OKLAHOMA GEOLOGY

Oklahoma Geological Survey Vol. 50, No. 2 April 1990

On the cover—

Parasitic Fold in the Bigfork Chert, Potato Hills

The cover photograph illustrates a well-defined Z-fold on the north limb of a major anticlinal fold. The parasitic fold is ~3 m south of the Cedar Creek thrust, at a site in the central Potato Hills (SW¼SE¼SE¼ sec. 30, T. 3 N., R. 20 E., Latimer County, Oklahoma). The axial planes of the antiformal and synformal folds have been folded by S-directed compression. However, this S-directed compression was a result of back-thrusting along the North Potato Hills thrust, ~0.8 km north of this exposure. Possible rotation of strata along the Cedar Creek thrust might have also affected the orientation of the exposure. View is toward the east.

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Oklahoma Geology Notes, ISSN 0030-1736, is published bimonthly by the Oklahoma Geological Survey. It contains short technical articles, mineral-industry and petroleum news and statistics, abstracts, notices of new publications, and announcements of general pertinence to Oklahoma geology. Single copies, $1.50; yearly subscription, $6. Send subscription orders to the Survey at 100 E. Boyd, Room N-131, Norman, OK 73019. Short articles on aspects of Oklahoma geology are welcome from contributors; general guidelines will be sent on request.

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CONTENTS

TIAWAH LIMESTONE MEMBER OF THE SENORA FORMATION (PENNSYLVANIAN) IN ITS TYPE AREA

LeRoy A. Hemish[1]

Abstract

A core-hole drilled by the Oklahoma Geological Survey in the type area of the Tiawah Limestone is here designated as a reference well, in accordance with the North American Stratigraphic Code. A principal reference section also is established in the type locality of the Tiawah Limestone. The Tiawah is well exposed in the hills southeast of the city of Claremore, Oklahoma, and in the Tiawah Hills around the town of Tiawah, from which it takes its name.

A thin, generally noneconomic coal bed (Tebo) closely underlies the Tiawah Limestone. A black, platy shale containing phosphatic nodules generally overlies the Tebo coal. The Chelsea Sandstone Member of the Senora Formation fills channels cut into shales that overlie the Tiawah Limestone.

The Tiawah Limestone is an excellent marker; it and the black shale associated with it are readily identified in geophysical logs by their distinctive deflections on the log curves.

Introduction

The purposes of this article are (1) to describe the lithology and stratigraphy of the Tiawah Limestone Member of the Senora Formation in the type area; (2) to establish upper and lower boundaries for the member; (3) to establish a principal reference section in the type locality of the member; (4) to designate a reference well near the type section; and (5) to present a detailed log of the core from the reference well.

The type area of the Tiawah Limestone is the area of hills capped by the Chelsea Sandstone southeast of Claremore, Oklahoma. The type locality is the Tiawah Hills surrounding the town of Tiawah (Fig. 1).

Previous Investigations

The name Tiawah was first used in print by Lowman (1932) to identify a limestone "that is very persistent on the outcrop and is particularly well developed in the hills about the town of Tiawah (southeast of Claremore) from which it may take its name." The type section was selected by Tillman (1952, p. 23), and formally established by Branson (1954, p. 192) "as that in the north road cut on Oklahoma

[1]Oklahoma Geological Survey.

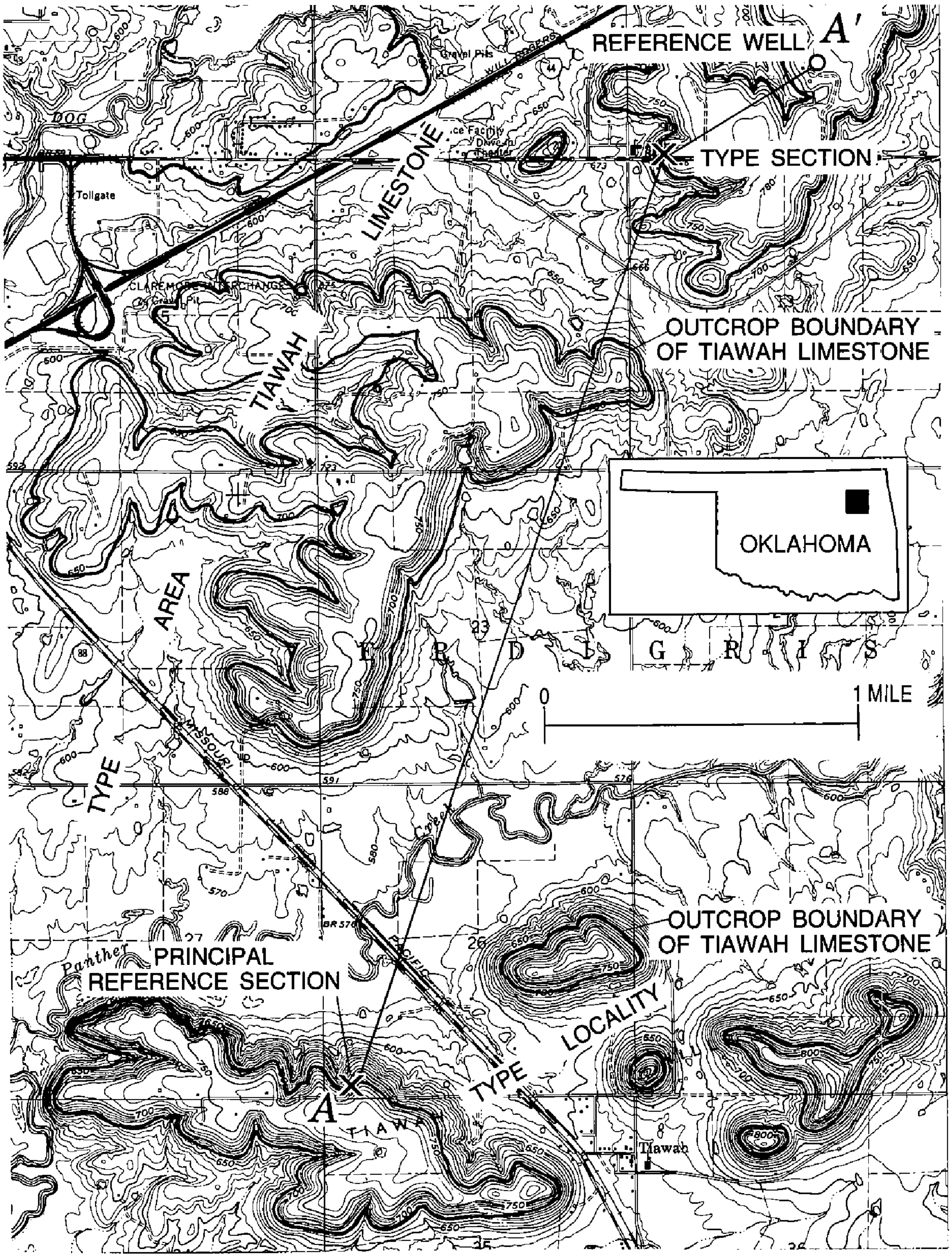

Figure 1. Map locating type area, type locality, type section, principal reference section, and reference well for the Tiawah Limestone Member of the Senora Formation in east-central Rogers County, Oklahoma.

Highway 20 on the west side of the hill in the SW¼ sec. 12, T. 21 N., R. 16 E." The section measured by Tillman is reproduced below. It was measured 0.1 mi east of southwest corner sec. 12, T. 21 N., R. 16 E.

Bed		Ft
12.	CHELSEA sandstone, massive, cross-bedded, coarse, red-brown	31.0
11.	Shale, hard, black to gray	3.0
10.	Ironstone, hard, gray	0.25
9.	Shale, soft, fissile, gray	1.5
8.	TIAWAH limestone, hard, fossiliferous, gray with dark spots, weathers reddish-brown	6.3
7.	Coal (TEBO?)	0.02
6.	Underclay, gray	0.3
5.	Shale, hard and black in lower part with phosphatic concretions, gray in upper part	2.5
4.	Siltstone, gray, hard	0.2
3.	Shale, fissile, gray	5.0
2.	"White" sandstone, fine-grained, micaceous, light-gray	5.6
1.	Shale, medium-hard, fissile, gray	14.0

The Tiawah Limestone is known in the subsurface as the "Pink lime" (Jordan, 1957, p. 157). She observed that it consisted of "two beds at places." Hemish (in preparation a) also observed that the Tiawah Limestone occurs as two beds at different locations south of the type area. In the earliest known discussion of the Tiawah to appear in print Lowman (1932) referred to an "itermittent limestone horizon (upper Pink lime)" separated from the "Pink lime" by a sandy shale.

Because the character of the Tiawah Limestone changes beyond the type area, and no boundaries have previously been defined, the writer here defines the Tiawah Limestone Member of the Senora Formation as all beds from the base of the first limestone above the Tebo coal bed to the top of the first limestone below the base of the Chelsea Sandstone Member.

Establishment of a Principal Reference Section

After the type section of the Tiawah Limestone was established by Branson (1954), a glossary of geology was published which states (Gary and others, 1972, p. 762) that a type section should be contained within a type locality, and that the type locality is contained within the type area. Type locality is defined as the place at which a stratigraphic unit is typically displayed and from which it derives its name—in this case, evidently, the Tiawah Hills. Even though the type section of the Tiawah Limestone is beyond the type locality, it is nevertheless an excellent, readily accessible, representative exposure and must not be changed, according to the North American Commission on Stratigraphic Nomenclature (1983, p. 856). To more closely comply with the definitions specified in the Glossary of Geology, the writer here designates measured section MS 1 (measured in the Tiawah Hills) as the principal reference section for the Tiawah Limestone (Appendix 1). The reference section is located in the type locality of the Tiawah Limestone in the SE¼SW¼SW¼SW¼ sec. 26, T. 21 N., R. 16 E., Rogers County.

Lithology and Stratigraphy

The Tiawah Limestone is recognized at localities extending from east-central Okmulgee County (Hemish, in preparation b) northward into Missouri. The northernmost known Oklahoma exposure is in Craig County, in Wolfe Creek just south of the bridge (NE¼NW¼NW¼ sec. 15, T. 28 N., R. 20 E.). Here the Tiawah is 0.2 ft of clay-ironstone containing brachiopods and gastropods (Branson and others, 1965, p. 35).

Hemish (in preparation a) observed the Tiawah Limestone in Wagoner County, south of the type area, in Fife Creek (NW¼NE¼SW¼ sec. 31, T. 18 N., R. 16 E.). Here the Tiawah consists of 2 beds separated by ~3 ft (covered interval). The upper bed is ~0.4 ft thick, dark-gray with reddish-brown iron oxide staining, fossiliferous, and very hard, forming a ledge in the creek bed. The lower bed is ~0.6 ft thick, dark-gray with reddish-brown staining, very ferruginous and silty in the upper part, abundantly fossiliferous, and has a hackly appearance on weathered surfaces owing to the abundance of broken fossils. A thin (0.1 ft) coal occurs <2 ft above the upper limestone bed. The 0.7-ft-thick Tebo coal bed occurs ~10 ft below the lower limestone at this location. Jordan (1957, p. 157) noted that the Tiawah Limestone consists of "two beds at places."

South of the Arkansas River is Wagoner County, in the SE¼NW¼ sec. 1, T. 16 N., R. 15 E., the Tiawah Limestone consists of two beds; an upper, 0.2-ft-thick, very dark-gray, impure, shaly, carbonaceous, fossiliferous limestone bed, separated from a lower, 1.0-ft-thick, brown-weathering, very dark-gray, wavy-bedded, coquinoidal limestone by 2 ft of dark-gray to black shale (Hemish, in preparation a). The upper bed is >62 ft below the base of the Chelsea Sandstone at this location. The Tebo coal occurs 0.4 ft below a 6.8-ft-thick, black, phosphatic shale immediately below the lower unit of the Tiawah Limestone.

In Kansas the Tiawah Limestone is recognized as a bed in the Cabaniss Formation containing brachiopods and gastropods, and averaging ~0.3-ft thick (Jewett and others, 1968, p. 24). Howe (1956, p. 54) described the Tiawah Limestone as typically extremely dense, tough, and pyritic, forming a single resistant ledge. In exposures in Cherokee County, Kansas (just north of Craig County, Oklahoma), the bed is somewhat shaly and generally carbonaceous, and averages ~0.4 ft thick.

Figure 2 is generalized columnar section showing the position of the Tiawah Limestone relative to other named units in the Boggy and Senora Formations in Rogers County, Oklahoma. Key units for stratigraphic recognition of the Tiawah Limestone Member include the Weir-Pittsburg coal, at the base of the Senora Formation; the Tebo coal, closely underlying the limestone; and the Chelsea Sandstone, which lies 2–15 ft above the limestone (Tillman, 1952, p. 22). In Craig County, the interval between the Tiawah Limestone and the Chelsea Sandstone ranges from 0 to 30 ft, pre-Chelsea erosion and channeling having removed the Tiawah locally (Branson and others, 1965, p. 36).

The Tiawah Limestone is generally separated from the Tebo coal by a few feet of black, fissile shale, which may extend somewhat above the Tiawah or below the Tebo (Oakes, 1977, p. 38). This unnamed black shale and the Tiawah Limestone are readily identified in geophysical logs by their distinctive deflections on the log curves. Figure 3 shows excerpts from geophysical logs identifying the Tiawah ("Pink lime") and associated beds. Figure 3A shows the Tiawah Limestone along

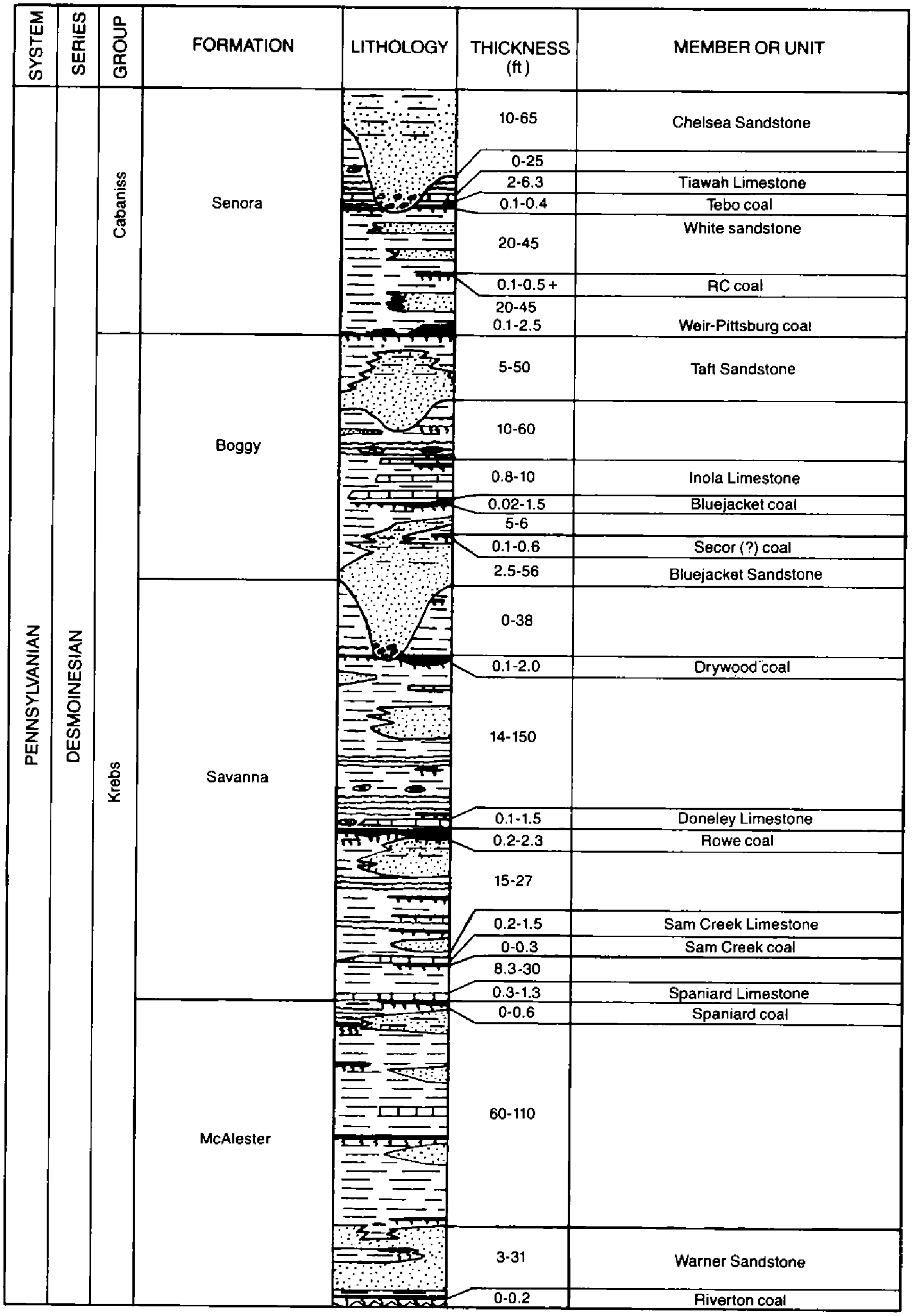

Figure 2. Generalized columnar section, showing rocks from the base of the McAlester Formation to the top of the Chelsea Sandstone Member of the Senora Formation in Rogers County, Oklahoma (modified from Hemish, 1989).

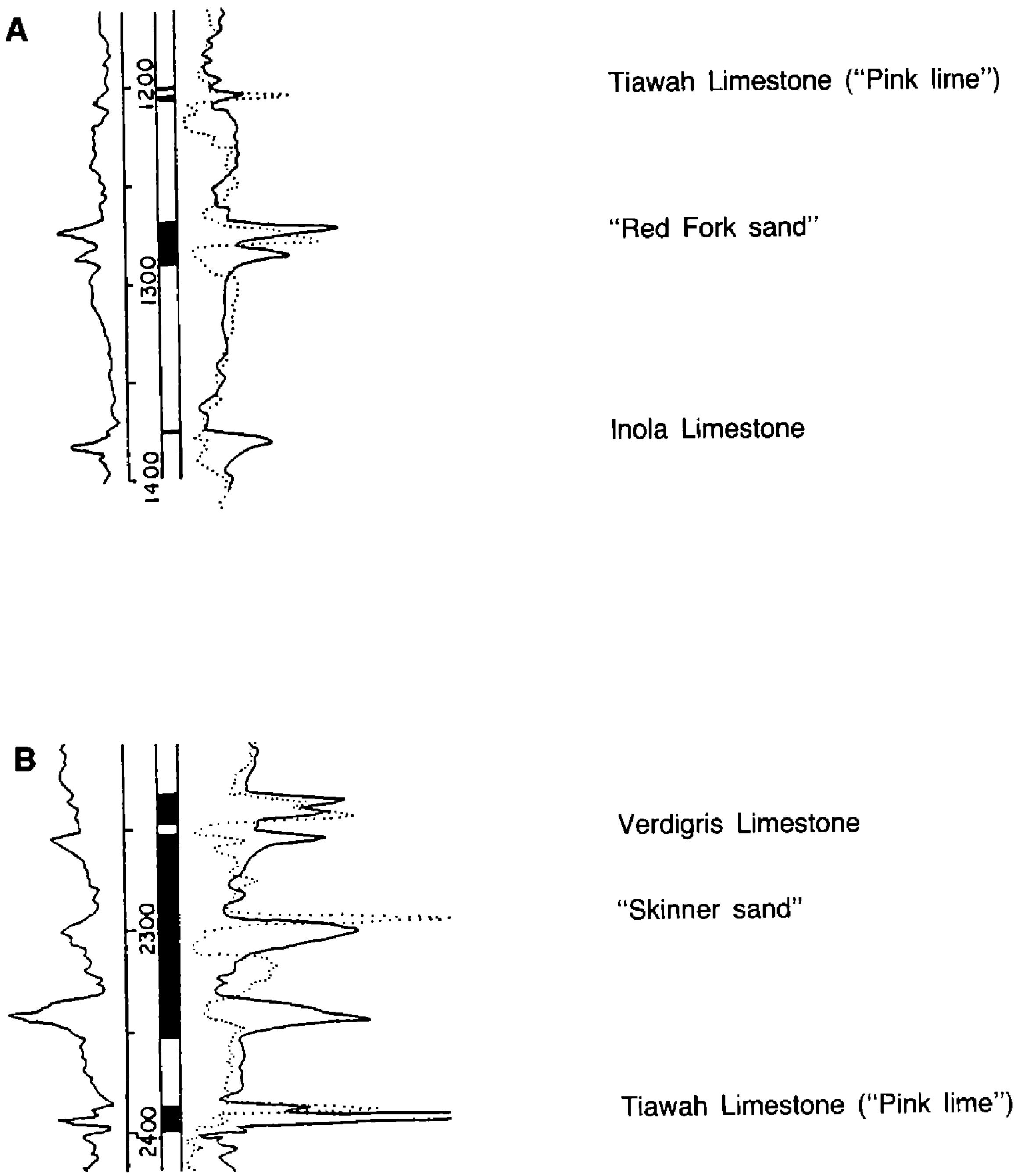

Figure 3. Exerpts from geophysical logs. *A*—Sequence of beds below the Tiawah Limestone; Carter No. 1 M. Big Pond, C W½NW¼SW¼ sec. 6, T. 18 N., R. 12 E. *B*—Sequence of beds above the Tiawah Limestone; Johnson-Clark No. 1-A McArthor NE¼NW¼SW¼ sec. 10, T. 20 N., R. 8 E. From Jordan (1957, p. 165 and 179).

with markers below the unit (the "Red Fork sand" is equivalent to the Taft Sandstone of surface terminology). Figure 3B shows the Tiawah Limestone along with markers above the unit (the "Skinner sand" is equivalent to the Chelsea Sandstone of surface terminology).

Figure 4 is an abbreviated cross section showing the relationships among the strata in a reference well (CH 1, Appendix 2), Tillman's type section, and the principal reference section measured by the writer in the Tiawah Hills (Fig. 1). Photographs of the Tiawah Limestone taken at the type section are shown in Figure 5.

Establishment of Reference Well

In accordance with procedures recommended by the North American Commission on Stratigraphic Nomenclature (1983, p. 853–854) for establishing reference wells, a reference well for the Tiawah Limestone Member of the Senora Formation is here described and defined. The reference well (CH 1, Appendix 2; Figs. 1,4) is located in the SE¼SW¼NW¼SE¼ sec. 12, T. 21 N., R. 16 E., Rogers County, Oklahoma, on the Bill Ramm farm. Continuous 2-in. core was cut from below a 9-ft surface casing to a total depth of 308 ft. Samples of cuttings were collected and bagged from the upper 9 ft. Core drilling was completed on 23 August 1988. Surface elevation was estimated from a topographic map at 773 ft above sea level.

All the core-drilling was done by the Oklahoma Geological Survey. Cores and cuttings from the reference well have been boxed and labeled, and are available for study by the public at the Okahoma Geological Survey Core and Sample Library.

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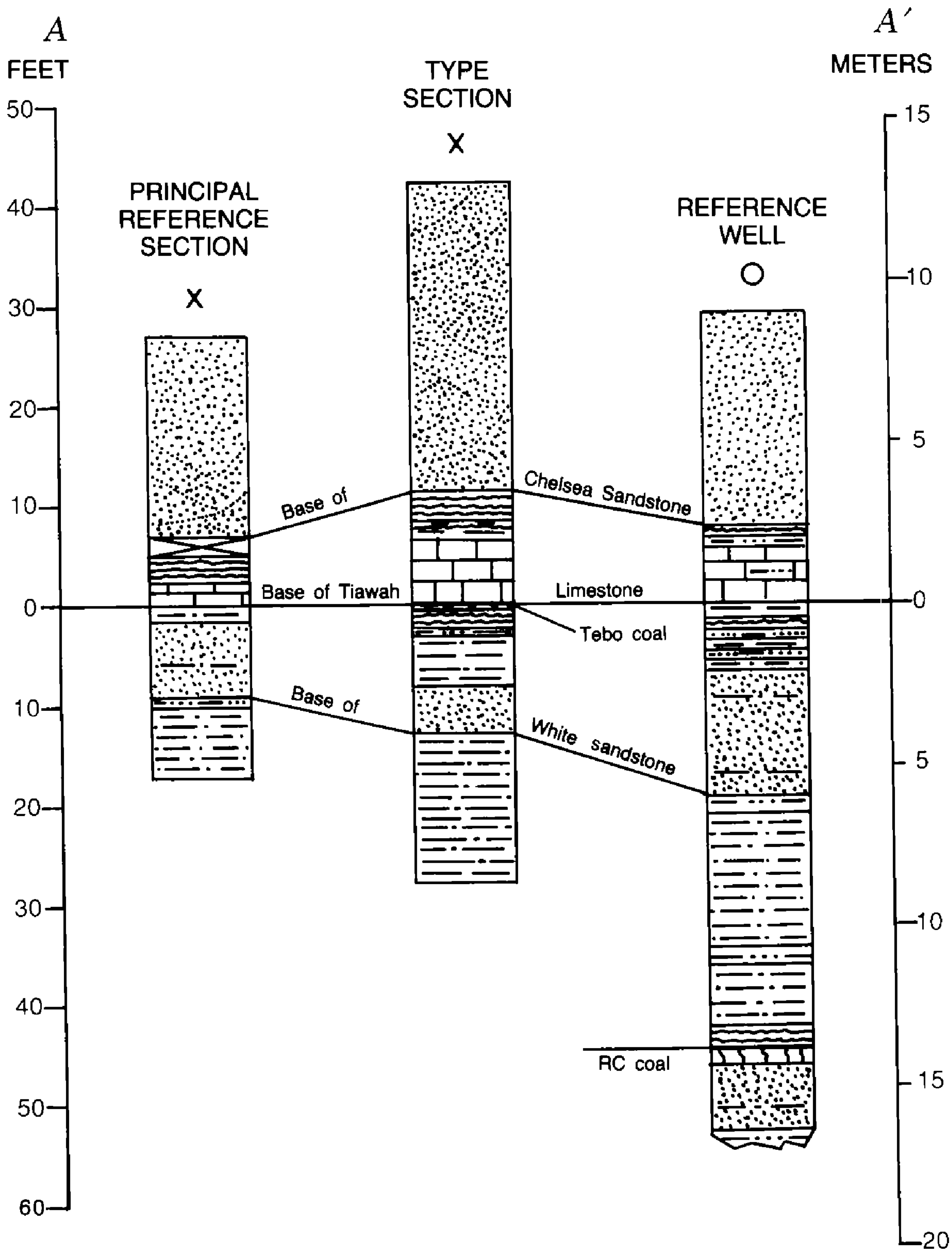

Figure 4. Cross section showing correlations of key units in the type area of the Tiawah Limestone. Line of cross section shown in Figure 1; descriptions of lithologic units in Appendixes 1 and 2, and in measured section from Tillman (1952).

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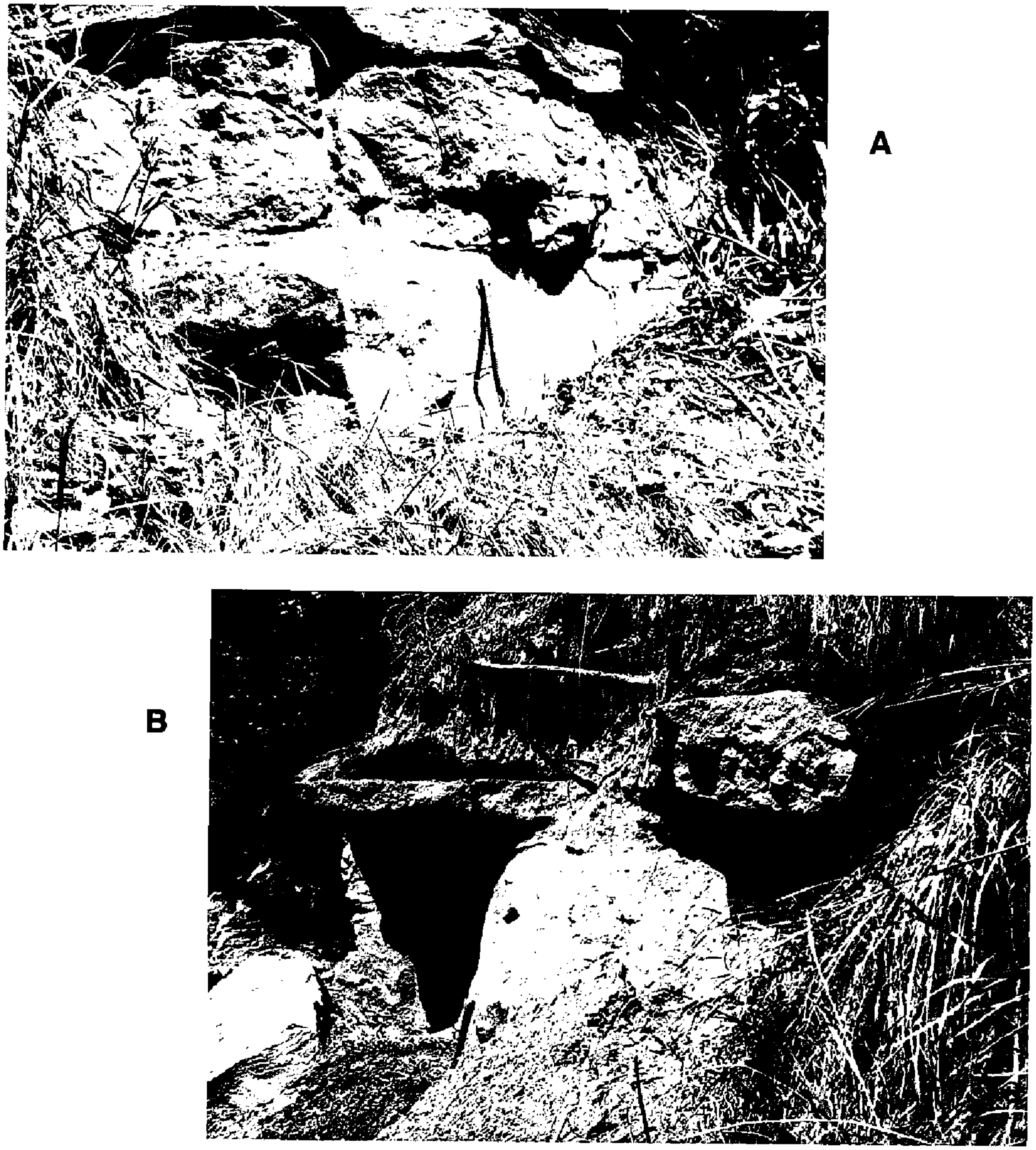


Figure 5. Photographs of the Tiawah Limestone at the type section. *A*—View of the Tiawah in the north road cut on Oklahoma Highway 20, in the SW¼ sec. 12, T. 21 N., R. 16 E. The limestone is >6 ft thick at this exposure. *B*—View of the Tiawah ~100 ft west of the exposure shown in *A*. Note the ledge formed at the break between the upper, medium-gray, vuggy, more-resistant part of the bed, and the lower, light-gray, smooth-weathering part (shown in back of shovel handle in *A*).

Appendix 1

Core-Hole Log

CH 1
(OGS Core and Sample Library No. C RM 2)

SE¼SW¼NW¼SE¼ sec. 12, T. 21 N., R. 16 E., Rogers County, Oklahoma. Well cored by Oklahoma Geological Survey; lithologic descriptions by LeRoy A. Hemish. Drilled in pasture 1,540 ft FSL and 2,060 ft FEL. (Surface elevation, estimated from topographic map, 773 ft.)

	Depth to unit top (ft)	Thickness of unit (ft)
Cabaniss Group		
Senora Formation		
Sandstone, moderate-reddish-orange, fine-grained, noncalcareous; occurs as broken, weathered, angular cobbles in dark-yellowish-brown silty soil	0.0	1.0
Sandstone, dark-yellowish-orange, fine-grained, noncalcareous, micaceous	1.0	5.0
Sandstone, dark-reddish-brown, fine-grained, noncalcareous, micaceous	6.0	3.0
Sandstone, dark-yellowish-orange, moderate-reddish-orange, and dark-reddish-brown in alternating layers, fine-grained, noncalcareous, micaceous, ferruginous, fractured; some blackish-red maganese dioxide staining on fracture surfaces; crossbedded; contains clasts of ironstone in lower 3.5 ft and abundant coal spars in lower 6 in. (base of Chelsea Sandstone)	9.0	12.8
Shale, brownish-black, blocky fracture, noncalcareous	21.8	0.7
Siltstone, olive-black, muddy, massive, noncalcareous; contains very small fossil shells	22.5	0.3
Limestone, medium-gray, fine-grained, impure, silty, pyritic, vuggy, fossiliferous; poorly preserved marine shells common; dark-gray in places; very light-gray with light-gray mottling and wavy laminae in lower 4 ft; fossil hash concentrated in lower 4 in. (Tiawah Limestone)	22.8	5.6
Shale, medium-gray with greenish-gray tint, clayey, calcareous in upper 1 in.; contains rare streaks of black carbonaceous shale and some coaly streaks	28.4	2.0
Shale, grayish-black, carbonaceous, noncalcareous	30.4	0.7
Sandstone, light-brownish-gray, shaly, calcareous, very fine-grained, burrowed	31.1	0.1
Shale, medium-gray, clayey, noncalcareous	31.2	2.0
Sandstone, light-gray, shaly, very fine-grained, noncalcareous, burrowed	33.2	0.9
Shale, medium-light-gray with light-gray streaks, noncalcareous, silty	34.1	1.4
Sandstone, medium-light-gray with medium-dark-gray shale streaks, noncalcareous, very fine-grained; mostly flat-bedded, but contains some low-angle cross-beds and		

cross-laminae; burrowed in part; includes mica and black, macerated plant material on bedding planes; medium-gray below 38 ft; grades into underlying unit . . .	35.5	12.5
Siltstone, medium-dark-gray with light-gray streaks of very fine-grained sandstone, noncalcareous, shaly, flat-bedded; contains pyrite-filled burrows; grades into underlying unit	48.0	2.0
Shale, medium-dark-gray with minor light-gray streaks, silty, hard; contains rare, pyrite-filled burrows	50.0	13.1
Siltstone, medium-gray with light-gray sandstone streaks, noncalcareous, shaly, flat-bedded; includes rare burrows and black, macerated plant material on some bedding planes	63.1	1.9
Shale, medium-dark-gray, silty, noncalcareous	65.0	6.2
Shale, grayish-black, very calcareous; contains irregular bands of limestone composed mostly of shell fragments . .	71.2	0.3
Shale, grayish-black, noncalcareous, pyritic, brittle, crumbly, slickensided; includes a 0.25-in.-thick pyritic coal band at base of unit (RC coal)	71.5	1.9
Underclay, light-gray, mottled, slickensided, very sandy, extensively burrowed	73.4	1.6
Sandstone, very light-gray, noncalcareous, very fine-grained, churned; cross-bedded and wavy-bedded, with some bioturbation features below 77 ft; shaly from 77.7 ft to base of unit	75.0	6.7
Siltstone, medium-light-gray, noncalcareous, shaly, flat-bedded; contains rare burrows and some very fine-grained sandstone layers	81.7	3.8
Shale, medium-gray with light-gray siltstone streaks, noncalcareous, dark-gray in lower 6 in.	85.5	7.5
Sandstone, medium-dark-gray with light-gray streaks, noncalcareous, very fine-grained, shaly, bioturbated	93.0	0.5
Shale, medium-dark-gray with numerous streaks of light-gray, very fine-grained sandstone, rippled, noncalcareous, burrowed	93.5	1.4
Sandstone, medium-dark-gray with light-gray streaks, very fine-grained, shaly, noncalcareous; contains some wavy beds and low-angle cross beds; burrowed	94.9	0.7
Siltstone, medium-dark-gray with light-gray, very fine-grained sandstone streaks, noncalcareous, shaly, flat-bedded; contains rare burrows, some pyrite-filled; coarse-grained in lower 2 ft	95.6	10.0
Shale, dark-gray, noncalcareous; contains light-brownish-gray sideritic concretions up to 3 in. thick, and rare pyritized and carbonized plant fragments	105.6	4.7
Limestone, dark-gray, shaly, fine-grained; contains streaks of coal	110.3	0.1
Shale, black, carbonaceous; contains coal streaks	110.4	0.1
Sandstone, medium-gray to medium-light-gray, shaly, calcareous in upper 2 in., very fine-grained, churned in upper 2 ft, cross-bedded in part, burrowed	110.5	6.0
Shale, medium-gray, silty, noncalcareous; contains numerous streaks of very fine-grained, light-gray sandstone . .	116.5	2.5

Sandstone, medium-dark-gray to medium-gray, very fine-grained, cross-bedded, micaceous, noncalcareous, contains scattered dark-gray shale streaks and abundant black, macerated plant debris on bedding planes; burrowed in part; grades into underlying unit	119.0	29.0
Siltstone, medium-dark-gray with light-gray sandstone streaks and lenses, shaly, noncalcareous; micaceous; mostly flat-bedded, but includes some low-angle cross-beds; contains scattered bioturbation features, minor pyritic and carbonized plant fragments, and rare coal spars; grades into underlying unit	148.0	19.0
Shale, dark-gray, noncalcareous, silty; contains scattered sandy layers, rare pyrite-filled burrows, and some contorted bedding in the sandy layers; includes rare brachiopod fossils and seed-fern leaves below 186 ft	167.0	20.3
Shale, black, noncalcareous; contains scattered calcareous fossil shells and rare pyrite-filled burrows	187.3	2.8
Coal, black, bright, moderately friable; contains white calcite on cleats and layers of pyrite up to 0.25 in. thick (Weir-Pittsburg coal)	190.1	0.2
Krebs Group		
Boggy Formation		
Underclay, light-brownish-gray, blocky fracture, rooted in upper part, churned; grades into underlying unit	190.3	3.0
Shale, light-brownish-gray, noncalcareous, clayey	193.3	2.4
Sandstone, medium-dark-gray, very fine-grained, massive, hard	195.7	0.8
Shale, medium-gray, noncalcareous, carbonaceous and coaly in lower 1 in.	196.5	3.9
Mudstone, brownish-gray, churned in part; contains some wavy, carbonaceous layers in upper 6 in.	200.4	1.3
Claystone, greenish-gray, noncalcareous	201.7	3.0
Shale, medium-gray to dark-gray, noncalcareous; contains light-brownish-gray sideritic concretions up to 1.25 in. thick in lower 1.5 ft of unit	204.7	6.8
Sandstone, light-gray with medium-gray streaks, noncalcareous, silty, very fine-grained, bioturbated	211.5	2.1
Shale, medium-dark-gray, silty, noncalcareous; contains burrowed, light-brownish-gray, sideritic concretions up to 1.75 in. thick; includes rare, pyrite-filled burrows	213.6	4.7
Shale, medium-dark-gray with light-gray, very fine-grained, micaceous sandstone streaks, noncalcareous	218.3	0.7
Sandstone, light-gray to medium-light-gray with dark-gray streaks, very fine-grained, shaly, noncalcareous, micaceous; rippled in part, flat-bedded in part, cross-bedded in part; includes black, macerated plant debris on bedding planes; grades into underlying unit	219.0	13.0
Siltstone, medium-gray with medium-light-gray, sandy streaks, shaly, flat- to wavy-bedded, noncalcareous; grades into underlying unit	232.0	2.0
Shale, medium-gray with medium-light-gray siltstone and very fine-grained sandstone streaks, noncalcareous;		

contains rare sandstone- and siderite-filled burrows and minor pyrite; hard; grades into shaly siltstone at about 247 ft	234.0	13.0
Siltstone, medium-gray, shaly, noncalcareous; contains rare pyrite-filled burrows and disseminated pyrite	247.0	6.0
Shale, medium-dark-gray, silty, noncalcareous; contains light-brownish-gray, sideritic concretions up to 1 in. thick	253.0	8.5
Shale, grayish-black to dark-gray, interbedded with light-gray, very fine-grained sandstone, noncalcareous	261.5	6.5
Shale, black, carbonaceous	268.0	0.1
Coal, black, friable, white calcite and minor pyrite on cleats (Wainwright coal)	268.1	0.8
Shale, dark-gray with light-gray, very fine-grained sandstone streaks, noncalcareous, burrowed	268.9	2.8
Sandstone, light-gray and medium-dark-gray, very fine-grained, interbedded with shale, noncalcareous, wavy-bedded to cross-bedded, micaceous; black, macerated plant debris on bedding planes; burrowed in part	271.7	8.3
Shale, dark-gray, interlaminated with light-gray, very fine-grained sandstone, noncalcareous; some sandstone layers show soft-sediment deformation features	280.0	2.3
Shale, dark-gray; contains rare streaks of very fine-grained, light-gray sandstone; noncalcareous; includes numerous light-brownish-gray, sideritic layers up to 0.5 in. thick; grades into underlying unit	282.3	6.7
Shale, grayish-black, noncalcareous; contains rare fossil brachiopods and scattered, pyrite-filled burrows; includes several light-brownish-gray sideritic concretions up to 1.5 in. thick	289.0	4.7
Ironstone, dark-gray, fractured; limestone containing fossil hash occurs in a ⅛- to 0.75-in.-thick layer at top of unit and in fracture fillings	293.7	0.3
Shale, grayish-black, noncalcareous; contains rare pyrite-filled burrows and small calcareous shells and shell fragments; includes limestone-filled burrows in lower 2 in.	294.0	5.5
Limestone, light-gray to dark-gray with greenish-gray tint in part, shaly in part, cross-bedded in places, fine-grained, fossiliferous; contains abundant fossil hash composed mostly of shell fragments (Inola Limestone)	299.5	2.3
Sandstone, very light-gray to light-gray with medium-gray streaks, fine to very fine-grained, micaceous, cross-bedded, very calcareous from 301.8 to 305 ft; contains rare burrows and scattered shale laminae (Bluejacket Sandstone)	301.8	6.2
Total depth		308.0

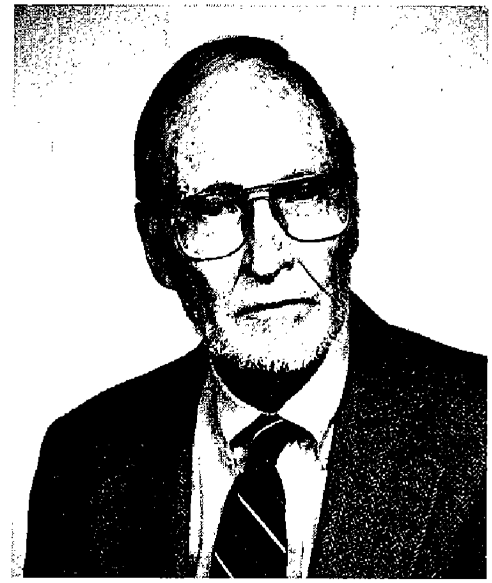
Appendix 2

Measured Section

MS 1
(Principal Reference Section for Tiawah Limestone)

SE¼SW¼SW¼SW¼ sec. 26, T. 21 N., R. 16 E., Rogers County. Measured along road from top of hill to just above hairpin bend in road, by LeRoy A. Hemish. Elevation at top of section, estimated from topographic map, 720 ft.

	Thickness (ft)
Cabaniss Group	
Senora Formation	
Sandstone, very dusky-red to dark-reddish-brown, fine- to very fine-grained, ferruginous, noncalcareous, medium-bedded to massive, cross-bedded in part, contains boxwork, limonite-cemented concretions, forms resistant cap at top of hill (Chelsea Sandstone)	20.0
Covered interval	2.0
Shale, grayish-black with light-brown, weathered streaks, fissile, noncalcareous	2.5
Limestone, medium-dark-gray, weathers grayish-orange, dense, hard, fine-grained, fossiliferous, contains poorly preserved to well-preserved brachiopods in some intervals, mottled and nodular-bedded in part, cellular and very porous where extensively weathered (Tiawah Limestone)	2.9
Shale, medium-gray, silty, poorly exposed	1.5
Sandstone, yellowish-gray with dark-yellowish-brown flecks, very fine-grained, medium- to thin-bedded, micaceous, noncalcareous, shaly and soft in some layers (White sandstone)	7.0
Siltstone, pale-yellowish-orange, sandy, very thin-bedded, micaceous, friable, noncalcareous	1.1
Shale, dark-yellowish-brown, silty, soft, noncalcareous	7.0
Total	44.0


Thomas W. Amsden

OGS GEOLOGIST PRESENTED PALEONTOLOGICAL SOCIETY MEDAL

Thomas W. Amsden, one of the Oklahoma Geological Survey's most respected and widely published geologists, was presented the Paleontological Society medal for significant contributions to paleontology at the Society's annual meeting, held in conjunction with the GSA annual meeting last November in St. Louis. The award is in recognition of Amsden's seminal studies of brachiopods and Silurian–Devonian and Ordovician–Silurian boundaries.

Charles J. Mankin, director of the OGS, said that although Amsden is now officially retired from the Survey, he is continuing his studies and remains actively involved in research.

"Tom spent more than 30 very productive years with the Survey," Mankin said. "During this time he produced a wealth of fundamental studies on lower Paleozoic strata and the contained brachiopod faunas of Oklahoma and elsewhere in the Midcontinent. Although Tom's studies were fundamental in nature, he recognized the practical applications of his work and made a concerted effort to convey that understanding to the practicing petroleum geologists of the region. Through the production of hydrocarbons and non-fuel minerals from these rocks, the State and its citizens have been the ultimate beneficiaries of Tom's contributions."

At the award ceremony in St. Louis, J. Thomas Dutro, Jr., of the U.S. Geological Survey, noted that Amsden is one of a handful of people who know and appreciate Silurian–Devonian faunas and what they reveal of the geologic history in the middle Paleozoic. (Dr. Dutro's remarks are to be published in the *Journal of Paleontology*, v. 46, no. 3, 1990.)

"Tom understands brachiopod systematics and phylogeny in detail and has applied this esoteric knowledge to solving practical geological problems in central North America, and to international deliberations on the positions of the Silurian–

Devonian and Ordovician–Silurian boundaries, among other stratigraphic subtleties," Dutro said. "His monographic studies of the Anadarko and Arkoma basins, in 1975 and 1980 respectively, are models of sedimentary basin analysis."

Dutro pointed out that the creative and imaginative graphics in Amsden's books incorporate combined structure, isopach, and insoluble residue maps; combined magnesium carbonate, isoluble residue, and biofacies maps; combined lithofacies and biofacies maps; a whole series of isopach/lithofacies maps; and paleogeologic maps of various parts of the Hunton Group and the overlying Woodford Shale and the underlying Sylvan Shale; not to mention the correlated stratigraphic sections that clearly show both depositional and erosional relationships.

Once settled into the region, Dutro said, Amsden examined all the brachiopod faunas that he could find in the pre-Carboniferous rocks. He described these faunas, centering on the similar Late Silurian and Early Devonian assemblages in the Hunton Group, and produced an imaginative analysis of the Ordovician–Silurian boundary beds and correlation problems within that interval in the Midcontinent region, stretching from Illinois southward through Missouri to Arkansas and Oklahoma.

"Along the way," Dutro said, "Tom produced gem-like studies of the genera *Microcardinalia* (1966) and *Triplesia* (1971), in which detailed paleobiologic data were used to sharpen the biostratigraphy and correlations in the Early Silurian (Llandoverian) strata in the central United States."

Dutro added that although Amsden is basically a brachiopod aficionado, he has always remained aware of the total faunal assemblages that he was analyzing, and has considered their stratigraphic setting.

In the last year, Dutro said, Amsden has summarized his life's work on brachiopods in an annotated range chart and correlation chart for the Late Ordovician through Early Devonian sequence in the southern Midcontinent region. The paper also discusses Amsden's thoughts about the paleoenvironments in which the various brachiopod faunas lived and the mode of evolution reflected by these occurrences. Amsden concluded that brachiopod evolution was dominantly episodic rather than gradualistic.

Amsden's career in geology began at Wichita State University, where he studied under the distinguished petroleum geologist Walter VerWiebe. He attended graduate school at the University of Iowa, where his master's thesis was a study of an Ordovician conodont fauna collected from the Big Horn Mountains of Wyoming.

He then went to Yale to pursue his developing paleontological interest and study under Professor C. O. Dunbar. When war interrupted his studies, he joined the Strategic Minerals Section of the U.S. Geological Survey. When the war was over, he completed his Ph.D. at Yale and began teaching paleontology at The Johns Hopkins University.

In 1955, Amsden moved from Baltimore to the Oklahoma Geological Survey. Since 1960, he has at various times received support from the National Science Foundation and the OGS to examine and collect brachiopods from strata of this age in Europe, Russia, China, and Australia.

The Oklahoma Geological Survey is grateful to Tom Amsden for his diligence and insight, and the body of work that he has produced in Oklahoma. All of us congratulate him wholeheartedly on this richly deserved award.

Connie Smith

NEW OGS PUBLICATIONS

GUIDEBOOK 27. ***Early to Middle Paleozoic Conodont Biostratigraphy of the Arbuckle Mountains, Southern Oklahoma,*** edited by Scott M. Ritter. 114 pages. Price: $9.

From the editor's preface:

> This guidebook was prepared for a Pander Society field trip held March 3–4, 1990, prior to the 1990 annual meeting of the South-Central Section of the Geological Society of America at Oklahoma State University, Stillwater, Oklahoma, March 4–6, 1990. The two-day trip examined the Early Ordovician through Middle Pennsylvanian stratigraphy and conodont biostratigraphy of the Arbuckle Mountains of southern Oklahoma. The stops were centered around excellent exposures along Interstate Highway 35 in the Arbuckle anticline (Stops 1–5) and in the Hunton anticline and Lawrence uplift (Stops 6–8). Revision and refinement of chronostratigraphic (both system and series) boundaries on the basis of new conodont data were emphasized.

Stops visited on the field trip were (1) Hunton Group; (2) Henryhouse and Haragan Formations and Woodford Shale; (3) Joins and Oil Creek Formations; (4) Upper Arbuckle Group; (5) Upper Simpson Group; (6) Woodford Shale, Pre-Welden Shale, Welden Limestone, and Basal Caney Shale; Hass G Section; (7) Upper Simpson Group, Highway 99 Section; and (8) Canyon Creek.

Contributed papers treat Ordovician Conodonts in the Arbuckle Group; Stratigraphy and Conodont Biostratigraphy of the Upper Simpson Group; Late Ordovician–Early Devonian Conodont Succession in the Hunton Group; The Devonian/Carboniferous Boundary in the Woodford Shale, Lawrence Uplift; Conodont Biostratigraphy of the Welden Limestone, Lawrence Uplift; and Canyon Creek: A Significant Exposure of a Predominantly Mudrock Succession Recording Essentially Continuous Deposition from the Late Devonian through the Middle Pennsylvanian.

SPECIAL PUBLICATION 90-1. ***Geology and Resources of the Frontal Belt of the Western Ouachita Mountains, Oklahoma,*** edited by Neil H. Suneson, Jock A. Campbell, and Maxwell J. Tilford. 196 pages. Price: $12.

From the editors' preface:

> The first geologic map of any part of the Oklahoma Ouachita Mountains was published in 1902 by J. A. Taff. Since that time, the Ouachita Mountains have proved to be a fertile field for many lines of geologic research, both academic and energy-related. Among the most productive and insightful Ouachita geologists was T. A. Hendricks, who, with co-workers, was responsible for the first modern geologic map of the western part of the frontal belt (Hendricks and others, 1947). Day two of this field trip is based largely on his excellent map.
>
> Day one of this trip is mostly within the Wilburton, Damon, and Higgins 7.5′ Quadrangles; the geology of these areas has recently been mapped by Suneson and Ferguson (1989a,b) and Hemish and others (in prep.). This mapping was funded by the

Oklahoma Geological Survey and the U.S. Geological Survey as part of the USGS COGEOMAP (Cooperative Geologic Mapping) program. The Ouachita project is a joint effort of the OGS, USGS, and the Arkansas Geological Commission to complete new, detailed surface geologic maps of the Ouachita Mountains in southeastern Oklahoma and western Arkansas.

Much of the well data in reports by OGS personnel is from a computerized file of oil and gas wells based on Oklahoma Corporation Commission Form 1002A. Initial funding for establishing this computerized data file was from the USGS as part of the COGEOMAP program; continued funding for the NRIS (Natural Resources Information System) activities has been through the U.S. Department of Energy, Bartlesville Project Office.

Stops visited on the field trip were (1A) Spiro Sandstone, (1B) Structural Style of Wilburton Area, (2) Buffalo Valley School—Bottom Marks in Atoka Sandstone, (3) Hairpin Curve Locality—Johns Valley Shale and Atoka Formation, (4) Transverse Structures in the Frontal Belt, (5) Wapanucka Limestone at Dolese Quarry, (6) New State Mountain (Amoco 1-5 Rosso Unit), (7) Atoka Formation, Brushy Narrows Section, Indian Nations Turnpike, (8) Pinetop Section, (9) Bigfork Chert and Stringtown Quarry, (10) Redden Oil Field, (11) Waldrop Ranch Grahamite Deposit, and (12) Jackfork Group Type Section.

Contributed papers address Lithofacies Association and Depositional Environments of the Jackfork Group; Comparative Study of Crude-Oil Compositions in the Frontal and Central Ouachita Mountains; Sandy Tempestites in the Lower/Middle Atoka Formation; Exploration Case Study: Atoka and Jackfork Section, Lynn Mountain Syncline; Preliminary Interpretation of a Seismic Profile across the Ouachita Frontal Zone; Carboniferous Conodont Faunas; and Geologic Review of the Ouachita Mountains Thrust Belt Play.

Guidebook 27 and SP 90-1 can be obtained over the counter or postpaid from the Survey at 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031.

UPCOMING MEETINGS

Midwest Friends of the Pleistocene, Field Trip, May 11–13, 1990, Council Bluffs, Iowa. Information: Art Bettis, Iowa Dept. of Natural Resources—Geological Survey Bureau, 123 N. Capitol St., Iowa City, IA 52242; (319) 335-1578.

American Geophysical Union Meeting, May 29–June 1, 1990, Baltimore, Maryland. Information: AGU, 2000 Florida Ave., N.W., Washington, DC 20009; (202) 462-6900.

Symposium on Naturally Occurring Radionuclides in Agricultural Products, May 29–June 1, 1990, Orlando, Florida. Information: IFAS Office of Conferences, University of Florida, 551 IFAS, Gainesville, FL 32611; (904) 392-5930.

Treatment Technology for Contaminated Ground Water and **Critical Issues in Underground Storage Tank Management,** August 7–9, Dallas, Texas. Information: National Water Well Association, 6375 Riverside Dr., Dublin, OH 43017; (614) 761-1711.

Penrose Conference: Transpressional Tectonics of Convergent Plate Margins, August 25–30, 1990, Bellingham, Washington. Information: Vicki L. Hansen, Dept. of Geological Sciences, Southern Methodist University, Dallas, TX 75275; (214) 692-4179.

National Water Well Exposition, September 24–26, 1990, Anaheim, California. Information: National Water Well Association, 6375 Riverside Dr., Dublin, OH 43017; (614) 761-1711.

Clay Minerals Society, 27th Annual Meeting, October 6–11, 1990, Columbia, Missouri. Information: W. D. Johns, Dept. of Geology, University of Missouri, Columbia, MO 65211; (314) 882-3785.

American Institute of Professional Geologists, Annual Meeting, October 9–12, 1990, Long Beach, California. Information: Stephen M. Testa, 6695 E. Pacific Coast Highway, Long Beach, CA 90803; (213) 430-6500.

Geological Society of America, Annual Meeting, October 28–November 1, 1990, Dallas, Texas. *Abstracts due July 11.* Information: Meetings Dept., GSA, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020.

NOTES ON NEW PUBLICATIONS

Petroleum Geology of the Nemaha Uplift, Central Mid-Continent

This USGS open-file report by G. L. Dolton and T. F. Finn contains 39 pages and three over-size sheets, scale 1:2,000,000 (1 in. = ~32 mi).

Order OF 88-0450-D from: U.S. Geological Survey, Books and Open-File Reports, Federal Center, Box 25425, Denver, CO 80225; phone (303) 236-7476. The price is $6.25 for microfiche and $7.25 for a paper copy; add 25% to the price for shipment outside North America.

Ground-Water-Quality Assessment of the Central Oklahoma Aquifer, Oklahoma—Analysis of Available Water-Quality Data through 1987

The water quality of the Central Oklahoma aquifer is assessed in this 80-page USGS open-file report by David L. Parkhurst, Scott C. Christenson, and Jamie L. Scholottmann.

Order OF 88-728 from: U.S. Geological Survey, Water Resources Division, 215 Dean A. McGee Ave., Room 621, Oklahoma City, OK 73102; phone (405) 231-4256. A limited number of copies are available free of charge.

AAPG ANNUAL CONVENTION
San Francisco, California, June 3–6, 1990

Welcome!

Nearly a decade has passed since the petroleum industry first felt the economic forces associated with oversupply—a decade filled with turmoil with which the industry has had to come to grips. Emerging from these difficult times comes a strong, re-invigorated industry prepared to face the "Challenges of the '90s."

San Francisco, "The City," is pleased to be the host of the 1990 convention where we expect to recognize the three major areas where our challenges are the greatest. These include complex environmental issues, continuing transition from domestic to international exploration, and the reallocation of people and resources from domestic exploration to development geology. Guest speakers and papers have been tailored to these topics, each of which should be of great interest to our membership.

Equally exciting to the membership and spouses alike will be the variety of entertainment available in the Bay Area. Culturally and aesthetically, San Francisco is second to none and will be long remembered by all attendees. Enjoy this great city at the apex of its development as you revitalize your thinking by attending this working convention. Your experience will be unique. It is not every day that a member of our profession can be educated, entertained, and be permitted to see first hand the effects of an earthquake of major national significance such as that which occurred in San Francisco in 1989.

—James R. Barroffio
General Chairman

AAPG Annual Convention Agenda

Technical Program

June 4

SEPM Advances in the Interpretation of Bedding Structures
AAPG Computer Applications in Exploration and Development
SEPM Eustatic vs. Tectonic Controls on Sedimentation I and II
AAPG Petroleum Geology of Pacific Rim Basins
AAPG Petroleum Generation and Migration
EMD Remote Sensing for Basin Analysis and Exploration Mapping in Remote Regions
AAPG Geophysics for Reservoir Characterization
AAPG Hydrodynamics and Hydrogeology
AAPG Computer Mapping and Modeling in Geology
SEPM/AAPG Ancient Carbonates
SEPM Platform and Slope Facies of Carbonates
SEPM Quantitative Aspects of Fluvial Sedimentation
SEPM Diagenesis in Water-Rock Interactions in Sedimentary Basins
AAPG Structural Geology at All Scales
SEPM Tectonic and Diagenetic Evolution of the Santa Maria Basin Province
AAPG New Concepts of the Structural Geometry of Petroleum Traps
AAPG/SEPM Siliceous Rocks of the Pacific Rim
AAPG Challenges of Development Geophysics: 2-D and 3-D Seismic Studies
SEPM Diagenesis and Sedimentation in Carbonate Environments
AAPG Development Geology: Reservoir Geology and Exploration
SEPM Depositional Sequences
SEPM Sedimentation and Tectonics, California Style
SEPM New Approaches and Interpretations in Sediment Diagenesis
AAPG Temperature Pressure (and Time) as Controls on Thermal Maturation
AAPG Organic Geochemistry and Thermal Modeling
AAPG Turbidite Systems
SEPM Seafloor Image Analysis
AAPG Computer Applications in Exploration and Development

June 5

SEPM Pacific Rim I: Sedimentation and Deformation of Convergent Margins
AAPG/SEG Research Symposium—Development Geophysics: Case Studies in Reservoir Delineation
SEPM Evolution of Mesozoic and Cenozoic Continental Margins I and II
AAPG Petroleum Geology of Central Asia
AAPG/PS Petroleum Geology of California
AAPG Geotechnical Phenomena Affecting Petroleum Production
SEPM Ancient Carbonates: Facies Models and Reservoirs
SEPM Case Studies in Basin Evolution I and II
AAPG Clastic Sedimentology

SEPM Diagenesis I and II
AAPG/SEPM Computer Models of Sedimentary Basin Processes
AAPG Western Hemisphere General Geology
SEPM High-Resolution Sequence Stratigraphy I and II
AAPG Paleoclimate and Petroleum Source Rocks
AAPG Opportunities for Improved Recovery
SEPM Pacific Rim II: Tectonics and Sedimentation
SEPM Eustatic Signatures in Carbonate Deposits: Deep vs. Shallow
AAPG Deep Water Hydrocarbon Accumulations
AAPG Petroleum Geology of the Eastern Hemisphere
SEPM Biogenic Structures and Macrofossils in Modern and Ancient Margin Deposits
EMD Fueling American Security in the 21st Century
AAPG Environmental Issues and Geotechnical Phenomena Affecting Petroleum Production
AAPG Computer Mapping, Biological Data Bases, and GIS Applications
AAPG Phanerozoic Plate Tectonics and Paleogeographic Reconstructions
AAPG Exciting Oil and Gas Plays
SEPM Eustatic vs. Tectonic Controls on Sedimentation III
AAPG Applications of Development/Production Geochemistry

June 6

SEPM Pore Fluid and Grain Interaction in Sandstones I and II
SEPM/AAPG Petroleum Potential of Active Convergent Margin Settings
AAPG Exciting Oil and Gas Plays I and II
AAPG/SEG/SPE/SPWLA Development Geology: Application and Technology
AAPG Petroleum Geology of South America
SEPM Sea Level Rise: Effects on Coastal Environments
SEPM Integrated Age Dating Techniques for the Neogene
EMD Energy Minerals in the 1990s: Coalbed Gas
AAPG Mixed Clastic Carbonate Systems
AAPG Monitoring and Remediation of Subsurface Hydrocarbon Contamination
SEPM Evolution of Mesozoic and Cenozoic Continental Margins III
SEPM Evolution of Carbonate Rocks
AAPG Alaskan North Scope: Framework and Petroleum Geology
AAPG Mediterranean Petroleum Geology I and II
SEPM Cretaceous Sequences of Sacramento Valley
AAPG Geology of International Tertiary Age Reservoirs
AAPG Tectonics and Sedimentation
EMD Coso Geothermal Project—History of Development
SEPM Applications of Strontium Isotope Chronostratigraphy

Short Courses

AAPG Evolution of Sedimentary Basins in the Arctic–North Atlantic Domain, *June 1–2*

PS/AAPG Horizontal Drilling—A Technology for the '90s, *June 2*
SEG Reservoir Heterogeneity: Causes, Detection, and Remedial Action, *June 2*
AAPG Construction of Balanced Cross Sections in Extensional and Compressional Environments, *June 2–3*
EMD Remote Sensing for Oil Exploration, *June 2–3*
PS/SEPM Applied Deep-Marine Sedimentation; Depositional Models and Case Histories in Hydrocarbon Exploration and Development, *June 2–3*
SEPM Integrated Stratigraphic Analysis, *June 2–3*
SEG Basin Analysis and Sedimentary Geology: A Primer for Geophysicists, *June 2–3*
SEPM Core Workshop: Miocene and Oligocene Petroleum Reservoirs of the Santa Maria and Santa Barbara–Ventura Basins, California, *June 3*
NCGS Hydrogeology/Waste Management: An Introduction to the Fundamentals and Principles of Ground Water Science, *June 7*
AAPG Deep Water Clastic Reservoirs, *June 7–11*

Field Trips

SEPM Fluvial Processes and Deposits of the Colorado River, Grand Canyon, Arizona, *May 25–June 2*
PS/AAPG/SEPM Stratigraphy, Structure, and Hydrocarbon Occurrences of the San Joaquin Basin, California, *May 31–June 3*
EMD Coso Geothermal Area, *June 2*
AAPG/SC Geological Setting of the San Francisco Bay Area (students and faculty only), *June 2*
NCGS The October 17, 1989, Earthquake: Geology and Impacts, *June 2 or June 7*
PS/AAPG Geology of the Napa/Sonoma Wine Region, *June 2 or June 7*
PS/SEPM Stratigraphy, Sedimentology, and Tectonic Evolution of the Central Diablo Range, California, *June 2–3*
NCGS San Andreas Fault and Franciscan Complex in Marin County, *June 3 or June 7*
PS/AAPG Yosemite and the Mother Lode Gold Belt: Geology, Tectonics, and Evolving Fluids, *June 6–9*
PS/SEPM Geology of the Sacramento Basin, *June 6–9*
PS/SEPM Marine Geology Expedition to San Francisco Bay and Continental Shelf, *June 7*
PS/AAPG Onshore and Offshore Santa Cruz Basins, *June 7–8*
PS/SEPM Submarine Fan Lithofacies, Sedimentary Processes, and Environments of Deposition, *June 7–8*
EMD Ground-Water Contamination Project: Investigation, Remediation, Demonstration; Lawrence Livermore National Laboratory, *June 8*

For further information about the annual meeting, contact AAPG, Convention Dept., P.O. Box 979, Tulsa, OK 74101; (918) 584-2555. The preregistration deadline is April 20.

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.

Style and Timing of Holocene Surface Faulting on the Meers Fault, Southwestern Oklahoma

ANTHONY J. CRONE, U.S. Geological Survey, Denver, CO 80225; and KENNETH V. LUZA, Oklahoma Geological Survey, Norman, OK 73019

Stratigraphic relations and radiocarbon ages of deposits exposed in several trenches and excavations help to establish the timing, sense of slip, and style of the deformation that resulted from late Holocene surface faulting on the Meers fault in southwestern Oklahoma. The eastern half of the scarp is formed on relatively ductile Permian Hennessey Shale and Quaternary alluvium, whereas the western half is formed on well-lithified, relatively brittle Permian Post Oak Conglomerate in the Slick Hills.

At Canyon Creek on the eastern half of the scarp, the shale and alluvium in two trenches are deformed mainly by monoclinal warping. These trenches contain stratigraphic evidence of one surface-faulting event that produced about 3 m of throw. At this site, the amount of throw in middle Holocene and middle Pleistocene deposits is similar. Lateral displacement is difficult to detect in these trenches, most likely because of plastic deformation in the shale and alluvium.

In contrast, trenches and excavations on the western half of the scarp show that the Holocene surface faulting produced at least as much lateral as vertical displacement. At two sites, the scarp has dammed small gullies and ponded fine-grained alluvium upslope from the scarp. The channels of the gullies at these ponded-alluvium sites have been separated 3–5 m left-laterally since they were dammed. The lateral displacement on the gullies is 3.3 to 1.6 times as much as the vertical displacement. In a pit excavated into the colluvium on the downthrown side of the scarp, subhorizontal striae on conglomerate clasts along the fault plane provide evidence of nearly pure strike-slip movement. The age of the striae is unknown, but they are believed to be Quaternary in age because it is unlikely that such delicate striae could be preserved in soluble carbonate rock in a near-surface weathering environment for many hundreds of thousands of years.

Multiple radiocarbon ages of soil-humus samples from the Canyon Creek trenches and the ponded-alluvium sites show that the last surface faulting occurred 1,200–1,300 yr ago. Limited geologic evidence, however, indicates a long-term recurrence interval on the order of 100,000 yr or more.

The youthful surface faulting compared to the apparently long recurrence interval presents a difficult problem for regional seismic-hazard assessments. Hazard assessments that rely on the long-term slip rate might seriously underestimate the hazard if the behavior of the fault is characterized by a temporal clustering of

events, and if the late Holocene surface faulting signals the beginning of a period of frequent faulting. Conversely, if strain accumulates steadily on the Meers fault and is released regularly over time intervals of 100,000 yr or more, then the hazard may be low because much of the stored strain was released only about 1,000 yr ago. Improved earthquake-hazard assessments in much of the central United States and in stable intraplate settings worldwide require a better understanding of the long-term and short-term behavior of seismogenic intraplate faults.

Reprinted as published in the Geological Society of America *Bulletin*, v. 102, p. 1.

Coal-Bed Methane Resources in Arkoma Basin, Southeastern Oklahoma

SAMUEL A. FRIEDMAN, Oklahoma Geological Survey,
Norman, OK 73019

A major federal tax incentive for unconventional gas production has interested entrepeneurs, geologists, and engineers in the occurrence and distribution of coal-bed methane resources in the Arkoma basin. Because the methane is trapped in coal beds, geology of the coal resources also has received renewed attention.

The Arkoma basin contains most of the coal-bed methane resources in Oklahoma, because it contains 76% of the 7.9 billion short tons of the remaining, identified Middle Pennsylvanian coal resources of the state.

This paper briefly reviews previous estimates of coal-bed methane resources in Oklahoma and presents an updated estimate for Haskell and Le Flore Counties and a new estimate for Latimer County.

Rieke and Kirr indicated that 2.8 tcf of coal-bed methane is present in 10 coals in eight Oklahoma counties of the Arkoma basin, 500–3,000 ft deep. Iannacchione and Puglio estimated that a maximum of 1.5 tcf of coal-bed methane occurs in the Hartshorne coals in Haskell and Le Flore Counties from 500–3,000 ft deep.

The present investigation shows that the Hartshorne and 11 other coals contain at least 1.8 tcf of coal-bed methane resources, based on identified coal resources 500–3,000 ft deep in Haskell, Latimer, and Le Flore Counties. An additional 1.2 tcf of coal-bed methane resources occur in the Hartshorne and four other coals from 3,000–7,000 ft deep, based on assumed stratigraphic and thickness continuity.

Thus, a revised estimate indicates that Haskell, Latimer, and Le Flore Counties alone contain about 3 tcf of coal-bed methane resources in 12 coal beds from 500–7,000 ft deep. Undoubtedly additional coal-bed methane resources are present in the westernmost part of the Arkoma basin.

Reprinted, with author corrections, from the American Association of Petroleum Geologists *Bulletin*, v. 73, p. 1453.