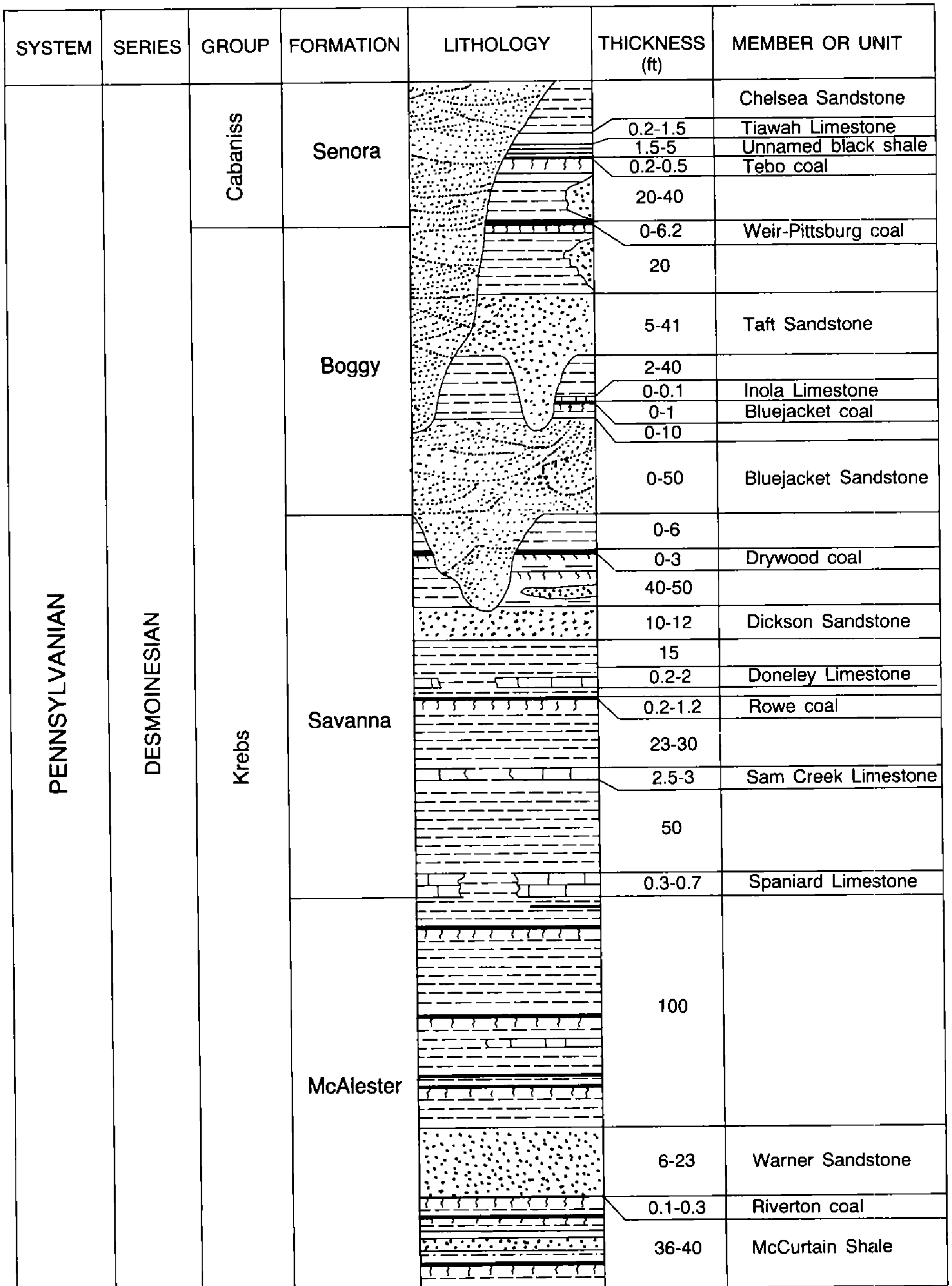

Figure 3. Generalized columnar section, showing rocks from the base of the Pennsylvanian to the lower part of the Senora Formation in Craig County, Oklahoma (modified from Hemish, 1986, fig. 4). For simplicity, the term *Member* is omitted here; the formal status of members is indicated by capitalization of the lithologic term (e.g., Chelsea Sandstone).

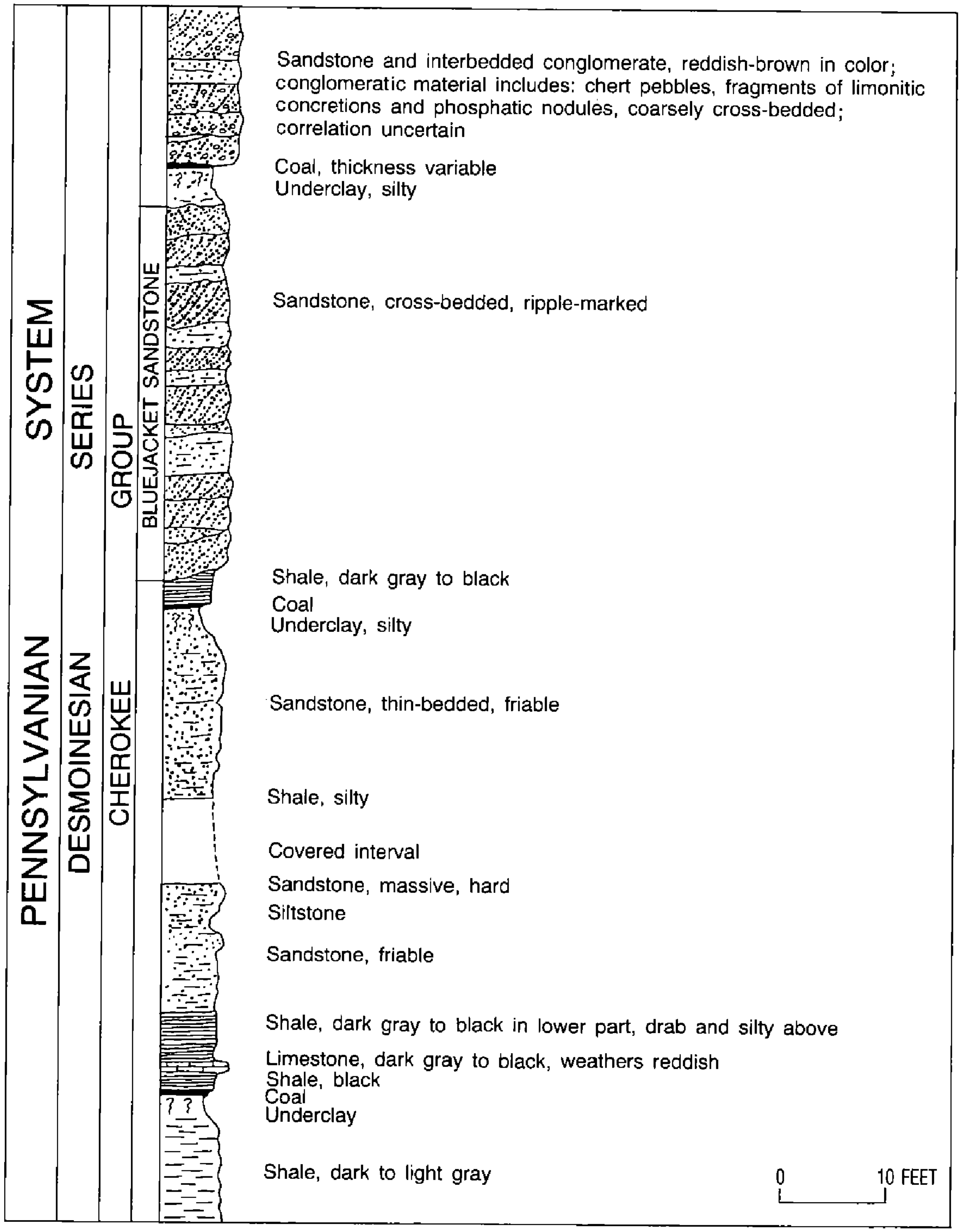

Figure 4. Generalized graphic section showing the sequence of rocks exposed in the type area of the Bluejacket Sandstone (after Howe, 1951, fig. 1).

3	Sandstone, gray, medium-grained, micaceous	8.8
2	Covered interval, probable gray shale	13.2
1	"Twelve-foot" sandstone, gray, medium-grained, micaceous, exposed	2.0

Chrisman's "Twelve-foot" sandstone is the Dickson Sandstone.

Equivalence of the Bluejacket Sandstone Member of the Boggy Formation in its type area to the lowest sandstone unit of the Boggy Formation in the Arkoma basin area of Oklahoma was demonstrated by a field party of the U.S. Geological Survey as early as 1934 (Dane and Hendricks, 1936, p. 312). Subsequent mapping has shown the correlation to be valid throughout northeastern Oklahoma.

Noteworthy early discussions of the Bluejacket Sandstone in Kansas include works by Abernathy, 1937; Pierce and others, 1937; and Howe, 1956.

Establishment of Reference Sections

In accordance with procedures recommended in the North American Stratigraphic Code (1983, p. 853–854) for establishing reference wells, two reference wells for the Bluejacket Sandstone Member of the Boggy Formation are herein described and defined. Reference Well 1 (CH1, Fig. 1, Appendix) is located in the SE¼NE¼NW¼SW¼ sec. 25, T. 27 N., R. 20 E., Craig County, Oklahoma, on the Jerry Taylor farm. Continuous 2-in. core was cut from below a 9-ft surface casing to a total depth of 180 ft. Samples of cuttings were collected and bagged from the upper 9 ft. Core-drilling was completed on 18 July 1988. Surface elevation was estimated from a topographic map at 945 ft above sea level.

Reference Well 2 (CH2, Fig. 1, Appendix) is located in the NW¼NE¼NE¼NE¼ sec. 24, T. 27 N., R. 20 E., Craig County, Oklahoma, on the Don Floyd farm. Continuous 2-in. core was cut from below a 9-ft surface casing to a total depth of 331.5 ft. Samples of cuttings were collected and bagged from the upper 9 ft. Core-drilling was completed on 25 July 1988. Surface elevation was estimated from a topographic map at 775 ft above sea level.

Both core holes were drilled in the type area of the Bluejacket Sandstone within 1 mile laterally on either side of the designated type section. Cores and cuttings from both wells have been boxed and labeled, and are available for study at the Oklahoma Geological Survey Core and Sample Library in Norman.

Stratigraphy and Lithology

Figure 5 is an abbreviated cross section showing the relationships among the strata in the type section and the two reference wells. Note the differences between the strata in the core-hole logs and the strata in the type section in the study interval. In CH1 the units from the Dickson Sandstone up to the channel deposits at the base of the Bluejacket Sandstone are similar to those at the other sites; however, the Drywood coal and several feet of overlying shale have been eroded by channeling at the base of the Bluejacket in the roadcut exposure. In CH2 the channeling has eroded virtually all the beds at the top of the Savanna Formation to within a few feet of the Dickson Sandstone.

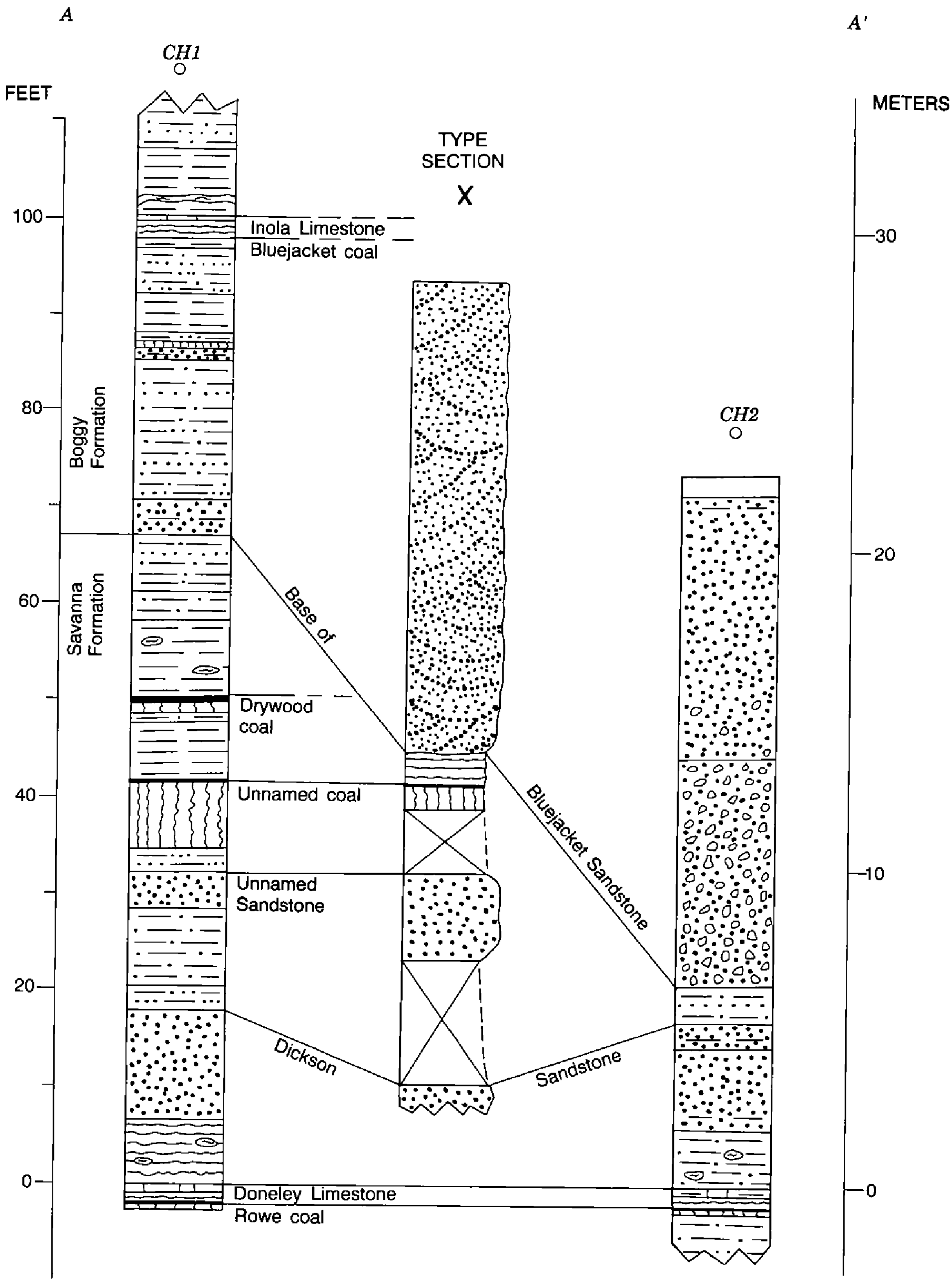

Figure 5. Cross section showing correlations of key units in the type area of the Bluejacket Sandstone. Line of cross section (A–A′) shown in Figure 1; descriptions of lithologic units in Appendix, and in measured section from Chrisman (1951).

In CH1 the interval from the base of the Inola Limestone (previously unrecognized in Craig County; Branson and others, 1965, p. 31) and underlying Bluejacket coal to the top of the upper unit of the Bluejacket Sandstone consists of shale, mudstone, and siltstone. An interval containing 14.6 ft of shale interbedded with sandstone and siltstone separates the upper part of the Bluejacket Sandstone from the basal part in CH1. At the type section, the Bluejacket Sandstone consists of 48.7 ft of uninterrupted fine- to medium-grained, cross-bedded sandstone. In CH2 the Bluejacket Sandstone consists of 23.7 ft of massive-bedded, coarse conglomerate (Fig. 6B,C) overlain by 9.1 ft of fine- to medium-grained, cross-bedded, conglomeratic sandstone (Fig. 6A), which, in turn, is overlain by 18.4 ft of fine-grained sandstone.

The sequence described above is similar to the Pennsylvanian Kissinger Sandstone of north-central Texas (Shelton, 1973, p. 18–24). Shelton's interpretation

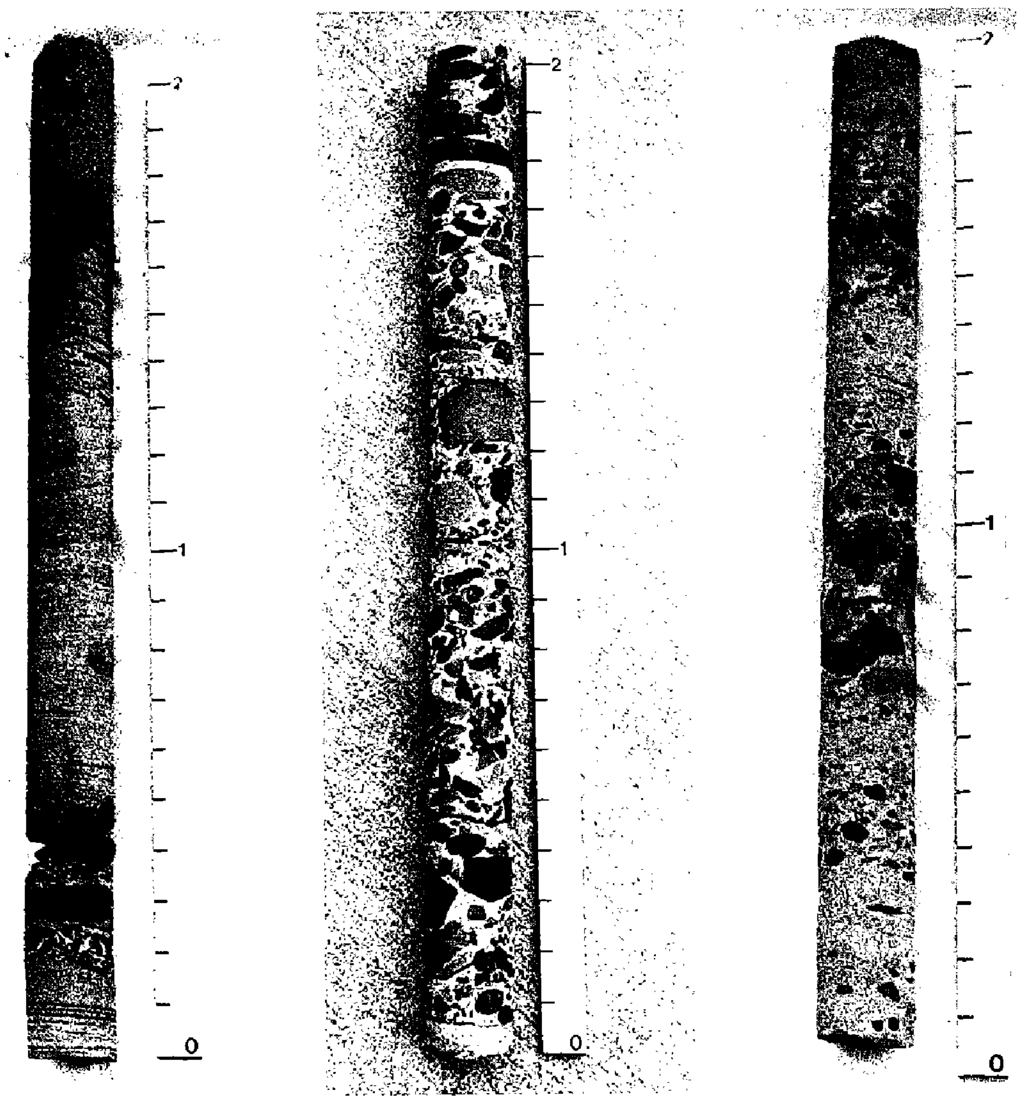

Figure 6. Photographs of cored 2-ft intervals of the Bluejacket Sandstone from CH2. 6A was cored from a depth of 28–30 ft and shows cross-bedded, medium-grained, conglomeratic sandstone; 6B and 6C were cored from depths of 32–34 ft and 36–38 ft, respectively. These intervals contain conglomerate consisting of pebbles and cobbles of ironstone, shale, and siltstone, with a medium- to coarse-grained sandstone matrix.

of the depositional history of the Kissinger Sandstone is that it was deposited in a valley by a river about 200–300 ft wide. He stated that the base of the unit was characterized by cutouts or channels.

The large size and angularity of the clasts in the basal Bluejacket conglomerate in CH2 indicate a high-energy environment, possibly flooding, and the presence of abundant reworked ironstone concretions and shale pebbles suggests that a river was eroding a valley into older rocks of the Savanna and McAlester Formations upstream.

Conclusions are that (1) the Bluejacket Sandstone at the type section and in CH2 originated as channel deposits in a distributary channel in a deltaic setting, and (2) the finer-grained sediments of the Bluejacket interval in CH1 probably originated as crevasse-splay and overbank deposits on an interchannel deltaic plain.

These interpretations of the depositional environments of the Bluejacket Sandstone in the study area as parts of a large delta distributary system fit the models of both Visher (1968) and Shelton (1973, p. 63–68).

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Appendix

Core-Hole Logs

CH 1

(OGS Core and Sample Library No. C CN 6)

SE¼NE¼NW¼SW¼ sec. 25, T. 27 N., R. 20 E., Craig County, Oklahoma. Well cored by Oklahoma Geological Survey; lithologic descriptions by LeRoy A. Hemish. Drilled in pasture just north of farm pond, 1,140 ft FWL and 2,200 ft FSL. Surface elevation, estimated from topographic map, 945 ft.

	Depth to unit top (ft)	Thickness of unit (ft)
Sand and clay, moderate-yellowish brown, silty, noncalcareous, contains organic material	0.0	1.0
Cabaniss Group		
Senora Formation		
Sandstone, light-brown, very fine-grained, noncalcareous, weathered, friable, oxidized	1.0	1.0
Siltstone, grayish-orange, clayey, calcareous, soft and weathered	2.0	1.0
Shale, dark-yellowish-orange, clayey, weathered; contains streaks of oxidized sandstone	3.0	6.0
Sandstone, dark-yellowish-orange, very fine-grained, cross-bedded, interlayered with very pale-orange siltstone and shale, fractured, weathered; grades into underlying unit	9.0	4.5
Shale, light-olive-gray with dark-yellowish- orange bands, micaceous, sandy, partly weathered, noncalcareous; grades into underlying unit	13.5	5.5
Sandstone, moderate-yellowish-brown to dusky-brown, shaly, fine- to very fine- grained, micaceous, noncalcareous, cross-bedded, bioturbated in part; includes streaks of black, macerated plant fragments	19.0	2.5
Shale, pale-yellowish-brown, noncalcareous, sandy, micaceous	21.5	0.7
Siltstone, dark-gray, noncalcareous, shaly; contains thin laminae of light-gray, very fine-grained sandstone and occasional lenses of medium-grained, light-brownish-gray sandstone	22.2	2.6
Sandstone, light-brownish-gray, medium-grained, noncalcareous; interbedded with layers of dark-gray siltstone up to 10 in. thick, cross-bedded in part; contains several coal bands up to 0.5 in. thick, as well as coal spars and black, macerated plant material in thin laminae (basal unit of Chelsea Sandstone)	24.8	4.6
Shale, medium-light-gray, noncalcareous; contains contorted sandstone layers as much as 3 in. thick; becomes medium-dark-gray in lower 4.5 ft of unit	29.4	8.1

Coal, black, friable; contains pyrite in veins and nodules, and gypsum on cleats (Weir-Pittsburg coal)	37.5	0.8
Krebs Group		
Boggy Formation		
Underclay, light-gray, silty, sandy, noncalcareous, churned	38.3	0.5
Sandstone, medium-light-gray, very fine-grained, noncalcareous, cross-bedded (upper unit of Taft Sandstone)	38.8	0.5
Shale, medium-gray, silty	39.3	0.8
Sandstone, medium-light-gray with grayish-red laminations, fine-grained, noncalcareous, cross-bedded (Taft Sandstone)	0.1	6.7
Shale, dark-gray, noncalcareous; contains streaks and cross-bedded lenses of very fine-grained, light-gray sandstone	46.8	1.2
Sandstone, medium-light-gray with grayish-black laminations, fine-grained, noncalcareous, cross-bedded (basal unit of Taft Sandstone)	48.0	2.5
Shale, dark-gray, very silty, noncalcareous; contains abundant laminations and lenses of light-gray, very fine-grained sandstone; some sandstone lenses show scour-and-fill and cross-lamination features; black, macerated plant fragments abundant in some layers; shaly siltstone in part; grades into underlying unit	50.5	19.5
Shale, medium-dark-gray to dark-gray in lower half, noncalcareous; includes rare burrows	70.0	5.2
Ironstone, light-brownish-gray, hard, dense	75.2	0.3
Shale, grayish-black, noncalcareous; includes some small pyrite-filled bioturbation features; very calcareous and fossiliferous in lower 2 in.; grades into underlying unit	75.5	1.7
Limestone, light-gray with black shaly matrix, bioclastic, bioturbated in upper part (Inola Limestone)	77.2	0.1
Shale, black, weakly calcareous in upper 1.5 ft, pyritic; contains calcite-filled burrows, rare fossil brachiopods, and white calcite in laminae and veinlets; slickensided on some fracture surfaces	77.3	2.4
Coal, black, moderately friable (Bluejacket coal)	79.7	0.1
Shale, medium-gray, noncalcareous; contains some black, carbonized plant fragments	79.8	0.2
Mudstone, medium-dark-gray with slight greenish-gray tint, extensively bioturbated, noncalcareous; grades downward into shale	80.0	5.0
Shale, medium-light-gray to medium-gray, noncalcareous; slickensided along fractures	85.0	3.8
Siltstone, light-gray with medium-gray bands, noncalcareous, wavy-laminated	88.8	0.7
Sandstone, medium-light-gray, fine-grained, cross-bedded; contains black, carbonized plant fragments; noncalcareous (upper unit of Bluejacket Sandstone)	89.5	0.8
Sandstone, medium-light-gray, interlaminated with medium-gray shale, very fine-grained, noncalcareous,		

wavy-bedded; contains some cross-lamination and minor bioturbation features; grades into underlying unit	90.3	1.4
Shale, medium-gray, interbedded with light-gray, thin, very fine-grained sandstone and siltstone layers; wavy-bedded in part, with abundant small-scale scour-and-fill, and bioturbation features; noncalcareous; includes several light-brownish-gray sideritic layers 0.5–1.5 in. thick; becomes dark-gray to grayish-black with fewer sandstone and siltstone stringers in lower 8 ft of unit	91.7	14.6
Sandstone, medium-light-gray, very fine-grained, silty, interstratified with dark-gray shale; wavy-bedded, extensively bioturbated, cross-laminated in part, coarsens downward (basal unit of Bluejacket Sandstone)	106.3	3.7
Savanna Formation		
Shale, dark-gray, interstratified with very fine-grained, light-gray sandstone; noncalcareous, bioturbated in places; small-scale scour-and-fill features abundant; sandstone content decreases downward; grades into underlying unit	110.0	6.0
Shale, dark-gray, noncalcareous; includes minor laminae of light-gray sandstone in upper part, and some sideritic layers as much as 0.75 in.; contains pyrite-filled burrows	116.0	3.2
Shale, dark-gray, noncalcareous; contains pyrite-filled burrows and light-brownish-gray sideritic layers up to 1 in. thick	119.2	7.7
Coal, black, moderately friable; contains white calcite on cleat surfaces; contains crusts and 1-in.-thick, irregular masses of pyrite (Drywood coal)	126.9	0.7
Underclay, medium-gray, bioturbated, slickensided; contains black, carbonized plant fragments	127.6	0.7
Shale, medium-dark-gray, silty; contains pyrite-filled burrows and disseminated pyrite	128.3	1.5
Shale, dark-gray to grayish-black, noncalcareous; contains pyrite-filled burrows and lenses; includes rare sideritic concretions as much as 1 in. thick	129.8	5.9
Coal, black, moderately friable; pyrite and calcite on fracture surfaces (unnamed coal)	135.7	0.2
Underclay, medium-light-gray, silty; contains black, carbonized plant fragments; bioturbated; grades into underlying unit; includes rooted zones from 139.7 to 140.1 and from 141.0 to 142.3 ft	135.9	6.4
Siltstone, shaly, medium-gray, noncalcareous; contains grayish-orange, sandstone-filled burrows	142.3	2.7
Sandstone, medium-light-gray with dark-gray shale streaks, rippled, noncalcareous, very fine-grained; flat-bedded in some intervals, massive in others	145.0	3.8
Shale, dark-gray, silty, burrowed; includes laminae containing burrows filled with light-gray, very fine-grained sandstone; wavy-bedded in part, noncalcareous; con-		

tains minor coaly laminae; slickensided at contact with underlying unit	148.8	8.0
Siltstone, dark-gray, very fine-grained, shaly, noncalcareous; contains closely spaced laminae of light-gray, very fine-grained sandstone; rippled, with minor bioturbation	156.8	2.6
Sandstone, medium-light-gray, with minor dark-gray shale streaks, micaceous, rippled, noncalcareous, very fine-grained to fine-grained, massive from 161 to 167 ft; angle of faint shale laminae suggests cross-bedding on lower part from 167 to 168 ft; basal contact sharp (Dickson Sandstone)	159.4	11.3
Shale, grayish-black to black, with minor light-gray shale streaks, noncalcareous; contains some small brachiopods, pyrite crusts, bioturbation features, and light-brownish-gray sideritic concretions as much as 3 in. thick	170.7	6.8
Limestone, medium-gray, contains abundant fossil shells, including a 2-in.-wide pelecypod; grades into underlying unit (Doneley Limestone)	177.5	0.8
Shale, black, very calcareous; contains abundant fossil shells	178.3	0.6
Coal, black, moderately friable (Rowe coal)	178.9	0.2
Underclay, medium-light-gray, unbedded, slickensided; contains black, carbonized plant fragments	179.1	0.9
Total depth		180.0

CH 2

(OGS Core and Sample Library No. C CN 7)

NW¼NE¼NE¼NE¼ sec. 24, T. 27 N., R. 20 E., Craig County, Oklahoma. Well cored by Oklahoma Geological Survey; lithologic descriptions by LeRoy A. Hemish. Drilled in hay meadow just south of pond 220 ft FNL and 400 ft FEL. Surface elevation, estimated from topographic map, 775 ft.

	Depth to unit top (ft)	Thickness of unit (ft)
Silt, pale-yellowish-brown; contains some very fine-grained sand and organic material	0.0	2.0
Krebs Group		
Boggy Formation		
Sandstone, light-brown to moderate-brown with dusky-brown flecks, clayey, weathered, friable	2.0	3.0
Sandstone, moderate-yellowish-brown, fine-grained, well-cemented, noncalcareous	5.0	4.0
Sandstone, moderate-brown with black flecks, fine-grained, massive, noncalcareous; includes some laminae of black macerated plant fragments in lower 6 in.	9.0	5.3

Sandstone, light-brownish-gray with black coal bands and dark-reddish-brown oxidized zones; micaceous	14.3	6.1
Sandstone, pale-yellowish-brown to light-brown to light-brownish-gray, fine- to medium-grained, noncalcareous, micaceous, massive in part, cross-bedded in lower part, conglomeratic; contains dark-gray shale pebbles and some reddish-brown-rimmed ironstone pebbles in lower part	20.4	9.1
Conglomerate, light-brownish-gray, medium-dark-gray from 38.0 to 39.5 ft, noncalcareous, massive-bedded; pebbles and cobbles are predominantly light-brownish-gray ironstone and black and gray shale and siltstone; matrix is medium- to coarse-grained sandstone containing black, macerated plant material; lower contact sharp (base of Bluejacket Sandstone)	29.5	23.7
Savanna Formation		
Shale, medium-dark-gray with light-gray, interbedded sandstone; mostly flat-bedded, with minor low-angle cross-bedding, bioturbated	53.2	3.9
Sandstone, medium-dark-gray, shaly, very fine-grained, noncalcareous, partly churned; wavy-bedded in lower part, with some bioturbation features (Dickson Sandstone)	57.1	2.7
Sandstone, medium-gray with dark-gray shale streaks, rippled, noncalcareous; contains some sideritic concretions as much as 1.25 in. thick; fines downward, with increased shale content in lower 2 ft of unit (Dickson Sandstone)	59.8	8.2
Shale, medium-dark-gray to dark-gray, noncalcareous, silty; includes minor sandstone streaks and burrow fillings; contains light-brownish-gray, sideritic concretions as much as 2 in. thick	68.0	5.9
Limestone, medium-light-gray, impure and shaly in lower 6 in., very fossiliferous; brachiopod shells and shell fragments abundant (Doneley Limestone)	73.9	1.2
Shale, grayish-black, noncalcareous; contains rare pyrite-filled burrows; becomes carbonaceous, with calcite laminae in lower 0.5 in. of unit	75.1	0.7
Coal, black, moderately friable; includes minor pyrite on fracture surfaces (Rowe coal)	75.8	0.2
Underclay, medium-gray; contains black, carbonized plant fragments, slickensided	76.0	0.5
Shale, medium-gray, silty, churned; noncalcareous; contains disseminated pyrite and irregular pyritic masses	76.5	1.8
Shale, medium-dark-gray to dark-gray, with wavy bands of light-gray siltstone and very fine-grained sandstone, noncalcareous, burrowed; contains minor pyrite; includes a 0.75-in.-thick by 2-in.-wide lens of crinoidal limestone at 82.5 ft (Sam Creek[?] Limestone)	78.3	12.9
Coal, black, moderately friable, pyrite on cleat surfaces (Sam Creek[?] coal)	91.2	0.1

Underclay, medium-gray, churned, slickensided; contains black, carbonized plant fragments	91.3	1.5
Shale, medium-light-gray, noncalcareous, sandy, bioturbated	92.8	1.3
Shale, grayish-black with light-gray, very fine-grained sandstone streaks, burrowed, wavy-bedded, noncalcareous	94.1	2.3
Sandstone, light-gray with dark-gray shale layers, very fine-grained, noncalcareous, extensively bioturbated	96.4	0.5
Sandstone, light-gray, very fine-grained, noncalcareous, cross-bedded; includes some blackish-red, oxidized grains	96.9	3.4
Sandstone, light-gray, with medium-dark-gray shale streaks, rippled, noncalcareous, low-angle cross-bedded in part	100.3	3.2
Shale, medium-dark-gray with light-gray sandstone streaks, noncalcareous, wavy-bedded, burrowed; includes a light-brownish-gray, 0.5-in.-thick, sideritic concretion at 110.2 ft	103.5	7.9
Shale, dark-gray, noncalcareous, layered with light-brownish-gray sideritic concretions as much as 4 in. thick; includes disseminated pyrite and minor streaks of light-gray sandstone	111.4	5.5
Shale, medium-dark-gray to dark-gray, noncalcareous; contains streaks of very fine-grained, light-gray sandstone, wavy-bedded, burrowed	116.9	5.5
Limestone, grayish-black, very impure, shaly; contains abundant fossil shells (Spaniard Limestone)	122.4	0.8
McAlester Formation		
Shale, black, noncalcareous; contains sparse, small, calcareous fossil shells and fossil fragments; grades into underlying unit	123.2	2.0
Shale, grayish-black, interbedded with thin limestone layers consisting of fossil shells, crinoid ossicles, and fossil fragments	125.2	1.1
Shale, black, carbonaceous, calcareous in part; contains wavy laminae of calcite and pyrite	126.3	0.2
Coal, black, pyrite on cleats, moderately friable (Spaniard coal)	126.5	0.5
Underclay, medium-gray, churned, slickensided; contains black, carbonized plant fragments; sandy in lower part	127.0	2.0
Sandstone, medium-light-gray, very fine-grained, silty, massive, noncalcareous	129.0	1.1
Shale, grayish-black to black, noncalcareous; contains rare streaks of very fine-grained sandstone, rare fossil shells, and minor pyrite	130.1	8.7
Coal, black, moderately friable (Keota[?] coal)	138.8	0.2
Underclay, medium-gray; contains black, carbonized plant fragments	139.0	0.2
Shale, dark-gray, noncalcareous; includes some 1/16- to 1/8-in.-thick coal bands in lower 3 in.	139.2	1.0

Underclay, medium-light-gray, soft, crumbly, slickensided	140.2	1.8
Shale, medium-gray, broken, churned, noncalcareous	142.0	2.0
Shale, grayish-black, noncalcareous; streaked with light-gray, very fine-grained sandstone and siltstone; burrowed	144.0	8.4
Shale, black, noncalcareous; contains yellowish-gray, dense, massive, calcareous ironstone concretions as much as 1 in. thick, minor calcareous burrow-fillings, and rare, small fossil shells	152.4	15.6
Shale, grayish-black, noncalcareous; contains abundant white, calcareous fossil fragments	168.0	0.3
Shale, dark-gray to grayish-black with medium-gray bands, noncalcareous, sparsely bioturbated; contains rare fossil shells and very thin streaks of light-gray siltstone; includes minor pyrite on parting surfaces	168.3	13.5
Sandstone and siltstone, medium-light-gray, interlaminated with medium-gray shale, noncalcareous, rippled; includes rare burrows with pyritic fillings	181.8	1.2
Shale, black with light-gray, wavy, siltstone bands, noncalcareous	183.0	0.2
Underclay, brownish-gray in upper 4 in. to medium-gray downward, blocky fracture, slickensided; contains some black, carbonized plant fragments in upper part; churned; grades into underlying shale	183.2	2.2
Shale, medium-gray, noncalcareous, blocky fracture, burrowed	185.4	1.0
Siltstone, medium-gray with wavy bands of grayish-black shale, noncalcareous	186.4	0.4
Shale, dark-gray with light-gray siltstone streaks in upper 1 ft, noncalcareous	186.8	1.6
Shale, grayish-black with light-brownish-gray, sideritic bands, noncalcareous; contains minor streaks of light-gray siltstone, and small bioturbation features with associated pyrite	188.4	7.4
Limestone, yellowish-gray, fine-grained, dense, fossiliferous, with shells and fossil hash concentrated in lower 1 in. and upper 2 in.; shaly in places	195.8	0.6
Shale, dark-gray, silty, hard, weakly calcareous; contains scattered white fossil shells and pyrite-filled burrows, as well as light-brownish-gray sideritic concretions as much as 1.75 in. thick	196.4	8.7
Shale, medium-gray with light-gray siltstone and very fine-grained sandstone layers, wavy-bedded, noncalcareous	205.1	2.8
Shale, dark-gray, noncalcareous; contains sparse, thin laminae of light-gray siltstone, light-brownish-gray ironstone concretions, and pyrite-filled burrows	207.9	5.2
Coal, black, moderately friable, pyrite on cleats (Stigler coal)	213.1	0.04
Underclay, medium-light-gray, rooted, silty; contains black, carbonized plant fragments	213.2	0.7

Siltstone, light-gray, sandy, noncalcareous; contains black, carbonized plant fragments; grades into underlying unit	213.9	2.1
Sandstone, medium-light-gray, very fine-grained, silty, wavy-laminated, noncalcareous, burrowed in part	216.0	1.3
Shale, medium-dark-gray, silty, noncalcareous; contains rare black, carbonized plant fragments	217.3	1.5
Shale, grayish-black with light-brownish-gray sideritic bands in upper 2 ft, noncalcareous; contains scattered pyrite-filled burrows	218.8	11.2
Shale, grayish-black, noncalcareous, uniform in appearance; includes a 1-in.-thick zone of light-brownish-gray, sideritic concretions, with pyrite-filled burrows and disrupted fragments of underlying sandstone at basal contact of unit	230.0	4.3
Sandstone, light-gray, very fine-grained, massive, noncalcareous; grades into underlying unit	234.3	0.7
Shale, medium-light-gray, sandy, noncalcareous, burrowed	235.0	1.3
Shale, medium-dark-gray, noncalcareous, slickensided	236.3	0.4
Shale, black with light-gray, wavy sandstone streaks; carbonaceous, silty; contains minor coaly streaks	236.7	0.1
Underclay, medium-dark-gray, slickensided	236.8	2.0
Siltstone, medium-dark-gray, shaly, noncalcareous, burrowed; shale layers slickensided	238.8	1.0
Shale, grayish-black, noncalcareous; contains widely scattered, thin streaks of light-gray siltstone, pyrite-filled burrows, and yellowish-gray, sideritic concretions as much as 3 in. thick	239.8	26.7
Siltstone, dark-gray, shaly, noncalcareous; contains thin laminae of light-gray, very fine-grained sandstone; grades into underlying unit	266.5	3.2
Sandstone, medium-light-gray, fine-grained, noncalcareous; contains dark-gray shale streaks, sideritic concretions and siderite-filled burrows in upper part; rippled, cross-bedded in part; includes some black coal streaks and macerated, pyritized plant fragments in lower 8 ft; basal contact sharp (Warner Sandstone)	269.4	16.3
Shale, medium-dark-gray, noncalcareous, slickensided, broken	286.0	0.5
Underclay, medium-light-gray, churned, slickensided, broken	286.5	1.0
Shale, medium-gray, noncalcareous, slickensided	287.5	0.2
Sandstone, medium-gray, extremely calcareous, very fine-grained, massive; contains rare, poorly preserved marine fossils	287.7	0.7
Shale, medium-dark-gray, noncalcareous, slickensided; contains some light-gray siltstone streaks and rare pyrite-filled burrows	288.4	1.6
Shale, grayish-black, silty, noncalcareous; contains streaks, lenses, and burrows filled with light-gray, very fine-grained sandstone and pyrite	290.0	11.7

Sandstone and siltstone, medium-gray with dark-gray shale streaks, noncalcareous, rippled; grades into underlying unit	301.7	0.8
Shale, medium-dark-gray; silty, noncalcareous; contains abundant lenses and burrows filled with pyrite	302.5	1.5
Coal, black, bright, moderately friable; contains a 1-in. lens of pyrite (unnamed coal)	304.0	0.3
Underclay, light-olive-gray, slickensided, churned in upper part; contains pyrite-filled burrows in lower part	304.3	0.5
MISSISSIPPIAN SYSTEM		
Chesterian Series		
Fayetteville Formation		
Limestone, dark-yellowish-brown with brownish-black mottling, calcarenitic, fine- to medium-grained, cross-bedded, highly fractured in upper part; shows cone-in-cone structure in upper 2 ft; contains abundant fossil fragments; good oil show; becomes very light-gray with dark-gray streaks and stylolites from 311 to 324 ft; contains greenish-gray shale clasts below 323 ft	304.8	24.4
Limestone, pale-yellowish-brown with light-gray and greenish-gray shale bands, fine- to medium-grained, calcarenitic, cross-bedded; conglomeratic in places; contains some greenish-gray shale pebbles and tar stains	329.2	2.3
Total depth		331.5

SPECIAL PUBLICATION 89-1. *Selection and Geology of Oklahoma's Superconducting Super Collider Site,* by Kenneth V. Luza and others. 85 pages. Price: $8.50.

Divided into two sections, this report deals with (1) the site-selection process and (2) the geology of the selected site for Oklahoma's proposed Superconducting Super Collider (SSC) site.

The site-selection section presents information about the processes used to evaluate the State for possible SSC sites. Three tables contain geotechnical criteria used to evaluate and rank 12 sites. One table compares the natural, environmental, and cultural factors that affect the top four rated geotechnical sites. The Kingfisher site received the highest total of points in both the geotechnical and non-geotechnical analysis.

The geologic section includes a discussion of geologic framework, stratigraphy and structure of exposed strata, geomorphology and topography, evaporite deposits beneath the site, petroleum development, and seismicity and faulting of the Kingfisher site. Two structural cross sections showing Permian strata beneath the proposed SSC facility are included.

GEOLOGIC MAPS OF THE HIGGINS, DAMON, AND BAKER MOUNTAIN QUADRANGLES, LATIMER COUNTY, OKLAHOMA, by Neil H. Suneson and Charles A. Ferguson. Scale 1:24,000. Ozalid copies. Price: $6 each.

The Ouachita COGEOMAP Project is a joint effort of the U.S. Geological Survey, Oklahoma Geological Survey, and Arkansas Geological Commission to prepare a series of new geologic maps of the Ouachita Mountains in Oklahoma and Arkansas. The project includes review and compilation of existing information and maps on the Ouachita Mountains, and new geologic mapping at a scale of 1:24,000 (7.5′ topographic base). The purpose of the mapping is threefold: The new maps should provide a basis for (1) resource exploration and development, (2) land-use planning such as highway construction, and (3) university field trips and future theses.

Based on existing geologic maps and resource interest and potential, the Oklahoma Geological Survey elected to focus its mapping effort on a west-to-east strip of 7.5′ quadrangles starting immediately southeast of Hartshorne, Oklahoma, and ending at the Arkansas state line. The mapping effort was designed to begin where the excellent geologic map by Hendricks and others (1947) ended, and to include all the area within the quadrangles south of the Choctaw fault. Later, it was decided to map those parts of the Arkoma basin affected by Ouachita tectonics and included in quadrangles that contain the Choctaw fault. Mapping began in 1986 and is continuing. The first three maps (Higgins, Damon, and Baker Mountain) are available as black-and-white, author-prepared ozalids, comprising geologic map, cross sections, description and correlation of units, and list of wells.

SP 89-1 and COGEOMAP geologic quadrangle maps of the Ouachita Mountains can be purchased over the counter or postpaid from the Survey at 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031.

T. H. Lee Williams

WILLIAMS APPOINTED ASSOCIATE DEAN OF OU COLLEGE OF GEOSCIENCES

T. H. Lee Williams, an associate professor of geography, has been appointed associate dean of OU's College of Geosciences. Established in 1981, the College comprises the School of Geology and Geophysics, School of Meteorology, and Department of Geography.

Williams came to OU in 1986 to work in remote sensing in the College of Geosciences. He is director of both the Geosciences Remote Sensing Group and the Cooperative Institute for Applied Remote Sensing, a collaborative effort between OU and the National Oceanic and Atmospheric Administration. He also is involved in the development and enhancement of the image-processing facilities of the University's Geosciences Computing Network, which has evolved into a major facility for image processing, graphic visualization, and numerical modeling.

Born in Wales, Williams received his bachelor's degree in 1972 and his doctoral degree in 1977 from the University of Bristol. He spent nine years at the University of Kansas, where he was granted an intrauniversity visiting professorship in electrical engineering.

AAPG MID-CONTINENT SECTION MEETING
Oklahoma City, Oklahoma, September 24–26, 1989

Welcome to Oklahoma City. The members and spouses of the Oklahoma City Geological Society have worked diligently to provide a great meeting for the Mid-Continent Section of the American Association of Petroleum Geologists.

Oklahoma City's birth began with a single gunshot 100 years ago on April 22, 1889. A vast crowd waited eagerly at the border of the Unassigned Lands to rush across the broad prairie land and stake claims for new homes and new opportunities. It was a dramatic beginning for this Mid-Continent city. When the dust had settled, 10,000 pioneers were proud to have set the stage for Oklahoma City by converting stark prairie land into a foundation for healthy homes and businesses.

The untamed spirit of the pioneers and cowboys has propelled the city into the modern era with one of the most extensive urban-renewal projects in the country, resulting in a look of considerable new development and a host of modern skyscrapers dominating the skyline.

The theme of the meeting is "Stake Your Future in the Mid-Continent, Where Success Meets the West." This theme was selected to emphasize the geologist's continuing role in exploration, production, and secondary recovery in the Mid-Continent area. Recent major discoveries have proven that the Mid-Continent continues to be a prime place to explore for large reserves of oil and gas in deeper formations of the old producing areas and the vast wildcat areas.

A variety of papers on Mid-Continent geology, poster sessions, two field trips, two short courses, special presentations, and a host of entertaining events offer a broad range of learning opportunities and fun.

The Sheraton-Century Center, Oklahoma City's finest convention hotel, will be our headquarters. The technical sessions and exhibits will be located in the adjacent Myriad Convention Center.

We look forward to seeing all of you in Oklahoma City.

—Gary W. Hart
General Chairman

AAPG Mid-Continent Section Meeting Agenda

Technical Sessions

September 25

The Role of Diagenesis in Development of Upper Morrow Fan-Delta Reservoirs in the Anadarko Basin
Depositional and Diagenetic Controls on Production in Morrow Valley Fills, Central State Line Area, Colorado/Kansas
Regional Geology of the Pierce Member of the Upper Morrow Formation in the Anadarko Basin, with a Detailed Look at South Dempsey Field in Roger Mills County, Oklahoma
The Current Economic Bias Against Exploration
Tetrahedral Model for Hydrocarbon Trap Classification: An Aid to Prospect Generation
Gravity and Magnetic Modeling of the Central Segment of the Midcontinent Rift in Iowa: New Insights into It's Stratigraphy, Structure, and Geologic History
Structural Aspects of the Mid-Continent Rift System in Kansas
Petroleum Potential of Lower and Middle Paleozoic Rocks in the Nebraska Portion of the Midcontinent
Thickness Variation of the Simpson Group in South-Central Oklahoma and Its Tectonic Significance
Primary and Secondary Porosity Development in Valley Fill, Marine Sandstone Reservoirs, Misener Formation, North-Central Oklahoma
Misener Sandstone—A Complex Cyclic Sequence
Reservoir Heterogeneity within the Bartlesville Sandstone, Glenn Pool Oil Field, Creek County, Oklahoma
Depositional Framework and Reservoir Distribution of Red Fork Sandstone in Oklahoma
Depositional Facies of Hydrocarbon Reservoirs of the Upper "Cherokee" Group
Petrography and Depositional Systems of the Tonkawa Format Interval (Virgilian) in Woods County, Oklahoma
Evaluation of the Stratigraphic Relations of Sandstone—Producing Reservoirs in the Upper Council Grove and Chase Groups (Permian) in North-Central Oklahoma

September 26

Earthquake Activity in Oklahoma
Petroleum Geology of the Ouachita Uplift Region of Oklahoma
Seismic Exploration of the Ouachita Frontal Fairway, Southeastern Oklahoma
Sedimentation and Petrology of the Fanshawe Sand, Red Oak Field, Arkoma Basin, Oklahoma
Recent Developments at Wilburton Field, Latimer County, Oklahoma
Coal Bed Methane Production in Eastern Kansas—Its Potential and Restraints
Kansas Coal Resources and Their Potential for Utilization in the Near Future

Coal Geology of Okmulgee County and Eastern Okfuskee County, Oklahoma
Coalbed Methane Resources in the Arkoma Basin, Southeastern Oklahoma
Multilayer/Wrench-Fault System Using Rock Models Deformed Under Confining Pressure
Seismic Stratigraphy of the Upper Pennsylvanian Swope Limestone of Kansas and Oklahoma: Quantification of Thin Bed Porosity through Attribute Analysis
Exploration for Hunton Production in Dewey and Blaine Counties, Oklahoma
Evidence of Paleokarstic Phenomena and Burial Diagenesis in the Ordovician Arbuckle Group of Oklahoma
Pressure Seals—Implications for Deep Gas Exploration in the Anadarko Basin
Effects of Organic Matter Content and Maturity on Oil Expulsion from Petroleum Source Rocks
Hydrocarbon Identification Using Mud Log Chromatography in Low-Resistivity Simpson Sandstones
Avoiding Pitfalls when Mapping with Personal Computers
Rocks and Money
Empirical Model of Temperature Structure, Anadarko Basin, Oklahoma

Short Courses

Turbidites and Arkoma Basin, Deep Water Sandstones, *September 23*
Characterization of Sandstone Reservoirs in the Mid-Continent Region—An Integrated Approach, *September 24*

Field Trips

Stratigraphy of the Arbuckle Group, Arbuckle Mountains, Oklahoma, *September 23*
Frontal Belt of the Ouachita Mountains, Southwestern Arkoma Basin, Oklahoma, *September 27–28*

For further information about the Mid-Continent Section Meeting, contact AAPG, Convention Dept., P.O. Box 979, Tulsa, OK 74101; (918) 584-2555. The preregistration deadline is September 9.

Oklahoma: A Summary of Activities of the U.S. Geological Survey, Water Resources Division, in Fiscal Years 1986–87

Compiled by John S. Havens, this 141-page USGS open-file report includes summary statements of current and recently completed projects, alphabetical and numerical listings of surface-water stations, and a bibliography of Oklahoma reports.

Order OF 88-0172 from: U.S. Geological Survey, Books and Open-File Reports, Federal Center, Box 25425, Denver, CO 80225. The price is $4 for microfiche and $22 for a paper copy; add 25% to the price for shipment outside North America. A limited number of copies are available for distribution free of charge from the U.S. Geological Survey, Water Resources Division, 215 Dean A. McGee Ave., Room 621, Oklahoma City, OK 73102; phone (405) 231-4256.

Flood of May 26–27, 1984, in Tulsa, Oklahoma

D. L. Bergman and R. L. Tortorelli compiled this USGS hydrologic investigations atlas. Latitude about 35°57′30″ to about 36°15′ longitude about 95°45′ to about 96°07′30″. Scales 1:96,000 (1 in. = 8,000 ft) and 1:48,000 (1 in. = 4,000 ft). Sheet 37 × 58 in.

Order HA 0707 from: U.S. Geological Survey, Map Distribution, Federal Center, Box 25286, Denver, CO 80225. The price is $3.60. (A $1 postage and handling charge is applicable on orders of less than $10.)

Review of the General Geology and Solid-Phase Geochemical Studies in the Vicinity of the Central Oklahoma Aquifer

E. L. Mosier and J. H. Bullock, Jr., wrote this USGS circular on the Central Oklahoma Aquifer, the principal source of ground water for municipal, industrial, and rural use in central Oklahoma. Arsenic, chromium, and selenium are found in the ground water in concentrations that, in places, exceed the Environmental Protection Agency's primary drinking-water standards. Gross-alpha concentrations also exceed the primary standards in some wells, and uranium concentrations are uncommonly high in places. As a prerequisite to a surface and subsurface solid-phase geochemical study, this 18-page report summarizes the general geology and results of previously reported solid-phase geochemical studies that relate to the vicinity of the Central Oklahoma Aquifer, including a summary of the analytical results and distribution plots for As, Se, Cr, Th, U, Cu, and Ba from the U.S. Department of Energy's National Uranium Resource Evaluation Program.

Order C 1019 from: U.S. Geological Survey, Books and Open-File Reports, Federal Center, Box 25425, Denver, CO 80225; phone (303) 236-7476. The circular is available free of charge.

Permian Rocks of the Midcontinent

This volume is an outgrowth of a symposium on "Permian Rocks of the Midcontinent," which was the subject of the Midcontinent SEPM Annual Meeting held in Ponca City, Oklahoma, October 30–November 1, 1986. Edited by William A. Morgan and Jack A. Babcock, the 12 papers included in the 224-page volume address such topics as regional geology, economic resources, lithostratigraphy and depositional facies, and biostratigraphy.

Order Midcontinent SEPM Special Publication No. 1 from: Kansas Geological Survey, 1930 Constant Ave., University of Kansas, Lawrence, KS 66046; phone (913) 864-3965. The price is $25 plus shipping.

Analyses of Natural Gases from Anadarko Basin, Southwestern Kansas, Western Oklahoma, and Texas Panhandle

D. D. Rice, C. N. Threlkeld, and A. K. Vuletich are the authors of this five-page USGS open-file report.

Order OF 88-0391 from: Kansas Geological Survey, 1930 Constant Ave., Campus West, University of Kansas, Lawrence, KS 66046; phone (918) 864-3965. The price is $4 for microfiche and $1.50 for a paper copy.

MINERAL INDUSTRY OF OKLAHOMA, 1988

Nonfuel mineral production value in Oklahoma was estimated at $215 million in 1988, down 3.6% from 1987. Oklahoma ranked 36th in the nation and accounted for 0.7% of the total U.S. nonfuel mineral value. Construction materials represented most of the output value; crushed stone, portland cement, construction and industrial sand and gravel, crude and calcined gypsum, and iodine were the leading commodities. The greatest increase in output was for iodine, followed by lime.

Employment—The number of workers employed in mining during October 1988, excluding workers in oil and gas extraction, was estimated to be 2,400, down 11.2% from October 1987, according to the Oklahoma Employment Security Commission. Overall employment in the State was down 2.8%.

Exploration—NERCO Minerals Co.'s subsidiary, NERCO Exploration Co., entered into an exploration joint venture with Newmont Exploration Ltd. and American Copper & Nickel Co. to conduct drilling exploration for precious metals in southwest Kiowa County, on lands that are partly federal. NERCO Exploration had conducted reconnaissance exploration in the county during the 1986 and 1987 field seasons. The company is in the early phase of a 5-year precious-metals exploration program that will test a geologic model developed by the firm.

Review by Nonfuel Mineral Commodities—Output and value of portland cement decreased insignificantly from 1987; however, masonry cement output and value rose about 10%. Also estimated to have decreased from 1% to 10% were production and value of common clay and shale, crude gypsum, construction sand and gravel, industrial sand, and dimension stone. Even larger decreases in output and value were estimated for salt and tripoli.

Iochem Corp., of Japan, began production from 10,000-foot-deep brine wells near Vici, Dewey County, in late 1987. Production in 1988 averaged about 20 tons of iodine per month. This second brine plant in western Oklahoma can be credited with some of the estimated 26% increase in quantity and 40% increase in value of iodine for 1988.

North American Brine Resources began construction in late December of northwest Oklahoma's third brine-processing plant. Cost of the project is expected to reach $5 million. The operation, near Woodward, initially will employ 6 to 14 persons; iodine production is expected in May 1989 from four wells in Harper County. North American Brine is a joint venture of Beard Oil Co. and two Japanese firms, Inorgchem Developments Inc. and Godoe (USA) Inc.

Kerr-McGee Corp. sold its Sequoyah Fuels Corp. subsidiary to General Atomics in early November. The sale ended Oklahoma City-based Kerr-McGee's involvement in the uranium industry. Sequoyah Fuels operates a plant at Gore at which it produces uranium hexafluoride and uranium tetrafluoride.

NONFUEL MINERAL PRODUCTION IN OKLAHOMA

Commodity	1987		1988[a]	
	Quantity[b]	Value (thousands)	Quantity[b]	Value (thousands)
Cement:				
Masonry (thousand short tons)	41	$ 2,436	45	$ 2,700
Portland (thousand short tons)	1,415	54,870	1,400	54,200
Clays (thousand short tons)	797	1,783	740	1,637
Gemstones	—	8	—	8
Gypsum (thousand short tons)	1,828	13,336	1,639	12,457
Sand and gravel:				
Construction (thousand short tons)	10,500[c]	24,200[c]	10,000	23,400
Industrial (thousand short tons)	1,243	17,078	1,200	17,000
Stone:				
Crushed (thousand short tons)	25,155[d]	83,732[d]	23,400[d]	74,200[d]
Dimension (thousand short tons)	8	861	8	785
Combined value of feldspar, iodine, lime, salt, stone (crushed dolomite 1987–88), and tripoli	—	24,915	—	28,781
Total	—	$223,219	—	$215,168

Source: USBM Denver Regional Office of State Activities in cooperation with the Oklahoma Geological Survey.
[a]Preliminary figures.
[b]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[c]Estimated.
[d]Excludes certain stones; kind and value included with "Combined value" data.

UPCOMING MEETINGS

Society of Petroleum Engineers, Exploration Technology Meeting, October 8–11, 1989, San Antonio, Texas. Information: Meetings Dept., Society of Petroleum Engineers, Box 833836, Richardson, TX 75083-3836; (214) 669-3377.

Society of Exploration Geophysicists, Annual International Meeting, October 29–November 2, 1989, Dallas, Texas. Information: SEG Annual Meeting, P.O. Box 702740, Tulsa, OK 74170-2740; phone James D. Robertson (214) 880-5860.

Geological Society of America, Annual Meeting, November 6–9, 1989, St. Louis, Missouri. *Abstracts due July 19.* Information: Meetings Dept., GSA, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020.

Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Restoration, November 15–17, 1989, Houston, Texas. Information: National Water Well Association, 6375 Riverside Dr., Dublin, OH 43017; (614) 761-1711.

Source Rocks, Generation, and Migration of Hydrocarbons and Other Fluids in the Southern Midcontinent, February 6–7, 1990, Norman, Oklahoma. *Tentative titles of presentations due July 15; abstracts due September 15.* Information: Kenneth S. Johnson, Oklahoma Geological Survey, 100 E. Boyd, Room N-131, Norman, OK 73019; (405) 325-3031.

Society for Mining, Metallurgy, and Exploration, Annual Meeting and Exhibit, February 26–March 1, 1990, Salt Lake City, Utah. *Abstracts due August 1.* Information: SME, Meetings Dept., P.O. Box 625002, Littleton, CO 80162; (303) 973-9550.

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OKLAHOMA ABSTRACTS

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

Relationship of Clay-Mineral Diagenesis to Temperature, Age, and Hydrocarbon Generation—An Example from the Anadarko Basin, Oklahoma

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The work reported here relates the diagenesis of interstratified illite/smectite (I/S) to burial history and oil generation and tests the dependence of temperature and time on the smectite-to-illite reaction.

Clay mineralogies of shales and sandstones of Morrowan–late Springeran age (Early Pennsylvanian) were determined by X-ray powder diffraction (XRD) of core samples from a 13-well profile extending northwest to southeast across the Anadarko basin, Oklahoma. I/S clay, as defined by XRD patterns, is abundant in both the shales and sandstones. Randomly interstratified I/S occurs in many of the shallow samples, but disappears in the present-day depth range of 2,750–3,050 m; only ordered I/S is found in samples below 3,050 m. A regional vitrinite-reflectance profile compiled for the Anadarko basin suggests an average erosional removal of about 800 m. Therefore, maximum burial depth of the zone where randomly interstratified I/S disappears is about 3,540–3,840 m.

Published temperature models suggest that, for Tertiary and Cretaceous rocks, the transition from randomly interstratified I/S to short-range ordered I/S occurs between 100 and 110°C. Assuming a constant geothermal gradient of 2.37°C/100 m and burial histories, maximum temperatures of 100–110°C correspond to present-day burial depths between 2,700 and 3,120 m. These independently calculated depths for the 100–110°C isotherm are in excellent agreement with the depths at which randomly interstratified I/S is observed to disappear in Morrowan–Springeran age rocks. The similarity in temperature for the I/S phase change in rocks of Early Pennsylvanian, Cretaceous, and Tertiary age spanning a time of some 300 million years suggests that time plays a secondary role in the diagenesis of these clay minerals.

The relation between the I/S transition and oil generation in the Anadarko basin is shown. The nonparallel bands illustrate the different time dependence assumed for kerogen maturation and clay diagenesis. The burial histories of two areas in the basin illustrate how clay-mineral diagenesis at these locations can be related to stages of hydrocarbon generation, the time and tectonic period at which clays entered critical temperature windows, and the length of time spent at or above critical temperatures.

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Oil and Gas Developments in Oklahoma and Panhandle of Texas in 1987

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Exploration in 1987 focused on development and extension of existing fields, with development wells outnumbering exploratory wells 13 to 1.

Operators completed 4.3% more exploratory wells and 25.7% fewer development wells than in 1986. The success rate for exploratory wells increased 7.7%; the success rate for development wells remained constant. The Cherokee shelf was the most active trend, with 53 exploratory wells completed in 1987.

The dominant plays were the Atoka, Morrow, Springer, and Marchand in the Anadarko basin; the Misener in Grant County, Oklahoma, on the Sedgwick shelf; the Viola in the Golden Trend along the Pauls Valley uplift; and the Wapanucka, Cromwell, and Atoka in the Arkoma basin.

Nineteen eighty-seven was a year of major sales and acquisitions of Oklahoma and Panhandle of Texas reserves and leases with more than 20 companies buying or selling out.

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Controls on Cyclic Sedimentation in the Strawn–Canyon Interval of North-Central Texas: Confessions of a Reformed Eustatiphobe

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The upper Strawn and Canyon Groups of North-Central Texas are composed of 15 transgressive-regressive couplets that accumulated on the Eastern Shelf of the Midland Basin. These units, on a large scale, represent in outcrop (respectively) updip fluvial-deltaic facies and downdip shelf and carbonate bank facies of a single overall facies tract. Workers who have attempted to explain the cyclicity of the units solely in terms of delta lobe-switching cycles or local tectonics have employed a perspective too broad to identify glacial eustatic effects in Pennsylvanian rocks. An approach that emphasizes regional subsurface mapping with electric logs and the use of surface stratigraphic sections for generating sandstone depositional models will very likely fail to identify marine "core" shales, deeper marine invertebrate faunas in shelf settings, soil horizons developed in thick shale sequences, and subaerial exposure surfaces in carbonate banks. Only very detailed outcrop or core studies will be of use for identifying these features.

The best evidence for eustasy in the Texas Pennsylvanian section can be seen with the carbonate units. Reciprocal sedimentation with the Missourian double bank system on the Eastern shelf, as well as the presence of exposure surfaces in Canyon bank facies and oxygen-carbon stable isotope anomalies indicative of

meteoric diagenesis all strongly support the glacio-eustatic hypothesis. With the terrigenous clastic rocks, the presence of well developed soil zones in Strawn marine shales and the development of incised valley fill units both indicate drastic base level changes. "Core" shales have been identified in the Cisco part of the section. They should also be actively sought in the Canyon transgressive units.

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Late Pleistocene and Early Holocene Deposits in Western Oklahoma: Archaeological Implications

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The southern Prairie Plains of Western Oklahoma has a gently rolling but extensively dissected terrain. Most of the area is underlain by Permian sandstones and shales, which are commonly exposed in steep-walled canyons. Valley fill in these canyons is mainly (late?) Pleistocene and Holocene in age. Five canyons have been the focus of repeated study concerning this dynamic geologic and ecological period. ^{14}C dating of subfossil trees and charcoal has made possible correlation, throughout an area some 80 km in extent, of terminal Pleistocene and early Holocene alluvial deposits dating between 11,200–8,500bp. These deposits are referable to the lower member of the Domebo Fm. as defined by Albritton (1966). Artifacts of distinctive Paleoindian types are common to all of the canyons where the lower Domebo Fm. has been identified. The archaeological significance of these deposits is extreme for several reasons, including: (1) the opportunity to better understand the ecological stage occupied by Paleoindians regardless of the direct association of artifacts with specific exposures; (2) the potential for gaining detailed floral and faunal records for this period of environmental change; (3) documenting the rare and precarious nature of sites such as the Domebo mammoth kill; and (4) highlighting the need for systematic and well-grounded geomorphological investigations to be done in conjuction with archaeological excavations *and* surveys in regions where such deeply buried deposits occur.

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A Proposed Basis for Establishing a Formal Atokan/ Desmoinesian Boundary

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Both the Atokan and Desmoinesian Series have been based loosely on type regions rather than on precisely defined type sections. Moreover, the rocks of these regions overlap stratigraphically to some degree. Much of the type Atoka is poorly

fossiliferous, and the base of the type Desmoines is strikingly diachronous. Historically, the fusulinid zones of *Fusulinella* and *Beedeina* have been treated as equivalent to the upper Atokan and Desmoinesian, respectively. While this practice has provided some consistency in usage, confusion has resulted from the overlap in the ranges of these two genera. The utility of a post-Morrowan, pre-Desmoinesian series has become ingrained within the literature, and proposals to abandon the Atokan Series would not resolve the problems associated with this segment of earth history.

A consistent boundary should be defined by the first occurrence of widespread, abundant taxon. In the type Desmoinesian region in south-central Iowa, a marine stratum overlying the Cliffland Coal has yielded the first occurrences of several diagnostic conodonts. These include one species of *Neognathodus* and three of *Idiognathodus*, a genus that has been under-utilized for biostratigraphy in part because of a history of poor taxonomic practice. The horizon from which these taxa were recovered lies stratigraphically near the historical boundary based on fusulinids, and thus would be less disruptive than other candidate horizons. Of particular significance is the correspondence of this horizon with that recognized in the Midcontinent as the Atokan/Desmoinesian boundary based on palynomorphs. This would provide an integration of the marine and terrestrial biostratigraphic records that is all too often lacking. Work is progressing on identifying this horizon in lower Desmoinesian strata in the type Atokan region and elsewhere.

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The Late Proterozoic Zambezi Belt in Southern Africa: A Model for the Deeper Levels of the Southern Oklahoma Aulacogen

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Late Proterozoic (Pan-African) orogenic belts in southern Africa developed both as collisional orogens formed by consumption of ocean basins, and as intracratonic belts of subsidence, sedimentation and subsequent deformation. In south-central Africa, the EW-trending intracratonic Zambezi belt appears to represent an aulacogen exposed at mid-crustal levels. The belt is linked at its eastern end with the NS-trending continental margin Mozambique belt, and the resulting triple junction is directly analogous to relations between the Southern Oklahoma aulacogen (SOA) and the late Paleozoic Ouachita orogen.

The Zambezi belt contains extensive tracts of remobilized and mylontized sialic basement structurally overlain by thick supracrustal rocks. Bimodal volcanic rocks at the base of the sequence are inferred to record initial extension-related magmatism, which gave way to deposition of clastics and then shallow-marine carbonate rocks. Following accumulation of the sedimentary section, penetrative ductile deformation under amphibolite-facies conditions occurred in a transpressive regime and was associated with intrusion of large volumes of syntectonic granite.

The SOA contains a volcanic and sedimentary section as much as 15 km thick. Biomodal volcanics at the base are overlain by a dominantly shallow marine sequence that was strongly deformed in the late Paleozoic. Transpressive shortening and strike-slip faulting of this sequence must have been accompanied at depth by deformation of continental basement under ductile metamorphic conditions. We propose that the Zambezi belt provides a model for the geologic evolution of the deeper parts of the SOA, not as yet penetrated by drilling. Conversely, the SOA may be used as an analog for the upper parts of those Precambrian intracratonic orogens that are now exposed as belts of remobilized basement and metamorphosed supracrustal rocks.

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Regional Depositional Trends and Organic-Carbon Content of the Woodford Shale, Anadarko Basin, Oklahoma, Based on Gamma-Ray, Density and Resistivity Logs

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The organic-rich, highly compacted Woodford Shale of Late Devonian and Early Mississippian age is widely regarded as a major hydrocarbon source rock in the Anadarko basin of Oklahoma. The Woodford is divided here into three informal units—the upper, middle, and lower members of the Woodford Shale—on the basis of log character. Higher kerogen content of the middle member is the likely physical basis for this subdivision.

Isopachs of the Woodford Shale and its three members reveal a positive structural feature that divided the Woodford into northeast and southwest depocenters. This feature, which is parallel to and about 120 km north of the Wichita Mountains front, was a hinge line separating areas of regional basement flexure during Woodford time. Lower and middle members of the Woodford thicken to the southwest into the now-eroded central trough of the southern Oklahoma aulacogen. The upper member thickens to the northeast reflecting initial development of the Sedgwick basin of south-central Kansas.

Total organic carbon (TOC, wt%) is calculated here from log-derived formation density (P_b, g/cm^3) using the equation $TOC = (156.956/P_b) - 58.272$. TOC of the upper, middle, and lower members of the Woodford Shale averages 2.7, 5.5, and 3.2 wt%, respectively. TOC does not correlate with formation thickness, but does decrease with increasing thermal maturity in response to the progressive generation and expulsion of hydrocarbons.

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Spatial and Temporal Correlation of Pennsylvanian Uplift and Subsidence: Wichita Uplift and Anadarko Basin, Southwest Oklahoma

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The Wichita uplift and the adjoining Anadarko basin represent one of the largest and most continuously active uplift/basin pairs of the Ancestral Rocky Mountains. The sedimentary record preserved in the Anadarko basin is used to decipher the tectonic evolution of the Pennsylvanian Wichita uplift in southwest Oklahoma and the Texas Panhandle.

Paleozoic subsidence histories derived from five deep wells within the basin show: (i) an initial pulse of rapid subsidence related to Cambrian rifting, (ii) a gradual decline of subsidence rates until the end of the Devonian, and (iii) a gradual increase in rates during the Mississippian culminating in rapid Pennsylvanian subsidence. During the Late Paleozoic, the Wichita uplift was thrust over the southern margin of the Anadarko basin. The locus of maximum synorogenic deposition migrated from the center of the basin to the southwest during the Early–Middle Pennsylvanian (Morrowan–Missourian), and finally to the northwestern portion of the basin during Late Pennsylvanian (Virgilian).

Decompacted sediment thickness trends within the basin indicate diachronous uplift and subsequent erosion of the ancestral Wichita Mountains. We interpret second-order perturbations on these patterns to be the result of depositional thinning above detached anticlines within the deep basin adjacent to the uplift.

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Rugose Coral Occurrence in Pennsylvanian Transgressive and Regressive Missourian Limestones of Kansas with Remarks on Deep and Shallow Water Corals of Texas and Oklahoma

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Missourian rugose corals are abundant in several regressive and a few transgressive limestones in Kansas. These corals are mostly lophophyllids and the dissepimental aulophyllids, caniniids are ubiquitous, occurring in transgressive and regressive limestones and transgressive shales as well as marine portions of outside shales. The aulophyllids and geyerophyllids occur in only 2 transgressive limestones, but the dissepimental corals occur in all regressive limestones. The four dissepimental genera are: the aulophyllids *Amandophyllum*, *Sestrophyllum*, and *Orygmophyllum*; the geyerophyllid *Kionophyllum* and the caniniid *Caninia*. Col-

lectively the lophophyllids above and the dissepimental genera make up the *Lophamplexus–Amandophyllum* Assemblage of shallow water corals.

The *Lophophyllidium–Amplexizaphrentis* Assemblage of deeper water corals occur in the thick regressive phase of the core shales in Oklahoma and Texas, but is unknown in Kansas core shales. Common rugose genera are *Lophophyllidium*, *Amplexizaphrentis*, and *Bradyphyllum*. The occurrence of the two assemblages is mutually exclusive in the Upper Pennsylvanian Missourian rocks in the 3 steps where both occur, however, Jeffords (1948) noted mixing of the assemblages in both deep and shallow water deposits of Oklahoma.

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Anti-Verging Folds in the Western Plunge of the Benton Uplift, Arkansas

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Although the most widely accepted tectonic model for the Ouachita Mountains calls for the off-scraping and disruption of Paleozoic rocks along a south-directed subduction zone and generation of north-verging folds, folds with axes parallel to the trend of the orogen (east–west) but axial planes dipping away from the general south direction of thrusting are documented in all lithological units on the western plunge of the Benton uplift.

Models have been proposed by several workers for the generation of these folds. These include (1) the back-folding of the nappes to the south during the second folding period, (2) rotation and uplift due to underthrusting of thrust slices, and (3) existence of mechanical boundary (presence of low-strength, overpressurized zones) within the accretionary prisms that results in development of landward-verging structures.

Field studies and structural analysis show that rocks in the western plunge of the Benton uplift have experienced three episodes of deformation and the anti-verging folds are formed during the second phase and have formed in response to the same stress components that generated chevron and conjugate folds. Therefore, geometrical similarities between a series of conjugate folds and the anti-verging folds recorded from different lithological units in several fault-bounded structural domains are used in an attempt to explain their origin. Stereographic plots show that both the poles to the axial surfaces of conjugate folds and also their axes are coincident with the poles to axial surfaces and the axes of the anti-verging folds. Results represent that (1) north- and south-verging folds are formed at the same time (second phase, simultaneous with the conjugate folds), and (2) parallelism of their axial planes and fold axes with the conjugate folds may indicate that they form one side or the other of large conjugate folds in the area, reflecting regional south-verging, overturned folds.

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Sedimentary Character and Provenance of the Crystal Mountain Sandstone, Broken Bow Uplift, McCurtain County, Oklahoma

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Precise determination of depositional environment and detrital source area for the lower Ordovician Crystal Mountain Sandstone is complicated by complex regional deformation and lack of paleontologic data for bed to bed correlation.

Sedimentary structures and textures of the Crystal Mountain indicate a probable shallow water origin. Sands in the formation are well sorted, medium to fine grained orthoquartzites which occur as amalgamated beds with little or no fine sediments between. In most places the Crystal Mountain appears to be a massive sandstone, but a close examination reveals rocks which exhibit laminations and crossbeds in virtually every locality. Parallel laminations are the most common sedimentary structures, but some beds show long, low angle crossbeds or shorter, high angle crossbeds. Though some previous works have suggested deeper environments, it would appear that the Crystal Mountain represents deposition in a shallow shelf environment.

Precise environmental interpretations remain difficult, but determination of a more precise source area of Ordovician sediments into the Ouachita trough will enable a better understanding of sedimentary processes which led to the formation of the Crystal Mountain. Detrital zircons were separated for morphologic and U–Pb age analysis. Two distinct populations were found, one rounded and one euhedral. The zircon ages are currently being investigated so as to discriminate source area and sediment transport direction of sediments in the early Ouachita trough.

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Chronostratigraphic Boundaries in the Midcontinent—Problems, Practices, and Proposals

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Chronostratigraphic boundaries must be incorporated into a lithostratigraphic framework to minimize the problems of facies control and to prevent the development of a nomenclature system that is not only meaningless but difficult to communicate to fellow workers.

Problems regarding Midcontinent chronostratigraphic studies arise chiefly because: (1) boundary correlations are only approximate because of different lithostratigraphic and biostratigraphic interpretations of the boundaries in the type areas; (2) biostratigraphic concepts and procedures vary (some are Oppelzones, some taxon-range-zones, others are lineage zones, etc.); (3) data on stratigraphic

ranges and evolutionary lineages of potentially stratigraphically useful taxa are incompletely known; (4) most depositional sequences are diachronous in nature; and (5) first appearances of species are rarely globally isochronous and furthermore, may be migratory rather than evolutionary events.

Stratigraphic practices also compound the problem: (1) many local chronostratigraphic units were based initially on equally local lithostratigraphic units that lack designated stratotypes, that are poorly exposed and defined, their boundaries are vague, and are now known to include beds both older and younger than those included in the original definition; (2) early paleontological collections were not tied into particular sections, such as would now be called stratotypes; (3) different sets of local chronostratigraphic units are used in different parts of the world; and (4) differences of opinion exist concerning the rank of some chronostratigraphic units.

The main emphasis in chronostratigraphic studies should be toward: (1) designating and defining boundary stratotypes, (2) identifying well-defined rock sequences where many diverse taxonomic groups are represented, (3) designating supplementary reference sections to adequately depict regional facies relationships, (4) developing a sequence of independently based biostratigraphic zones from the integration of paleontological data from the different taxonomic groups represented, and (5) extending the lateral limits of those erected zones regionally to test their chronostratigraphic integrity.

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