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December 1997

On The Cover —

Boxwork Concretion from the Warner Sandstone, Pittsburg County, Oklahoma

The cover photograph shows the raised, interlocking "boxwork" pattern on a detached slab from an outcrop of the Warner Sandstone Member of the McAlester Formation (Desmoinesian) in the SW¼ sec. 26, T. 4 N., R. 15 E., Pittsburg County, Oklahoma. Iron oxide minerals form the concretionary structures, which are fracture-fillings that follow joints in the sandstone. Pettijohn (1975, p. 463) says that iron oxides (particularly limonite) are common in sediments; in places, the iron oxides may be segregated into concretionary bodies. The cross-cutting fracture-fillings are secondary features that form after consolidation of the host rock. Distribution of the mineral deposits is controlled by permeability.

Amateurs sometimes mistake boxwork concretions, such as the one shown, for Mayan hieroglyphic tablets because the boxwork patterns have a man-made appearance. However, the "symbols" are impossible to decipher.

Boxwork concretions are rather common in the Warner Sandstone Member of the McAlester Formation, which typically is ferruginous. Therefore, it can be inferred that iron is present in sufficient quantities to be a source for the minerals in the fracture-fillings. The dimensions of the featured slab are about 8 in. × 18 in. For further descriptions of the Warner Sandstone Member, see Appendix 1, p. 220, in "Composite-Stratotype for the McAlester Formation (Desmoinesian), Pittsburg County, Oklahoma," this issue.

Reference Cited

Pettijohn, F. J., 1975, Sedimentary rocks [3rd edition]: Harper & Row, New York, 628 p.

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OKLAHOMA GEOLOGY Notes

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Composite-Stratotype for the McAlester Formation (Desmoinesian), Pittsburg County, Oklahoma

LeRoy A. Hemish[1]

Abstract

Although the McAlester Formation (Desmoinesian) is a well-established geologic unit in Oklahoma, a formal type section has never been specified for it. A composite-stratotype is designated herein in order to establish a standard by which the McAlester Formation and its boundaries can be recognized.

The McAlester Formation is poorly exposed in its type locality, presumably around the city of McAlester, Oklahoma, although a formal type locality has never been designated. Good and accessible outcrops of the McAlester Formation occur in the Blanco–Ti Creek–Gardner Creek area, ~10 mi southeast of the city of McAlester, where the formation, as shown by this study, is about 1,800–1,850 ft thick. All but one of the formation's six named members crop out in the study area, and its upper and lower boundaries are well exposed.

A continuous sequence of strata in a formation almost 2,000 ft thick is virtually impossible to find. Thus, five sections were measured and described in the study area and then compiled to make a composite-stratotype for the McAlester Formation. The new composite-stratotype is in close agreement with the original definitions of the formation's nomenclator.

Introduction

The purpose of this paper is to define and establish a composite-stratotype for the McAlester Formation (Appendix 1) by formally presenting and describing several reference sections for the formation (Appendix 2). It is unrealistic to expect to find a continuous, unbroken sequence of strata that is representative of the entire unit because of both the thickness of the McAlester Formation (1,600–2,000 ft) in the Hartshorne SW quadrangle (Suneson and Hemish, 1996), and its shaly character, which results in poor exposures. The area selected for the designation of a composite-stratotype, ~10 mi southeast of the city of McAlester, is within the type area for the McAlester Formation (Fig. 1). The type locality for the formation, although never formally designated, is presumed to be around the city of McAlester. "The type area is the geographic area encompassing the type locality" (North American Commission on Stratigraphic Nomenclature, 1983, p. 853). The various lithologic components of the McAlester Formation are well represented in the selected area, and good exposures of both the base and the top of the unit are present. Although outcrops of parts of the McAlester Formation can be found in and around the city of McAlester, it was necessary to establish the composite-stratotype elsewhere because of difficult access, modification of the exposures by man, and a lack of exposures of the upper and lower boundaries. The area adjacent to State Highway 63, northeast of Blanco (Fig. 1), was selected for establishment of a com-

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posite-stratotype on the basis of good quality and accessibility of outcrops, representation of all significant units, and the area's location within the type area of the McAlester Formation.

Previous Investigations

The McAlester Formation (McAlester shale as originally defined) was named and first described by Taff (1899, p. 437), who divided the formation into three parts:

> The lowest one is composed almost entirely of shale, with thin sandstone and coal, in all 800 feet thick. Locally sandstone occurs with thin coal beds near the center of this shale. The Hartshorne or Grady coal occurs at the base of this shale. The middle division of the McAlester shale is composed of three to four beds of sandstone separated by shale 100 feet to 200 feet thick. Together these beds of sandstone and shale are about 500 feet thick. The upper division is almost entirely of shale nearly 700 feet thick and the McAlester coal is about 50 feet above its base. Several thin seams of coal occur in this shale also, but none have been found thick enough to be workable. The shale is blue, gray, or black, with the gray color predominating.

The lowest interval described by Taff (1899, p. 437) is approximately equivalent to the McCurtain Shale Member of present usage, exclusive of the Hartshorne coal;

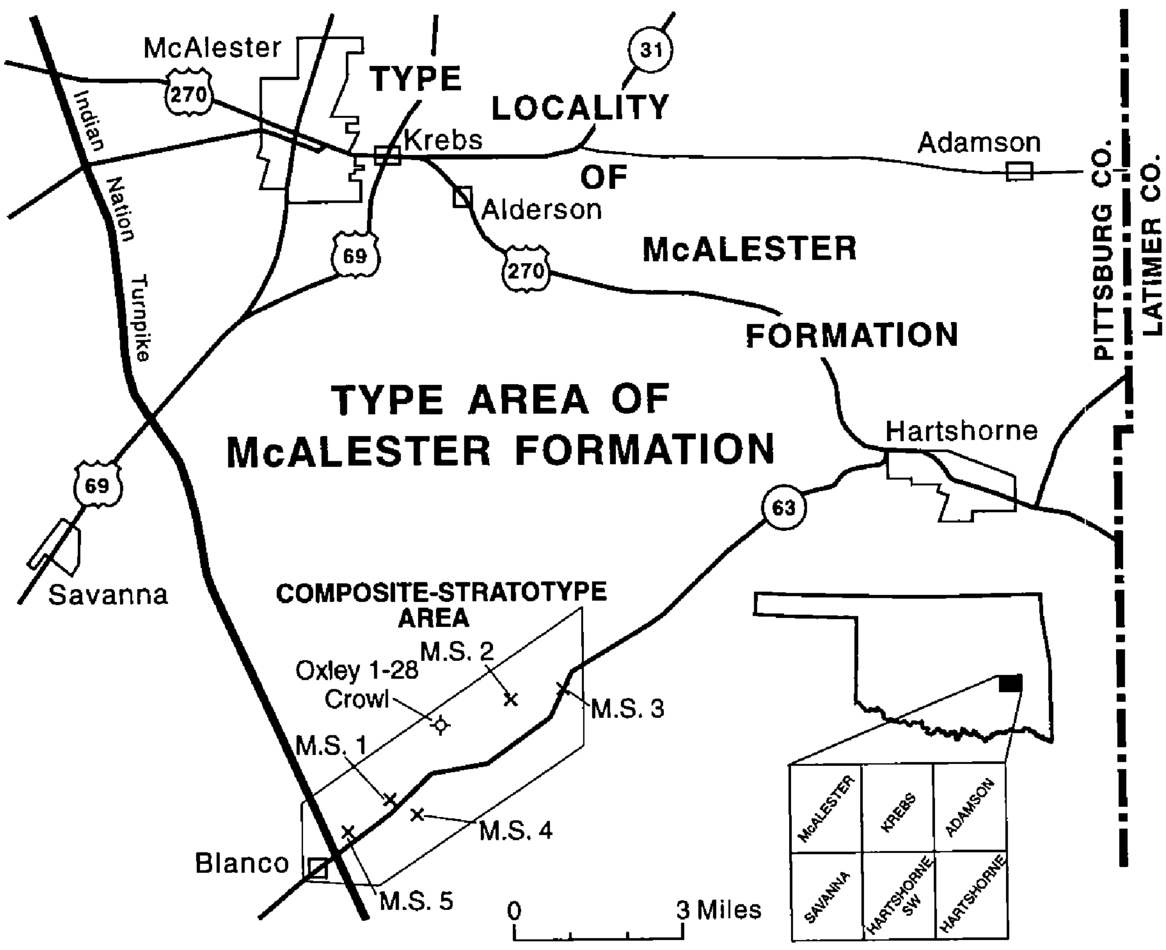


Figure 1. Map showing the type locality, type area, and the composite-stratotype area for the McAlester Formation in east-central Pittsburg County, Oklahoma. The approximate locations of the five measured sections (M.S. 1–5) compiled into the composite-stratotype are marked. Quadrangle maps used in this study are shown in the inset index map.

his middle interval extends from the base of the Warner Sandstone Member (below) to the top of the Cameron Sandstone Member (above), and his uppermost interval extends from the top of the Cameron Sandstone Member (below) to the base of the Savanna Formation (above) (Fig. 2). Taff (1899, p. 437) did not provide a specific location for a type section for the McAlester Formation, but he did indicate that the type locality (of modern terminology) was "in the region of McAlester, Krebs, and Alderson" and "the basin plain north of Hartshorne."

Taff and Adams (1900) included the upper Hartshorne coal bed in the McAlester Formation as its basal unit. Oakes and Knechtel (1948, p. 27) subsequently redefined the base of the McAlester Formation "as the top of the Upper Hartshorne coal," the definition accepted by the Oklahoma Geological Survey at present.

Wilson (1935) and Wilson and Newell (1937) formally assigned member status to several mappable units now included in the McAlester Formation, based on earlier unpublished work (Thom, W. T., Jr., 1935, Coal map of the Stigler-Poteau district, Pittsburg, Haskell, and Le Flore Counties, Oklahoma: U. S. Geological Survey unnumbered map, preliminary edition.) The named members (from oldest to youngest) are the McCurtain Shale Member, the Warner Sandstone Member, the Lequire Sandstone Member, the Cameron Sandstone Member, the Tamaha Sandstone Member, and the Keota Sandstone Member (Fig. 2). The Lequire and Tamaha Sandstone Members are either absent or poorly developed and discontinuous in the McAlester area. However, they are well developed in the Arkoma basin to the east, where they were named. The McCurtain, Warner, Cameron, Tamaha, and Keota Members all crop out in the study area, and are described in the measured sections in Appendix 2. The Lequire Sandstone Member does not crop out in the study area, but the geophysical log of a well in the composite-stratotype area shows that it is present in the subsurface (Appendix 3).

Further discussions of the McAlester Formation, its history of nomenclature and investigations of the McAlester Formation by earlier workers are presented in Hemish and Suneson (1997). They noted that "the sandstones in the McAlester Formation are generally referred to as the Booch sandstones in the subsurface" (Hemish and Suneson, 1997, p. 17). Jordan (1957, p. 21) said that the Booch sandstone was named for the Booch farm in Okmulgee County, Oklahoma; that it is equal to the Warner sandstone; and that, at places, it is called the "Upper, Lower, First, Second, Third Booch."

Stratigraphy

Figure 2 is a generalized stratigraphic column showing the position of the McAlester Formation within the Krebs Group in the central Arkoma basin. The positions of the six named members in the McAlester Formation are also shown.

A geologic map of the composite-stratotype area (Fig. 1) is given in Appendix 4. It shows the outcrop area of the McAlester Formation, as well as the underlying bedrock units (Atoka Formation, Hartshorne Formation) and the overlying bedrock unit (Savanna Formation). Figure 3 provides three maps from the same area, upon which the measured sections used to compile the composite-stratotype are located.

The original description of the stratigraphic units that comprise the McAlester Formation (Taff, 1899, p. 437), quoted earlier in this paper, remains valid. The McAlester Formation is underlain by the Hartshorne Formation (Fig. 2; Appendix 4). The contact is generally conformable. The McAlester Formation is overlain con-

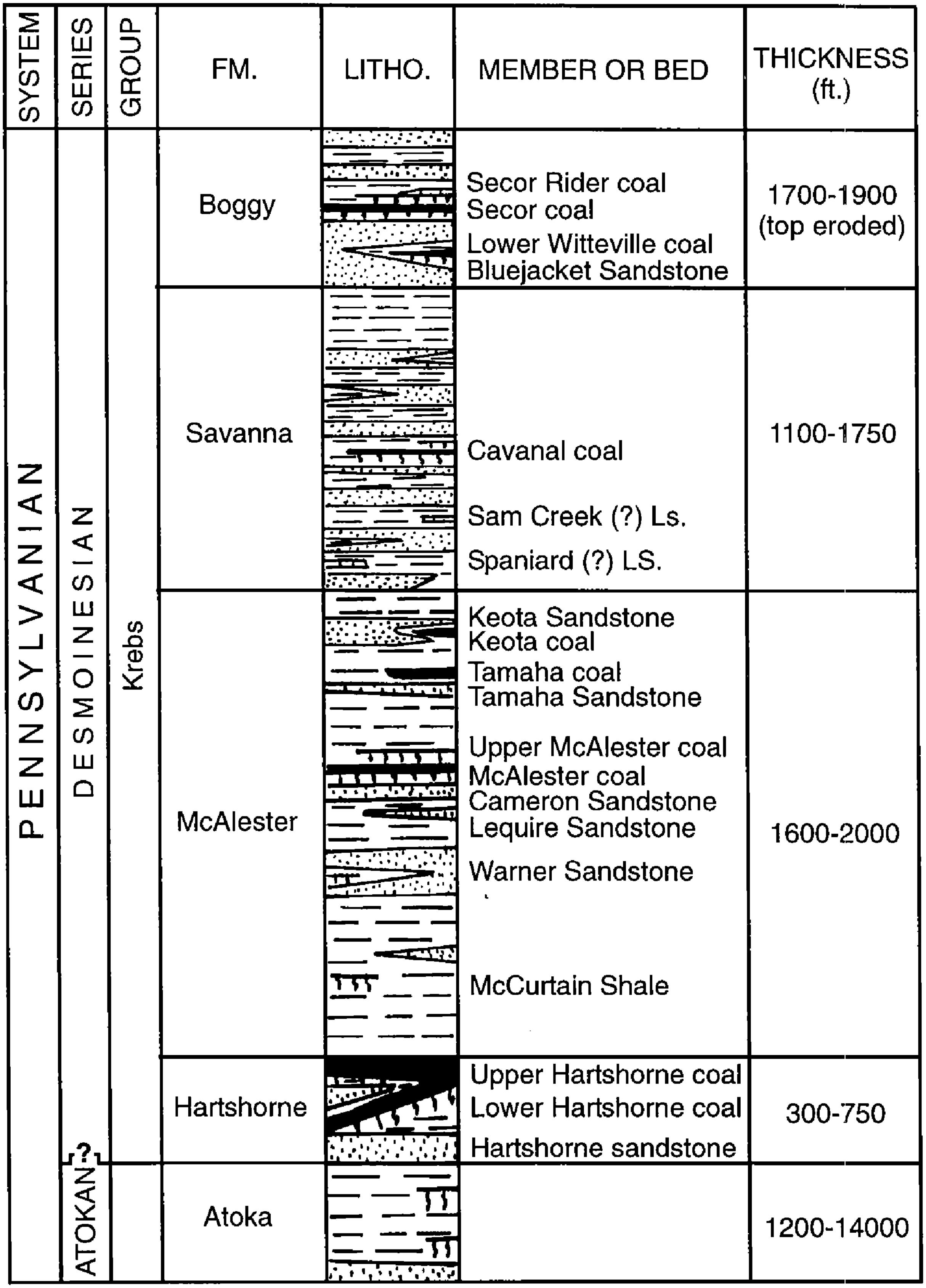


Figure 2. Generalized stratigraphic column showing the Krebs Group and the upper part of the Atoka Formation in the central Arkoma basin. Modified from Hemish (1996b, fig. 3). See Appendix 1 for explanation of symbols.

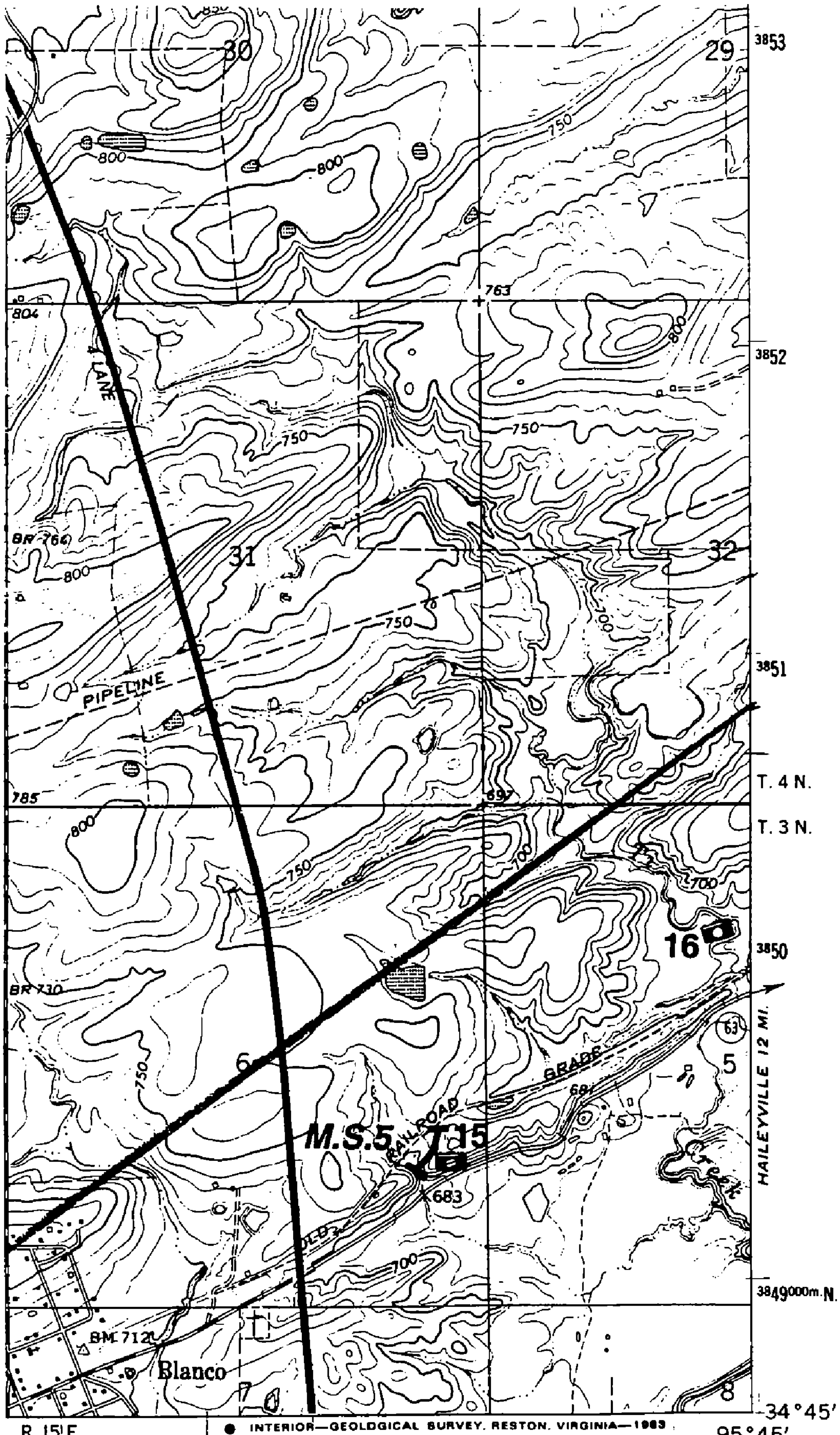
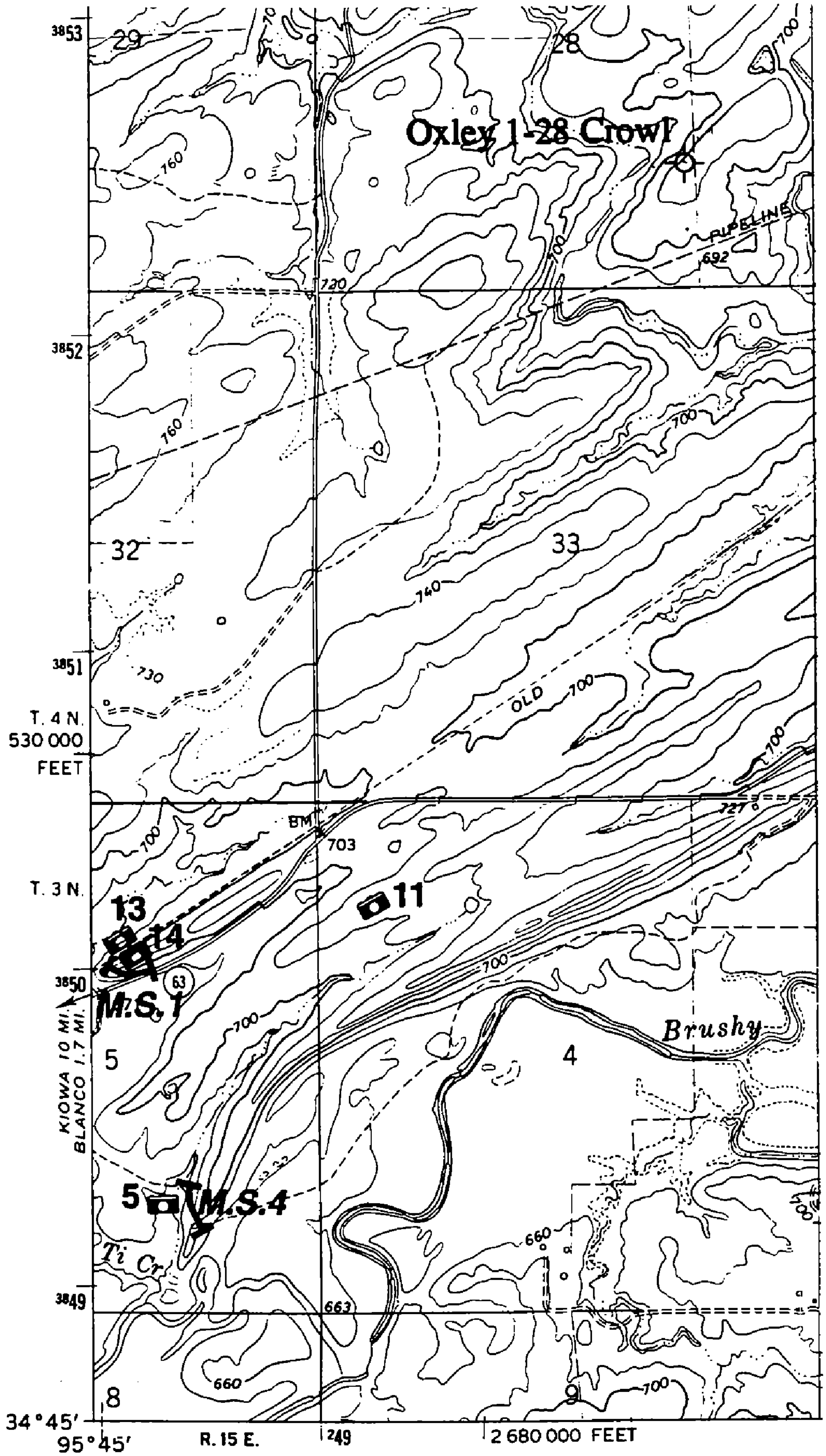


Figure 3A

(See page 206 for Figure 3 caption and explanation of symbols.)



Oxley 1-28 Crowl
29
28
32
33
5
4
8
9
PIPELINE
OLD
BM
703
13
14
11
M.S. 1
M.S. 4
5
63
Brushy
Ti Cr
KIOWA 10 MI.
BLANCO 1.7 MI.
3853
3852
3851
3850
3849
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FEET
T. 3 N.
34°45′
95°45′
R. 15 E.
249
2 680 000 FEET

Figure 3B

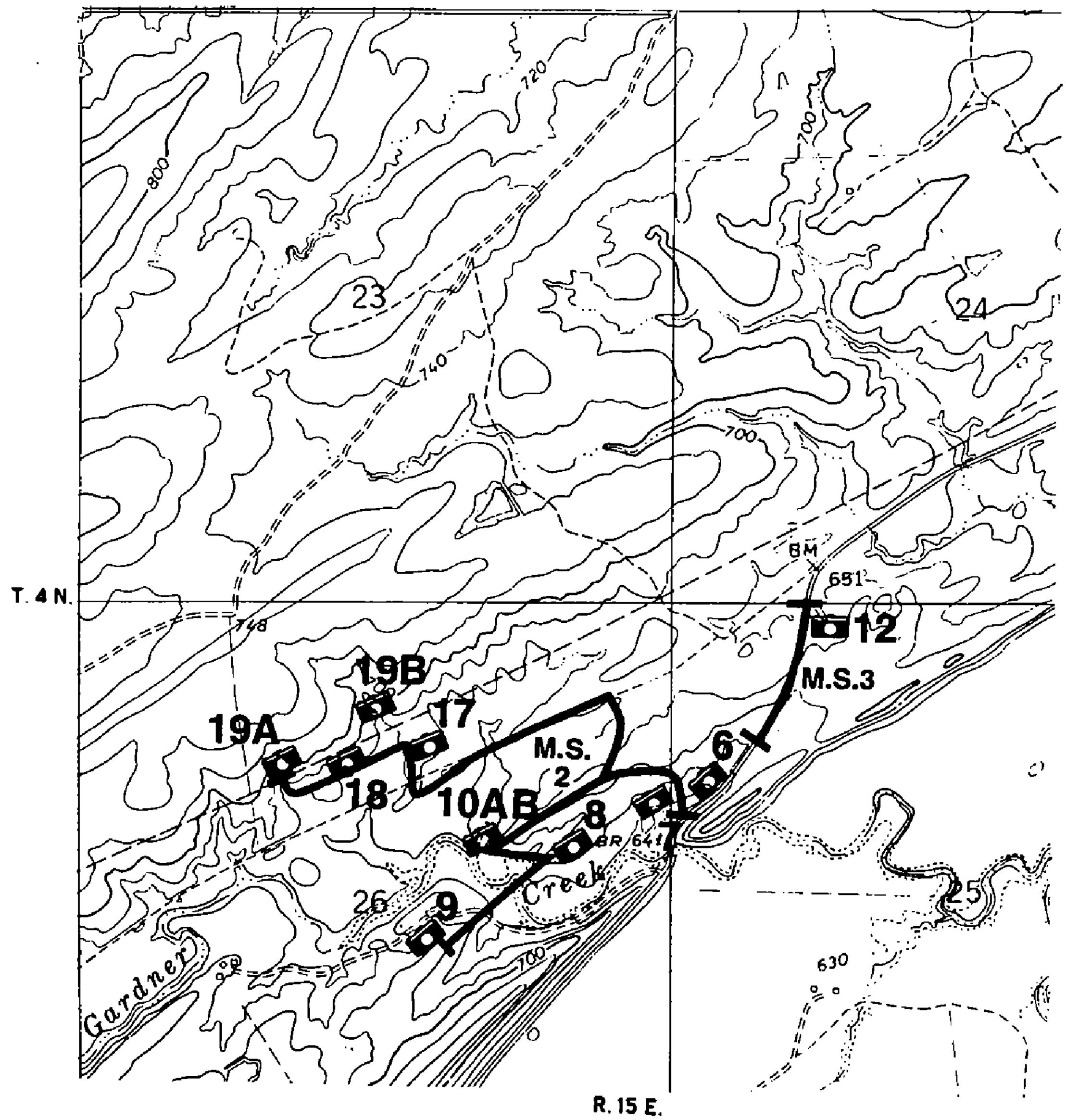


Figure 3C

EXPLANATION

Location of measured section with measured section number from Appendix 2

7 Location of photo with figure number

Location of well, Appendix 3

0 — 0.5 Mile

Figure 3. Excerpts of topographic maps showing the locations of measured sections (Appendix 2), the location of the Oxley No. 1-28 Crowl well (Appendix 3), and the locations of photographs used in Figures 5–19. *A (p. 204)*—From the Savanna 7.5′ quadrangle map. *B (p. 205)* and *C (above)*—From the Hartshorne SW 7.5′ quadrangle map.

formably by the Savanna Formation (Fig. 2; Appendix 4), although, the contact is paraconformable locally (Hemish and Suneson, 1997). The thickness of 800 ft given by Taff (1899, p. 437) for his lowest division (McCurtain Shale Member) is quite acceptable throughout the type area of the McAlester Formation. The thickness of ~500 ft given by Taff (1899, p. 437) for his middle division (which includes the Warner, Lequire, and Cameron Sandstone Members) is also acceptable, as is his estimated thickness of ~700 ft for his uppermost division. This uppermost interval includes the McAlester coal, Upper McAlester coal, Tamaha coal, Keota coal, Tamaha Sandstone Member, and Keota Sandstone Member. Thus, Taff's (1899) estimated thickness for the entire McAlester Formation is ~2,000 ft. Mapping by Hemish (1995, 1996a, 1997), Suneson (1996, 1997), and Suneson and Hemish (1996) indicates that the thickness of the McAlester Formation is variable, and about 1,600–2,000 ft in the type area of the formation.

Composite-Stratotype for the McAlester Formation

Description of Outcropping Units

"A stratotype is the standard (original or subsequently designated) for a named geologic unit or boundary and constitutes the basis for definition or recognition of that unit or boundary; therefore, it must be illustrative and representative of the concept of the unit or boundary being defined. A composite-stratotype consists of several reference sections (which may include a type section) required to demonstrate the range or totality of a stratigraphic unit" (North American Commission on Stratigraphic Nomenclature, 1983, p. 853).

The author measured five sections (M.S. 1–5) in the McAlester Formation in the Blanco–Ti Creek–Gardner Creek area on both sides of Oklahoma State Highway 63 (Figs. 2, 3A–C). The five measured sections are in east-central Pittsburg County, within the type area of the McAlester Formation. (See Appendix 2 for detailed descriptions of the measured sections.) In order to present a reasonably complete and definitive description of the McAlester Formation, including exposures of the contacts with both the underlying and overlying formations, it was necessary to combine selected parts from each of the five measured sections into a composite-stratotype (presented in Appendix 1, along with a graphic columnar section and lithologic descriptions). Easily recognizable stratigraphic units are used to correlate the five measured sections in a compilation diagram (Fig. 4).

A rare exposure of both the Lower and Upper Hartshorne coals, along with the basal part of the McCurtain Shale Member of the McAlester Formation, occurs in the SE¼ sec. 5, T. 3 N., R. 15 E., and is described in M.S. 4 (Appendix 2). The presence of both coals in the same outcrop eliminates all doubt about the validity of the contact between the Hartshorne Formation and the McAlester Formation (by definition, the top of the Upper Hartshorne coal).

Figure 5 shows the contact between the Hartshorne Formation and the overlying McAlester Formation. The segment of the composite-stratotype containing the contact (units 1–10, Appendix 1) is located ~0.5 mi south of Highway 63. It is easy to find and, during the dry season, it can be reached by vehicle on a trail across private property (Fig. 3B; Appendix 2, M.S. 4). Otherwise, a hike across a meadow and a pasture is required. The 10-ft-thick unnamed siltstone-sandstone unit (unit 10, Appendix 1) near the base of the McCurtain Shale (Fig. 6) is a convenient unit for correlation pur-

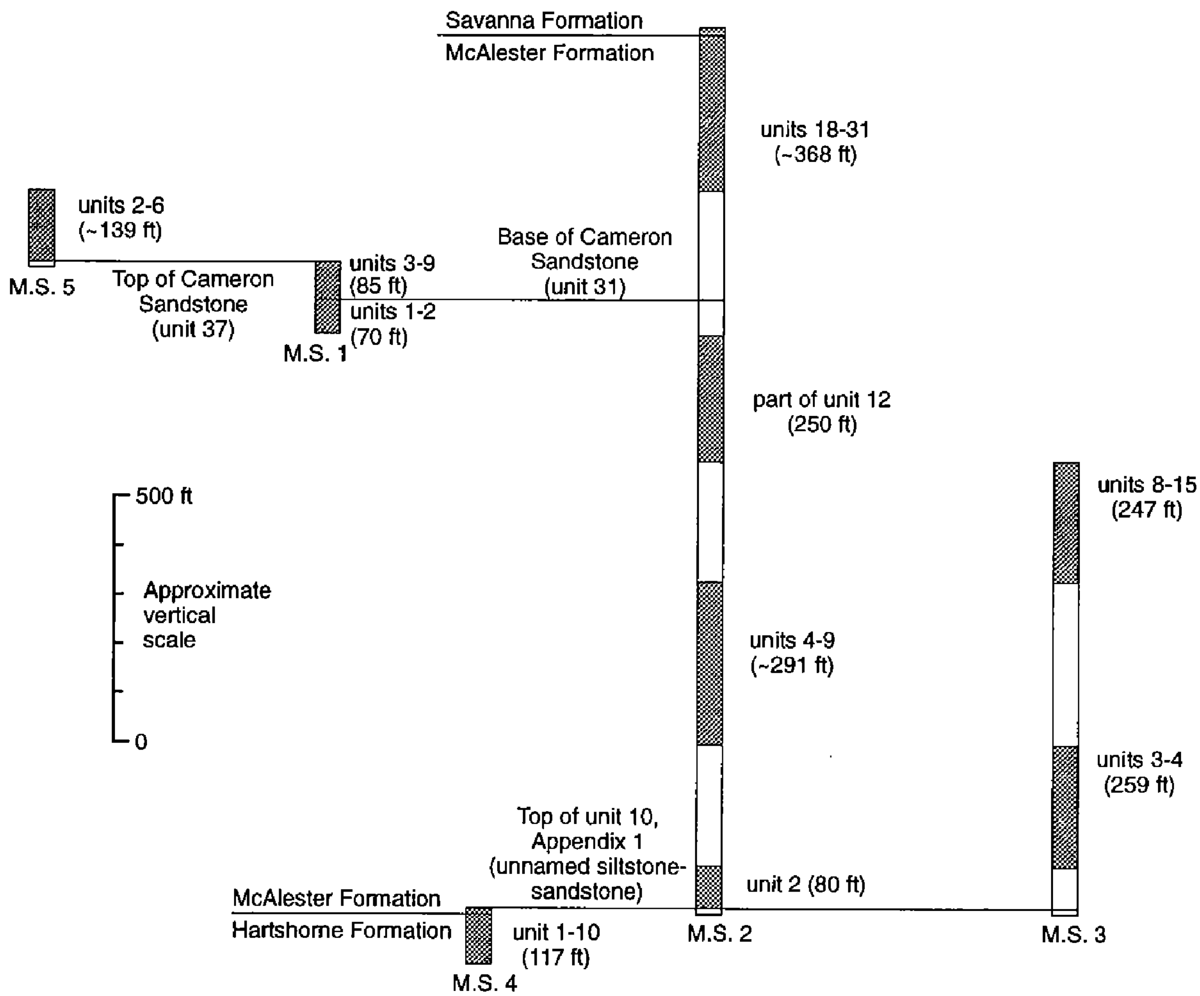


Figure 4. Correlation diagram showing how data from five measured sections (M.S. 1–5) were compiled to complete the composite-stratotype for the McAlester Formation (see Appendixes 1, 2). Correlation lines, labeled with unit numbers from the composite-stratotype (Appendix 1), indicate overlapping units among the measured sections. The segments from the measured sections that were used to compile the composite-stratotype are shaded. No horizontal scale.

poses because it is present in three of the five measured sections: M.S. 2 (lowermost unit); M.S. 3 (lowermost unit); and M.S. 4 (unit 10) (Fig. 4; Appendix 2).

Directly above unit 10 in the composite-stratotype is a medium gray shale that contains small, calcareous, brachiopod valves and other fossil fragments (unit 11, Appendix 1). The fossil shells can be found at the edge of a small pond in the SE¼ NE¼SE¼NE¼ sec. 26, T. 4 N., R. 15 E. (Fig. 7).

Unit 14 in the composite-stratotype (Appendix 1) is an unnamed sandstone, generally about 7–8 ft thick, that crops out intermittently across the study area. The sandstone occurs in about the middle of the McCurtain Shale Member. Typically, it is thin- to medium-bedded (in places, thick-bedded) and parallel-bedded with current-ripple marks. Locally, however, there is cross-bedding within the unit that fills channels cut into the parallel-bedded sandstone (Fig. 8). Figure 9 shows trace fossils on an overturned slab of the same unit (unit 14, Appendix 1).

Unit 15 of the composite-stratotype is ~200 ft of olive gray shale at the top of the McCurtain Shale Member that separates unit 14 from the basal sandstone of the Warner Sandstone Member (units 16, 17, 18, Appendix 1). The lower part of the

Figure 5. Contact between the Hartshorne Formation (below) and the McAlester Formation (above), shown in eroded, barren slopes in the NE¼NE¼SW¼SE¼ sec. 5, T. 3 N. R. 15 E. The contact is just below the head of the geologic pick (1.3 ft long), at the top of the 0.7-ft-thick Upper Hartshorne coal (unit 8, Appendix 1). The basal shale of the McCurtain Shale Member of the McAlester Formation (unit 9, Appendix 1) conformably overlies the coal. See Figure 3B for location of photograph.

Figure 6. Shaly siltstone-sandstone near the base of the McCurtain Shale Member (unit 10, Appendix 1) shown in an outcrop adjacent to a small stream, just north of Highway 63, SW¼ NW¼SW¼NW¼ sec. 25, T. 4 N., R. 15 E. Exposure is 10 ft thick. See Figure 3C for location of photograph.

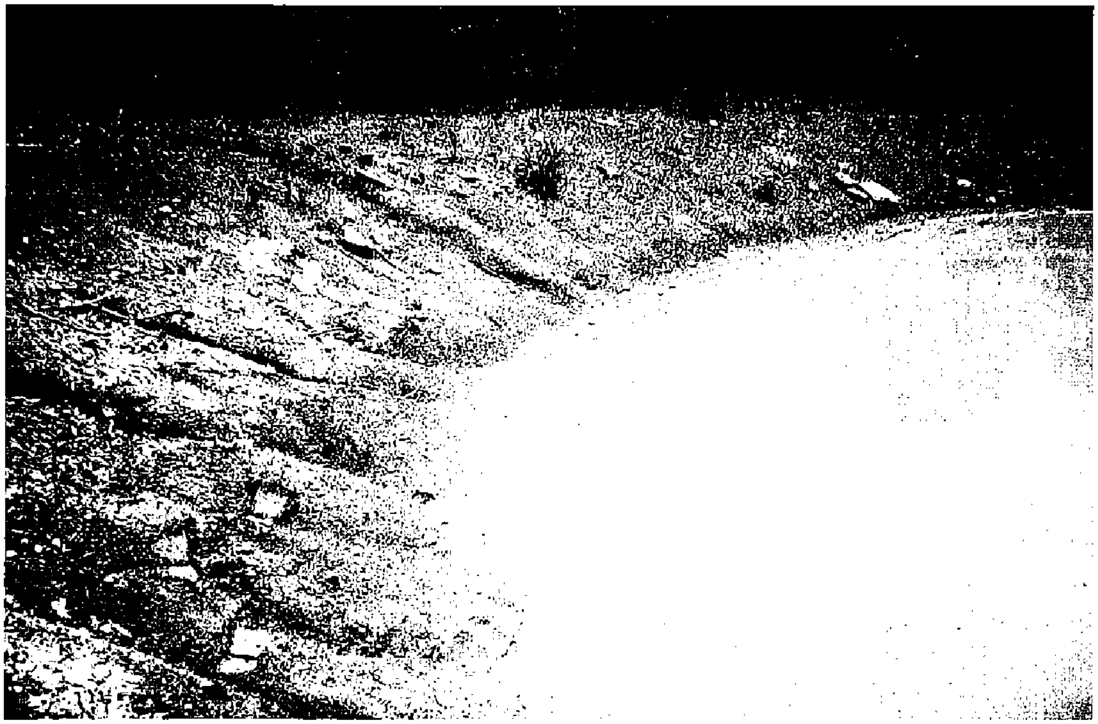


Figure 7. Fossiliferous gray shale in the lower part of the McCurtain Shale Member exposed at the edge of a small stock pond, just north of Highway 63, SE¼NE¼SE¼NE¼ sec. 26, T. 4 N., R. 15 E. About 5 ft of shale exposed above water in pond. See Figure 3C for location of photograph.

Figure 8. Unnamed sandstone in the McCurtain Shale Member (unit 14, Appendix 1) showing channeling and cross-bedding. Photographed on crest of ridge, SW¼NW¼SE¼NE¼ sec. 26, T. 4 N, R. 15 E. (Fig. 3C). Tape measure is ~2 in. wide.

Warner Sandstone Member, which is predominantly sandstone, is referred to informally herein as the "lower unit of the Warner Sandstone." A thick shale interval (units 19–25, Appendix 1), which includes thin sandstone beds in places, separates the lower unit of the Warner from the upper sandstone unit (unit 26, Appendix 1), which is referred to informally herein as the "upper unit of the Warner Sandstone." The entire lower unit of the Warner Sandstone generally is ~60 ft thick, but in places (see unit 7, M.S. 3, Appendix 2) it is represented by only 1 ft of hard sandstone overlain by a thick interval of shale within the Warner Sandstone Member. Figure 10 shows the blocky nature of the sandstone as well as sole markings on the underside of an overturned slab at the east end of the dam across Gardner Creek. Figure 11 shows a highly deformed facies of the lower unit of the Warner Sandstone in the NW¼ sec. 4, T. 3 N., R. 15 E. The entire Warner Sandstone Member varies in thickness across the study area, but probably averages ~300 ft. The upper unit of the Warner Sandstone (unit 26, Appendix 1) is a thin-bedded, shaly, sandstone-siltstone about 16–18 ft thick that seldom forms a resistant ridge in the area. Figure 12 shows the upper unit of the Warner Sandstone where it is exposed in the ditches on either side of Highway 63 at the northern edge of sec. 25, T. 4 N., R. 15 E.

In the composite-stratotype, more than 320 ft of shale (units 27–30, Appendix 1) separates the Warner Sandstone Member from the Cameron Sandstone Member

Figure 9. Trace fossils on the sole of an overturned bed of unit 14 (Appendix 1), the unnamed sandstone in the McCurtain Shale Member shown in Figure 8. Photographed in ridge at east side of spillway just southwest of Gardner Creek dam, NW¼NW¼NW¼SE¼ sec. 26, T. 4 N., R. 15 E. (Fig. 3). Geologic pick for scale.

(units 31–37, Appendix 1). This part of the section is largely covered and may contain the Lequire Sandstone Member. If present, the Lequire does not form a resistant ridge, is unmappable, and was not observed in the study area. However, the Lequire has been mapped in the Krebs quadrangle (just north of the Hartshorne SW quadrangle) (Hemish, 1996a), in the Hartshorne quadrangle (just east of the Hartshorne SW quadrangle) (Suneson, 1996), and in the Savanna Quadrangle, to the west (Suneson, 1997).

The Cameron Sandstone (units 31–37, Appendix 1) is well developed and well exposed in the area extending northeast from Blanco to Peaceable Road (Fig. 3A,B), where it is ≥85 ft thick (Fig. 4, M.S. 1). The slabby, parallel-bedded character of the Cameron is shown in Figure 13. A different, thicker-bedded, deformed facies of the Cameron is shown in Figure 14.

The McAlester coal (unit 41, Appendix 1) is exposed in a gully ~45 ft stratigraphically above the Cameron Sandstone (M.S. 5) in the SE¼SW¼NE¼SE¼ sec. 6, T. 3 N., R. 15 E. (Appendix 4). The coal is ~2 ft thick in this rare outcrop (Fig. 15). The

Figure 10. Lower unit of the Warner Sandstone Member exposed at the eastern end of the dam across Gardner Creek, NE¼SE¼SW¼NE¼ sec. 26, T. 4 N., R. 15 E. Large blocks of the sandstone have been overturned (*A*), probably during construction of the dam. A large groove cast and other sole markings can be seen in a close-up view (*B*) at the far right of the overturned slab in *A*. Tape measure for scale. See Figure 3C for location of photograph.

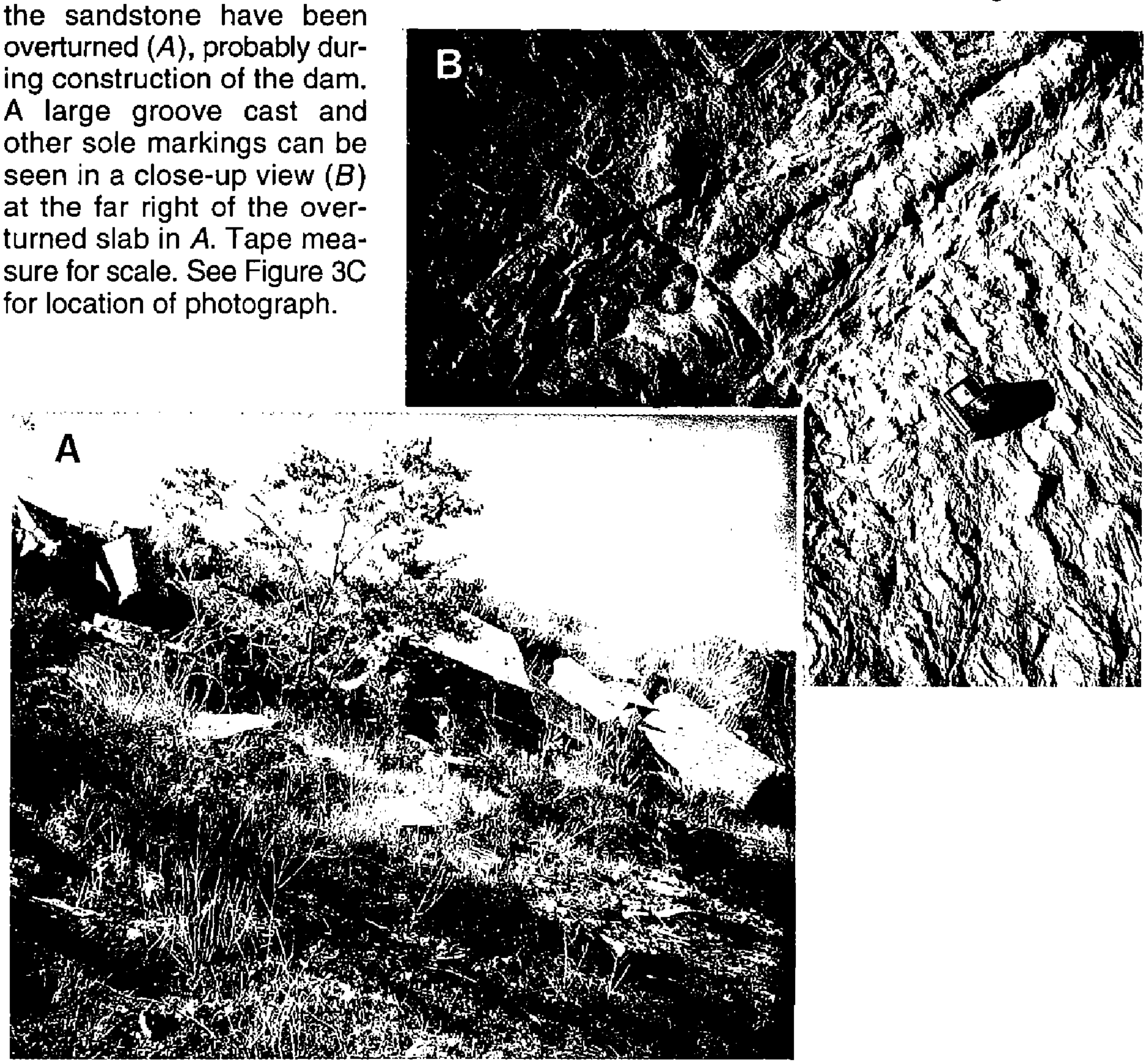


Figure 11. Convolute bedding in a deformed facies of the lower unit of the Warner Sandstone Member, well exposed in a resistant ridge ~0.25 mi south of Highway 63 in the NW¼ sec. 4, T. 3 N., R. 15 E. Geologic pick for scale. See Figure 3B for location of photograph.

Figure 12. A view of the upper unit of the Warner Sandstone Member just east of Highway 63, NE¼NE¼NW¼NW¼ sec. 25, T. 4 N., R. 15 E., showing the thin-bedded, shaly character of the unit. The view is looking down on the edges of beds that dip 62° to the northwest (left in the photograph). Geologic pick for scale. See Figure 3C for location of photograph.

Upper McAlester coal was not observed in the study area; it probably was not deposited there.

The Tamaha Sandstone Member (unit 44, Appendix 1) is the next named unit stratigraphically higher in the composite-stratotype. It is poorly developed in the area and consists of a series of silty shales interbedded with thin, ripple-marked sandstone beds (Fig. 16) that do not form resistant ridges. The Tamaha coal (unit 46, Appendix 1) occurs 6 ft above the Tamaha Sandstone. The coal is ~10 in. thick

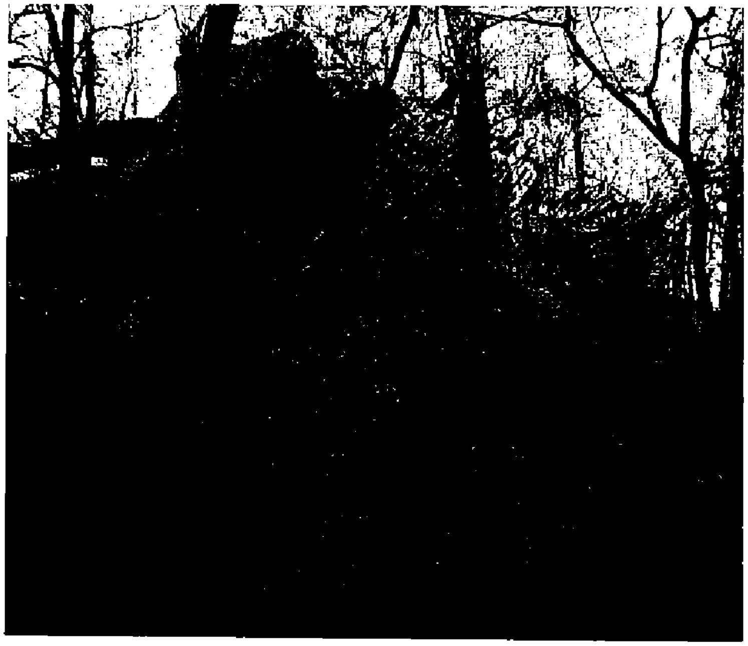


Figure 13. Steeply dipping beds (units 33 and 34, Appendix 1) of the Cameron Sandstone Member exposed in a bluff just east of Ti Creek, SW¼NW¼SW¼ NE¼ sec. 5, T. 3 N., R. 15 E. See Figure 3B for location of photograph.

Figure 14. Cameron Sandstone Member at the same location as Figure 13, but stratigraphically lower (unit 32, Appendix 1). Note the curved beds, and the soft-sediment-deformation features at the base of the unit. See Figure 3B for location of photograph.

(Fig. 17) and was observed in three outcrops in the study area: in the SW¼SW¼NW¼NE¼ sec. 26, T. 4 N., R. 15 E.; in the NW¼NE¼NW¼SW¼ sec. 26, T. 4 N., R. 15 E.; and along Ti Creek in the SW¼SW¼NW¼NE¼ sec. 5, T. 3 N., R. 15 E. (Appendix 4).

The Keota Sandstone Member (unit 51, Appendix 1), an interbedded sandstone-siltstone-shale unit, is 22 ft thick (Fig. 18). It is well exposed along a new gas-well road and in an abandoned shale pit in the NE¼NE¼SE¼NW¼ sec. 26, T. 4 N., R. 15 E.

The contact between the McAlester Formation and the overlying Savanna Formation is exposed in a gully in the SE¼NE¼SW¼NW¼ sec. 26, T. 4 N., R. 15 E. (Fig. 19A), just west of the new gas-well road. At the contact, which is sharp and paraconformable, a light olive gray shale with ironstone concretions (unit 55, Appendix 1) underlies a thin- to medium-bedded sandstone with low-angle cross-stratification. This sandstone is the lowermost bed of the Savanna Formation (unit 56, Appendix 13). The contact is also exposed in the channel of an intermittent stream in the NE¼NW¼SE¼NW¼ sec. 26, T. 4 N., R 15 E., where partings in the rock clearly show the low-angle cross-stratification in the basal sandstone of the Savanna Formation (Fig. 19B).

Figure 15. Exposure of the McAlester coal (unit 41, Appendix 1) in a gully in the SE¼ SW¼ NE¼SE¼ sec. 6, T. 3 N., R. 15 E. Tape measure shows that the coal is 2 ft thick. See Figure 3A for location of photograph.

Figure 16. A rare outcrop of the Tamaha Sandstone Member (unit 44, Appendix 1) in the McAlester area showing its thin-bedded, shaly character. Note the ripple marks (shown by arrow) on the surfaces of the sandstone beds, which dip ~50° to the northwest (left in the photograph). Photographed on the east side of Ti Creek, SW¼SW¼NW¼NE¼ sec. 5, T. 3 N., R. 15 E. (Fig. 3A).

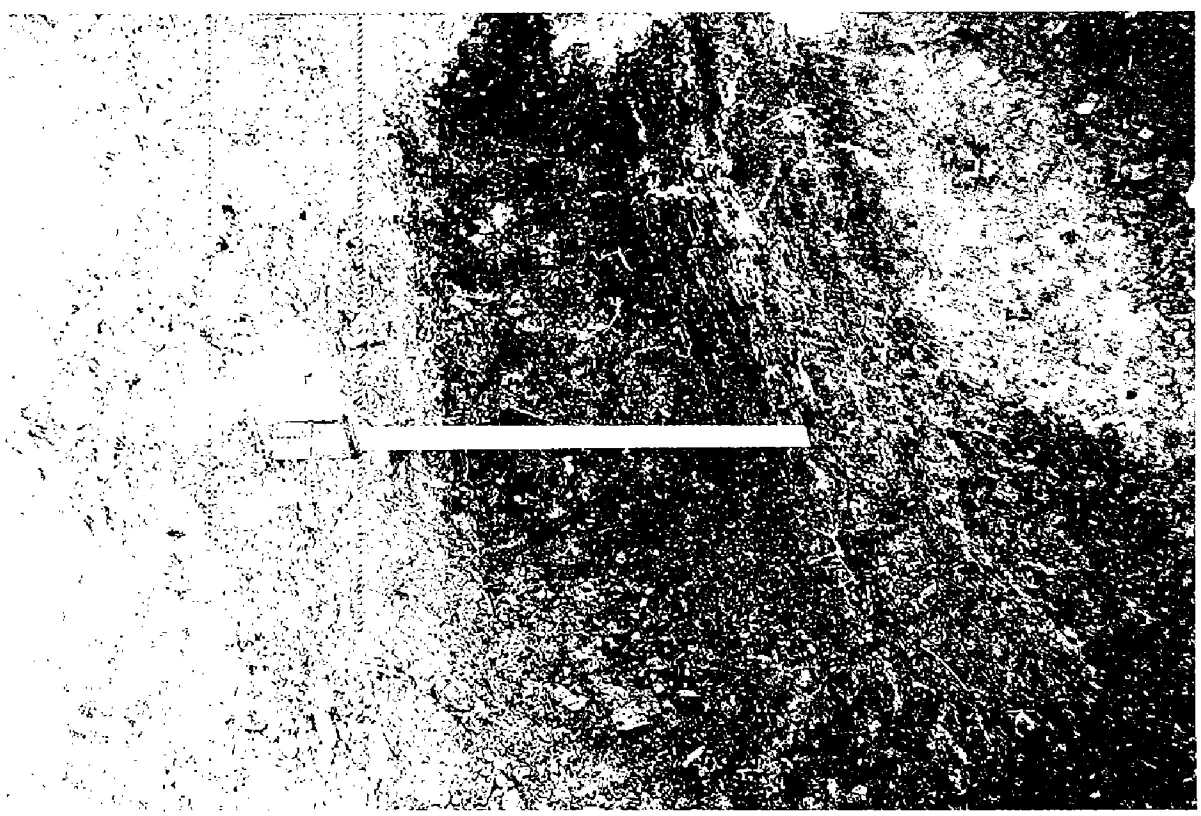


Figure 17. An outcrop of the Tamaha coal (unit 46, Appendix 1) in the SW¼SW¼NW¼NE¼ sec. 26, T. 4 N., R. 15 E. The tape measure shows the coal bed to be ~10 in. thick at this location. Beds dip 53° to the northwest (left in the photograph). See Figure 3C for location of photograph.

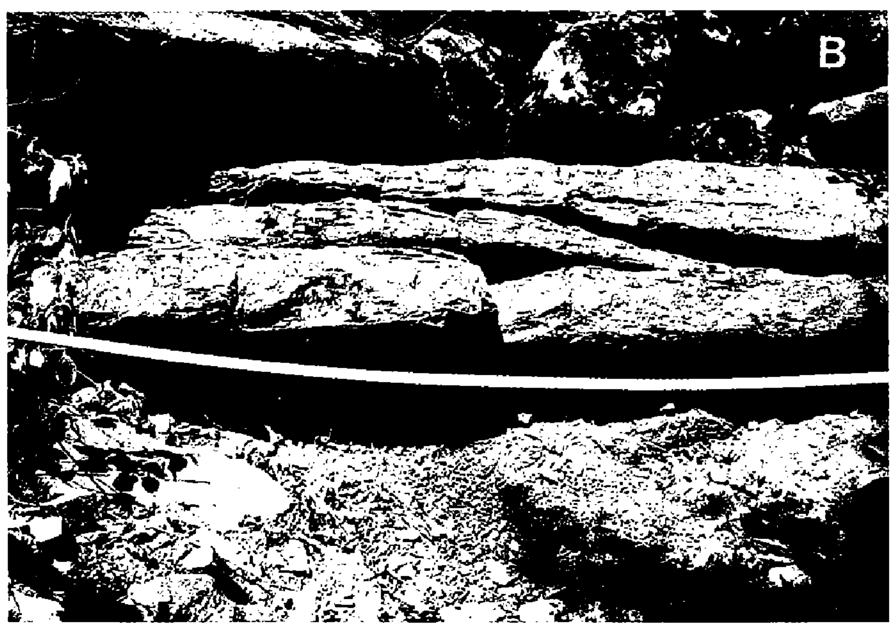
Figure 18. The Keota Sandstone Member (unit 51, Appendix 1) exposed in an abandoned shale pit in the NE¼ NE¼SE¼NW¼ sec. 26, T. 4 N., R. 15 E. The Keota is variable in thickness and character in the study area. In general, it consists of thin-bedded, lenticular, shaly sandstone; shale beds are predominant. Trenching shovel for scale. See Figure 3C for location of photograph.

Comparison of Composite-Stratotype with Lithologic Units on Geophysical Log

A geophysical log from a well drilled in the SE¼ sec. 28, T. 4 N., R. 15 E., 1.25 mi north of Highway 63 and well within the composite-stratotype area (Figs. 1, 3B), has been analyzed and compared to the composite-stratotype. Part of the log appears in Appendix 3. It shows the electric-log character of the lithologic units and the depth at which each unit was penetrated. Lithologic interpretations and picks on the geophysical log are those of the author.

The well was spudded in the Boggy Formation at an elevation of 730 ft above sea level, well above both the Savanna and McAlester Formations. The top of the Savanna was encountered at a drilled depth of 820 ft and the Savanna-McAlester contact was encountered at 1,930 ft. The base of the McAlester was picked at a drilled depth of 3,780 ft. Thus, the thickness of the McAlester Formation in the well is 1,850 ft, which is close to the thickness of 1,816 ft determined for the composite-stratotype. Note that all of the named members in the McAlester Formation can be identified on the log.

Figure 19. *A*—Contact between the McAlester Formation (below) and the Savanna Formation (above) shown at the base of the tape measure. The photograph was taken in a gully just north of a pipeline in the SE¼NE¼SW¼NW¼ sec. 26, T. 4 N., R. 15 E. *B*—Basal sandstone unit of the Savanna Formation exposed in the NE¼NW¼SE¼NW¼ sec. 26, T. 4 N., T. 15 E. The approximate contact with the underlying McAlester Formation, which is hidden in the dark shadow near the middle of the photograph, is shown by the white line. See Figure 3C for locations of photographs.



Summary

The three divisions of the McAlester Formation as defined by Taff (1899, p. 437) are readily distinguishable in the new composite-stratotype established herein. The formation has been divided into six named members and several unnamed shale members since Taff's original definition. All but one of the six named members crop out in the study area. Of the unnamed shale members, the only ones extensively covered in the composite-stratotype area are in the interval from the top of the Warner Sandstone Member to the base of the Cameron Sandstone Member.

The stratigraphic position of the Lequire Sandstone Member is within this same covered interval, so it was not described herein. The thickness of the McAlester Formation in the composite-stratotype is 1,816 ft. This is close to Taff's original estimate of ~2,000 ft.

Establishment of a composite-stratotype for the McAlester Formation fills just one of the voids in the stratigraphic framework of Oklahoma. More work is needed to establish standards by which other long- and well-established geologic units in the State can be recognized.

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APPENDIX 1. — Composite-Stratotype for the McAlester Formation

EXPLANATION

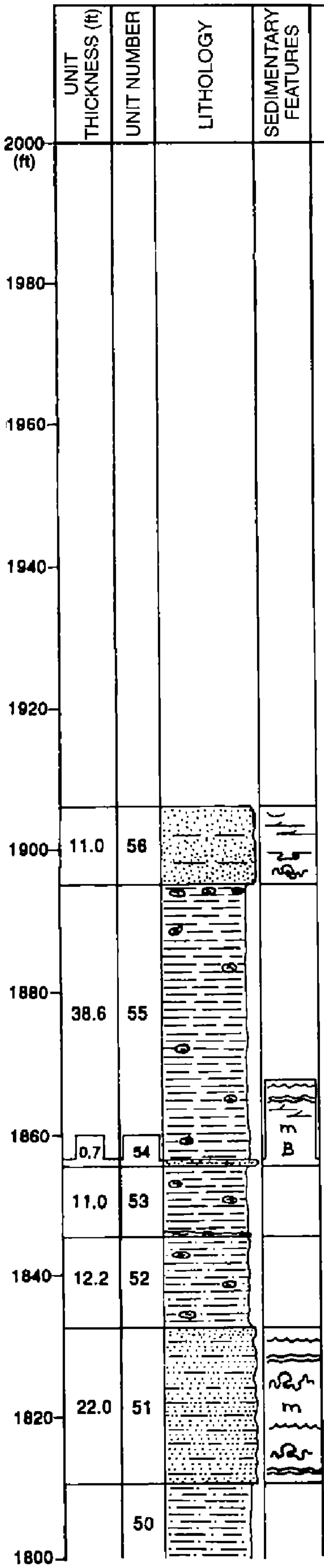
- Sandstone
- Sandstone, shaly
- Sandstone, siltstone, shale, interbedded
- Siltstone
- Siltstone, shaly
- Shale
- Shale, silty, sandy
- Shale, black
- Limestone
- Ironstone
- Coal
- Underclay
- Covered interval

SEDIMENTARY FEATURES

- Plane, parallel stratification
- Cross-stratification
- Low-angle cross-stratification
- Wavy bedding
- Lenticular bedding
- Swaly bedding, curved bedding
- Convolute, slumped, or contorted bedding
- Parting or current lineations
- Ripple marks
- Nodular bedding
- Ball-and-pillow
- Siltstone nodules
- Load structures
- Flute and groove casts
- Boxwork weathering
- Dewatering structures or dish and pillar
- fissile
- Plant fossils
- Macerated plant material
- Trace fossils
- Invertebrate fossils
- B Bioturbated
- L Liesegang banding
- m Micaceous
- p Pitted
- Fining-upward sequence
- Coarsening-upward sequence

Note: Rock-color terms are these shown in the rock-color chart (Rock-Color Chart Committee,1991).

APPENDIX 1. — Composite-Stratotype for the McAlester Formation



DESCRIPTION OF UNITS

DESMOINESIAN SERIES

KREBS GROUP

SAVANNA FORMATION

56. Sandstone, yellowish gray (5Y7/2); weathers light brown (5YR5/6; 5YR6/4) to moderate brown (5YR4/4); very fine grained, shaly; mostly thin- to medium-bedded (some thick beds); bedding slightly curved;internally contains low-angle cross-stratification; trace fossils and load casts abundant on soles; contact with underlying unit sharp.

MCALESTER FORMATION

55. Shale, light olive gray (5Y5/2); contains dark reddish brown (10R3/4) to light brown (5YR5/6) clay-ironstone concretions about 1-3 in. thick and 2-6 in. in diameter, notably concentrated in upper 6 in. of unit; includes some 2-in.-thick layers of medium dark gray (N4), blocky shale; contact with underlying unit sharp.

54. Sandstone and siltstone, light olive gray (5Y6/1) with dark yellowish orange (10YR6/6) staining; very fine grained, shaly, micaceous; thin- to very thin bedded; low-angle cross-stratification; bioturbated; includes some obscure wavy bedding and poorly preserved ripple marks; base sharp; thickness variable.

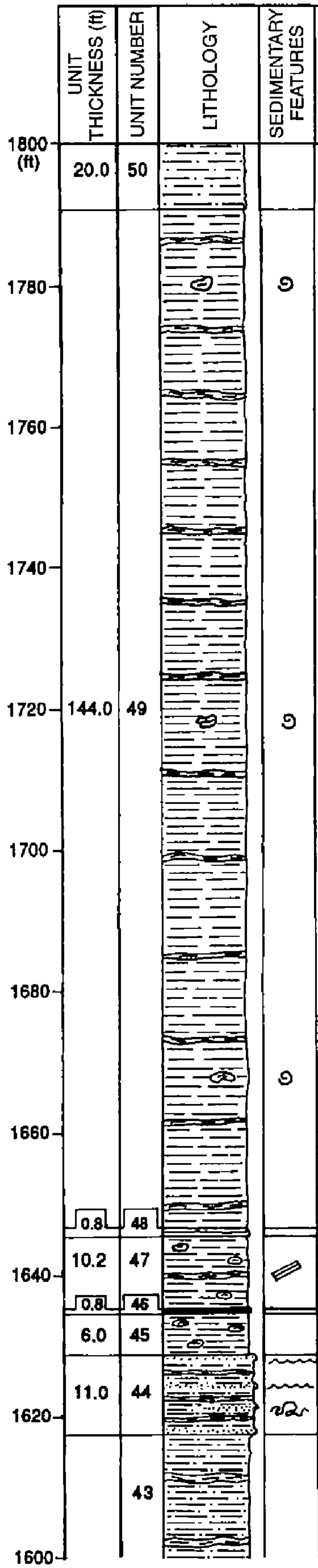
53. Shale, light olive gray (5Y6/1); weathers to tiny flakes; fissile; contains light brown (5YR5/6) and dark yellowish orange (10YR6/6), discoid clay-ironstone concretions that break into resistant fragments on the outcrop; includes at base of unit a 1-in.-thick, moderate brown (5YR4/4) and light brown (5YR5/6) continuous layer of silty clay ironstone.

52. Shale, olive gray (5Y4/1); weathers moderate yellowish brown (10YR5/4); silty; includes thin, flaky, light brown (5YR5/6) and dark yellowish orange (10YR6/6) clay-ironstone concretions.

51. Sandstone, siltstone, and shale, interbedded; banded grayish orange (10YR7/4), light olive gray (5Y5/2), and dark yellowish orange (10YR6/6); micaceous; wavy-bedded; ripple-marked; trace fossils abundant; in places at base includes an 0.8-ft-thick, well-indurated layer of wavy-bedded sandstone with an irregular base (Keota Sandstone Member).

Offset to abandoned shale pit ~70 yards east.

APPENDIX 1. — Composite-Stratotype for the McAlester Formation *(continued)*



DESCRIPTION OF UNITS

50. Shale, very silty; banded moderate yellowish brown (10YR5/4), light gray (N7) and moderate brown (5YR4/4); sharp color change at contact with underlying shale (exposed near eastern end of shale pit).

Offset to creek bank ~100 yards east.

49. Shale, medium dark gray (N4); flaky; includes distinctive light brown (5YR5/6) and dark yellowish orange (10YR6/6), brittle, flaky stringers of clay ironstone about 1-10 ft apart, as well as irregularly shaped, banded clay-ironstone concretions that contain rare, calcareous crinoid ossicles and brachiopod valves.

48. Shale, brownish black (5YR2/1); carbonaceous, flaky; includes near base of unit, a moderate yellow (5Y7/6), unidentified mineral occurring as small irregular nodules and flakes.

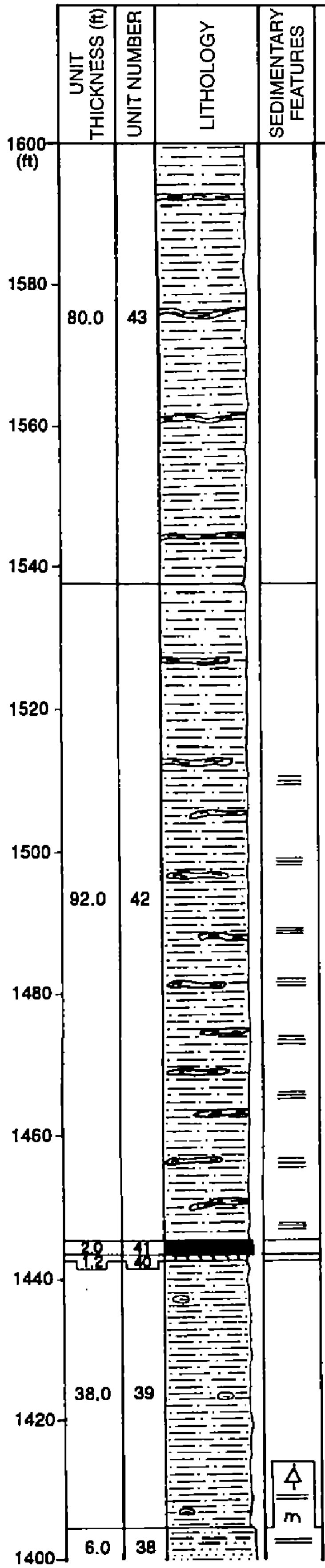
47. Shale, olive gray (5Y4/1); weathers moderate yellowish brown (10YR5/4); flaky; contains irregularly shaped clay-ironstone concretions and thin stringers, which include plant fossils such as fern leaves and ribbed plant fragments; contact with underlying unit sharp.

46. Coal, brownish black (5YR2/1); impure, shaly, highly weathered; contains the same moderate yellow (5Y7/6) mineral described in unit 48 (Tamaha coal).

45. Shale, medium gray (N5); weathers dark yellowish brown (10YR4/2) to light gray (N7); contains abundant, scattered, dark yellowish orange (10YR6/6) clay-ironstone concretions about 1-3 in. in diameter.

44. Shale, olive gray (5Y4/1); weathers grayish orange (10YR7/4) to yellowish gray (5Y7/2); very silty and sandy; includes widely-spaced 1- to 2-in.-thick layers of thin-laminated, ripple-marked, lenticular sandstone with trace fossils; also includes layers of dark yellowish orange (10YR6/6) and light brown (5YR5/6) clay-ironstone concretions so abundant that their fragments almost obscure the outcrop (Tamaha Sandstone Member).

APPENDIX 1. — Composite-Stratotype for the McAlester Formation *(continued)*



DESCRIPTION OF UNITS

43. Shale, light olive gray (5Y5/2) with pale red (5R6/2) shadings; weathers grayish orange (10YR7/4); very silty; includes some olive gray (5Y4/1) layers as well as some dark yellowish orange (10YR6/6) clay-ironstone layers.

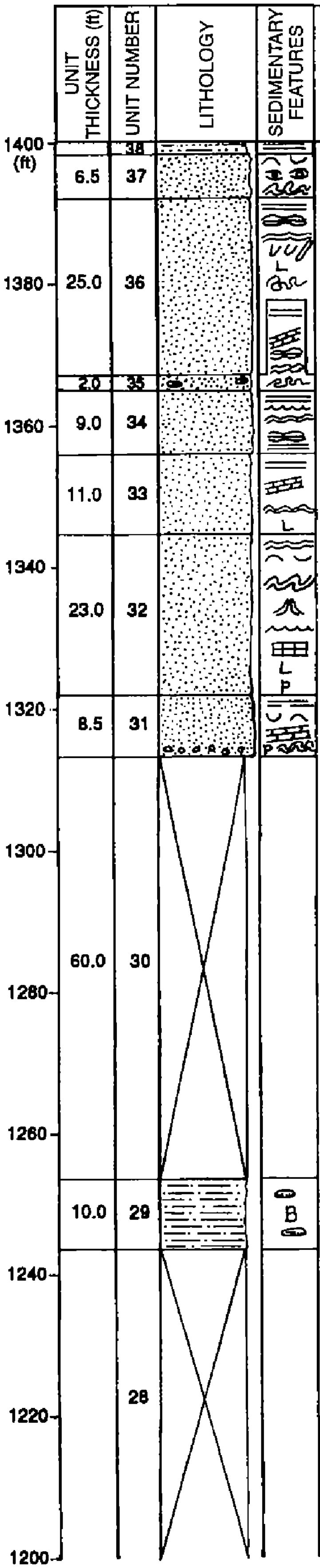
42. Shale, medium gray (N5) to light gray (N7); silty; weathers yellowish gray (5Y7/2); fissile to irregularly blocky in part; contains abundant discontinuous layers of dark yellowish orange (10YR6/6) and moderate brown (5YR4/4) clay-ironstone concretions 0.5-1.5-in. thick.

41. Coal, black (N1); soft, weathered; finely cleated where less weathered (McAlester coal).

40. Underclay, dark gray (N3) with light brown (5YR5/6) mottling; plastic, slickensided; grades into underlying unit.

39. Shale, light olive gray (5Y5/2); silty; weathers grayish orange (10YR7/4) to dark yellowish orange; contains minor dark yellowish orange (10YR6/6) clay-ironstone concretions.

38. Siltstone, grayish orange (10YR7/4) with thin, moderate yellowish brown (10YR5/4) bands; weathers very pale orange (10YR8/2); shaly, very thin bedded, micaceous; plane-, parallel-bedded; includes some 0.5-in.-thick, very fine grained, wavy-bedded sandstone layers in lower half of unit; fining-upward sequence.



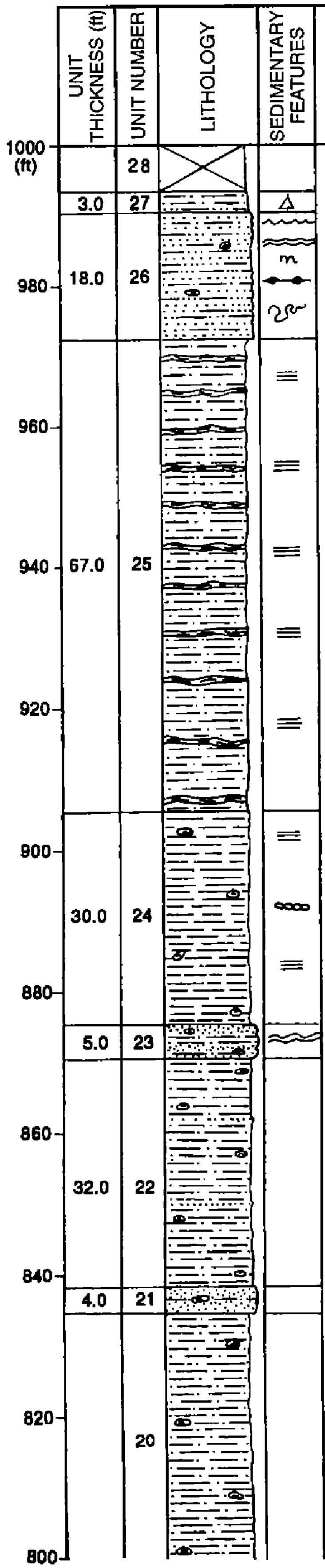
DESCRIPTION OF UNITS

37. Sandstone, grayish orange (10YR7/4) with dark yellowish orange (10YR6/6) bands; some moderate reddish brown (10R4/6) staining; very fine grained, mostly medium-bedded with some thin beds; swaly-bedded, with ball-and-pillow structures; surface irregular; convolute bedding just above contact with underlying unit (top unit of Cameron Sandstone Member).
36. Sandstone, grayish orange (10YR7/4) to dark yellowish orange (10YR6/6); weathers light brown (5YR5/6; 5YR6/4) to moderate brown (5YR3/4; 5YR4/4) very fine grained, some Liesegang banding, very thin to thin- to medium-bedded; plane, parallel-bedded; parting lineations common; some wavy-bedded intervals; some soles have groove and flute casts and rare, small trace fossils.
35. Sandstone, pale yellowish orange (10YR8/6) to moderate orange pink (5YR8/4); very fine grained; occurs as single thick-bedded unit with plane beds exhibiting internal cross-laminations; shows ferruginous concretions and parting lineations where broken; wavy bedded with trace fossils at contact with underlying unit.
34. Sandstone, grayish orange (10YR7/4) with dark yellowish orange (10YR6/6) banding; weathers light brown (5YR5/6); very fine grained, thin- to medium-bedded; mostly plane-, parallel-bedded, but some wavy beds and ripple marks; some parting lineations.
33. Sandstone, grayish orange (10YR7/4) to very pale orange (10YR8/2) to dark yellowish orange (10YR6/6); very fine grained; very thin to thin- to medium-bedded; plane, parallel-bedded in part; wavy-bedded with internal cross-bedding in part; some Liesegang banding.
32. Sandstone, very pale orange (10YR8/2) to grayish orange (10YR7/4) to moderate yellowish brown (10YR5/4); very fine grained, very thin to thin- to medium- to thick-bedded; wavy to swaly beds; many curved beds with 2-3-ft-thick convolute beds and dewatering features; ripple-marked on some surfaces; exhibits Liesegang banding and limonite-healed fractures; boxwork and pebble cavities and pits on some soles.
31. Sandstone, grayish orange (10YR7/4) to dark yellowish orange (10YR6/6); very fine grained, mostly medium-bedded; bedding discontinuous planar to curved; cross-bedded; some folded, deformed layers; numerous pits on weathered surfaces; includes an ironstone pebble conglomerate near base; thick-bedded in lower part; outcrop of lower 3.5 ft slumped; base covered (lowest exposed unit of Cameron Sandstone Member).
30. Covered interval.
29. Shale, medium dark gray (N4); flaky, silty; weathers grayish orange (10YR7/4) to dark yellowish orange (10YR6/6); contains abundant moderate yellowish brown (10YR5/4) siltstone nodules exhibiting bioturbation features; ~10 ft exposed in road cut just north of Highway 63; base covered.

APPENDIX 1. — Composite-Stratotype for the McAlester Formation *(continued)*

(ft)	UNIT THICKNESS (ft)	UNIT NUMBER	LITHOLOGY	SEDIMENTARY FEATURES	DESCRIPTION OF UNITS
1200					
1180					
1160					
1140					
1120					
1100	250.0	28			28. Covered interval.
1080					
1060					
1040					
1020					
1000					

APPENDIX 1. — Composite-Stratotype for the McAlester Formation *(continued)*



DESCRIPTION OF UNITS

27. Shale, dark yellowish orange (10YR6/6); silty, highly weathered, blocky; contains thin siltstone laminae in upper part; upper contact gradational.

26. Sandstone, grayish orange (10YR7/4) to dark yellowish orange (10YR6/6); silty, shaly, very thin bedded; interlaminated with siltstone; parallel, wavy-bedded; ripple-marked; micaceous; contains rare carbonized, macerated plant fragments on some stratification surfaces; includes scattered trace fossils, many with bulbous forms; also contains scattered, light brown (5YR5/6), ironstone concretions; uniform-appearing throughout unit (upper unit of Warner Sandstone Member).

25. Shale, olive gray (5Y4/1); fissile; silty; contains very thin light brown (5YR5/6), silty layers of ironstone 1-6 ft apart, upper contact sharp.

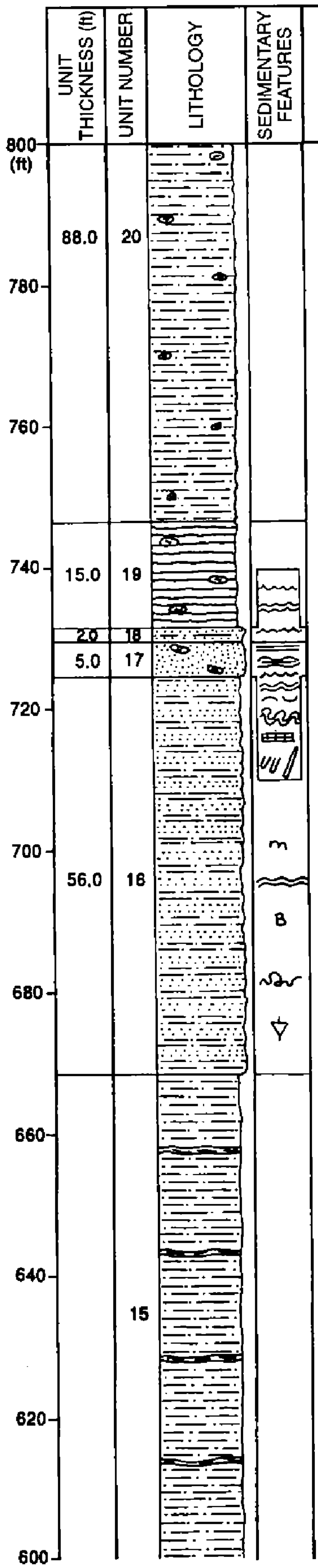
24. Shale, medium gray (N5); fissile to nodular; contains scattered, discontinuous layers of ovoid and discoid light brown (5YR5/6) clay ironstones.

23. Sandstone and shale, interbedded; sandstone is very pale orange (10YR8/2) to grayish orange (10YR7/4); very fine grained, very thin bedded; wavy, parallel-bedded; contains small ironstone concretions; shale is yellowish gray (5Y7/2), silty and sandy.

22. Shale, grayish orange (10YR7/4); very silty; contains small clay-ironstone concretions and two 1-in.-thick sandstone stringers.

21. Sandstone, grayish orange (10YR7/4); weathers moderate brown (5YR4/4); very fine grained; occurs as 1-2-in.-thick beds interbedded with grayish orange (10YR7/4), sandy shale containing ironstone concretions.

APPENDIX 1. — Composite-Stratotype for the McAlester Formation *(continued)*



DESCRIPTION OF UNITS

20. Shale, grayish orange (10YR7/4) to dark yellowish orange (10YR6/6); silty and sandy; contains small, dark yellowish orange (10YR6/6) clay-ironstone concretions.

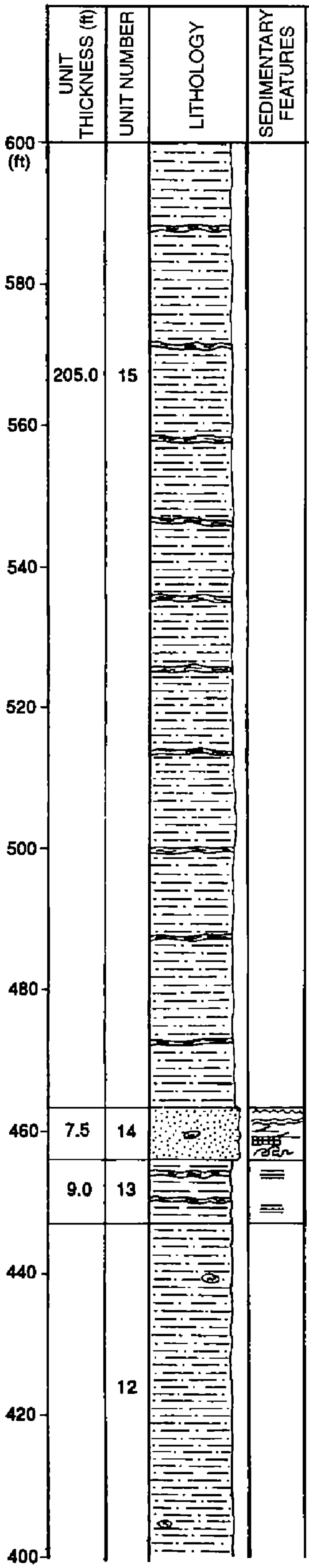
19. Shale, olive black (5Y2/1); clayey; weathers to small flakes on the outcrop; includes 2-3-in.-thick, light brown (5YR5/6) and dark yellowish orange (10YR6/6) discoid clay-ironstone concretions up to 1 ft in diameter.

18. Sandstone, grayish orange (10YR7/4); very fine grained, very thin bedded, wavy-bedded, ripple-marked; interbedded with grayish orange (10YR7/4) to light brown (5YR5/6) silty shale; contact with underlying unit sharp (lower unit of Warner Sandstone Member).

17. Sandstone, grayish orange (10YR7/4) to very pale orange (10YR8/2) to light brown (5YR5/6); very fine grained, medium- to thick-bedded; plane-, parallel-bedded with current lineations, to wavy-bedded and marked by current ripples; some curved beds with soft-sediment deformation in places; includes nodular and boxwork ironstone concretions; flute marks and grooves on some soles; blocky to slabby (lower unit of Warner Sandstone Member).

16. Sandstone and shale, interbedded; sandstone is pale yellowish brown (10YR6/2) and light brown (5YR5/6); very fine grained, micaceous, thin-bedded, wavy-bedded, bioturbated; trace fossils abundant; occurs as 1-5-in.-thick layers; shale is moderate yellowish brown (10YR5/4) to light brown (5YR5/6); silty, highly weathered; coarsening-upward sequence; unit forms resistant ridge (lower part of lower unit of Warner Sandstone Member).

APPENDIX 1. — Composite-Stratotype for the McAlester Formation *(continued)*



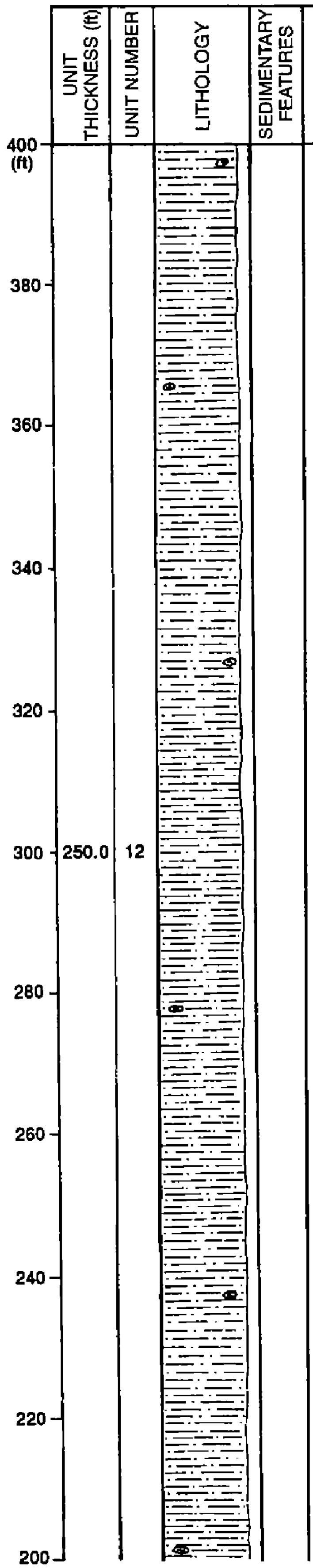
DESCRIPTION OF UNITS

15. Shale, light olive gray (5Y5/2); weathers grayish orange (10YR7/4); silty, flaky, contains stringers of light brown (5YR5/6) and dark yellowish orange (10YR6/6) clay-ironstone concretions (McCurtain Shale Member).

14. Sandstone, moderate orange pink (5YR8/4) to light brown (5YR6/4; 5YR5/6); very fine grained, medium- to thick-bedded; mostly parallel-bedded and wavy-bedded; symmetrical current ripples abundant; some low-angle cross-stratification; locally fills channels cut into same unit; ironstone concretions common in nodules, in boxwork, in ripple infillings, and in interbedded lenses; trace fossils abundant on some soles; slabby to blocky (unnamed sandstone in McCurtain Shale Member).

13. Shale, medium gray (N5); fissile; contains abundant 1-in.-thick, light brown (5YR5/6) clay-ironstone stringers (McCurtain Shale Member).

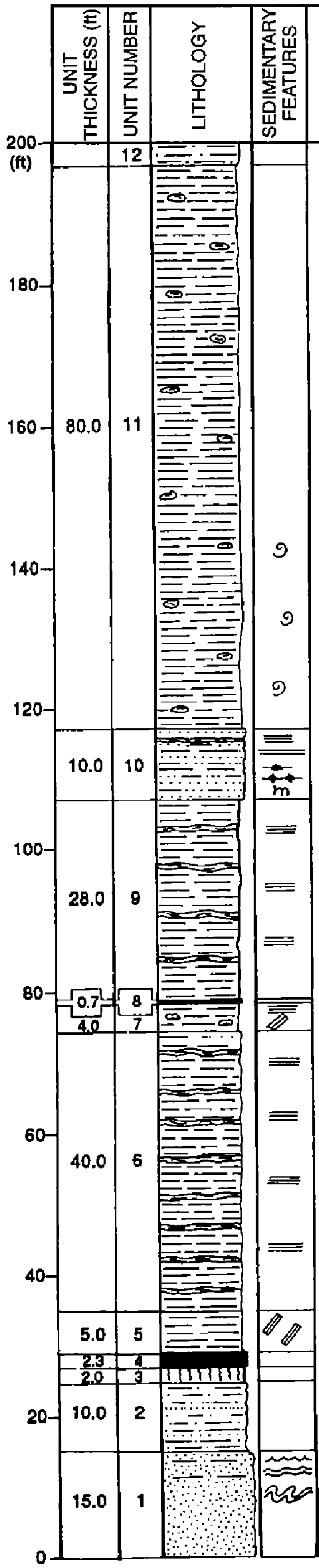
APPENDIX 1. — Composite-Stratotype for the McAlester Formation *(continued)*



DESCRIPTION OF UNITS

12. Shale, light olive gray (5Y5/2); weathers pale yellowish brown (10YR6/2); very silty; contains rare, small, light brown (5YR5/6) ironstone concretions (McCurtain Shale Member).

APPENDIX 1. — Composite-Stratotype for the McAlester Formation *(continued)*



DESCRIPTION OF UNITS

11. Shale, medium gray (N5); clayey; contains light brown (5YR5/6) clay-ironstone concretions; locally, near base of unit, contains very light gray (N8), small, calcareous, brachiopod valves and fossil fragments (at edge of small pond) (McCurtain Shale Member).

10. Siltstone and sandstone, dark yellowish brown (10YR4/2) to light brown (5YR6/4); very thin bedded, fissile; plane-, parallel-bedded; subtly lenticular bedded in part; micaceous; minor carbonized plant fragments on some stratification surfaces; shaly, with light brown (5YR5/6) clay-ironstone stringers in upper part (unnamed siltstone-sandstone in McCurtain Shale Member).

9. Shale, medium light gray (N6); fissile; contains abundant thin stringers of light brown (5YR5/6) and dark yellowish orange (10YR6/6) clay ironstone that weather out and litter the outcrop; contact with underlying unit sharp and conformable (McCurtain Shale Member).

HARTSHORNE FORMATION

8. Coal, black (N1) with light brown (5YR5/6) iron-oxide staining; soft, weathered (Upper Hartshorne coal).

7. Shale, dark gray (N3); fissile, carbonaceous; contains abundant plant compressions such as seed fern leaves, and other ribbed plant fragments; also contains 1-2-in.-thick discoid, light brown (5YR5/6) clay-ironstone concretions up to 1 ft in diameter; grades into overlying unit.

6. Shale, medium light gray (N6) to light gray (N7); fissile; contains abundant thin stringers of light brown (5YR5/6) clay ironstone

5. Shale, dark gray (N3) with light brown (5YR5/6) streaks; contains thin coal streaks; carbonaceous, with abundant ribbed plant compressions.

4. Coal, brownish black (5YR2/1); soft, highly weathered (Lower Hartshorne coal).

3. Underclay, dark gray (N3) with light brown (5YR5/6) mottling; blocky.

2. Shale, very pale orange (10YR8/2) with light brown (5YR5/6) mottling; silty; contains very thin stringers of very fine grained sandstone.

1. Sandstone, very pale orange (10YR8/2) to grayish orange (10YR7/4); weathers moderate brown (5YR4/4); very fine grained, mostly medium- to thin-bedded; parallel-, wavy-bedded, with some soft-sediment deformation; ripple-marked; becomes shaly in upper 5 ft (Hartshorne sandstone).

APPENDIX 2. — Measured Sections Used for Compilation of Composite-Stratotype for the McAlester Formation

For permission to enter private property to examine measured sections 1, 4, and 5, contact Doc Coker, Route 3, McAlester, OK 74501. To examine measured section 2, contact Ruyanna Fugitt, McAlester, OK 74501.

Measured Section 1 (Pi-4-97-H)

(Ti Creek section), Hartshorne SW 7.5′ Quadrangle

(Modified from Hemish and Suneson, 1997, p. 52–53.)

Measured in bluff overlooking Ti Creek, just northwest of Oklahoma State Highway 63, SW¼NW¼SW¼NE¼ sec. 5, T. 3 N., R. 15 E., Pittsburg County (Hartshorne SW 7.5′ quadrangle), by LeRoy A. Hemish.

Units 1–9 of this measured section are used in the composite-stratotype (units 29–37) for the McAlester Formation.

	Thickness (feet)
KREBS GROUP	
MCALESTER FORMATION	
Cameron Sandstone Member (units 3–9):	
9. Sandstone, grayish orange (10YR7/4) with dark yellowish orange (10YR6/6) bands, some moderate reddish brown (10R4/6) staining; very fine grained, mostly medium-bedded with some thin beds; swaly bedded, with ball-and-pillow structures; surface irregular; convolute bedding just above contact with underlying unit	6.5
8. Sandstone, grayish orange (10YR7/4) to dark yellowish orange (10YR6/6); weathers light brown (5YR5/6; 5YR6/4) to moderate brown (5YR3/4; 5YR4/4); very fine grained, some Liesegang banding, very thin to thin- to medium-bedded; plane-, parallel-bedded; parting lineations common; some wavy-bedded intervals; some soles have groove and flute casts and rare, small trace fossils	25.0
7. Sandstone, pale yellowish orange (10YR8/6) to moderate orange pink (5YR 8/4); very fine grained; occurs as single thick-bedded unit with plane beds exhibiting internal cross-laminations; shows ferruginous concretions and parting lineations where broken; wavy-bedded with trace fossils at contact with underlying unit	2.0
6. Sandstone, grayish orange (10YR7/4) with dark yellowish orange (10YR6/6) banding; weathers light brown (5YR5/6); very fine grained, thin- to medium-bedded; mostly plane-, parallel-bedded, but some wavy beds and ripple marks; some parting lineations	9.0
5. Sandstone, grayish orange (10YR7/4) to very pale orange (10YR8/2) to dark yellowish orange (10YR6/6); very fine grained; very thin to thin- to medium-bedded; plane-, parallel-bedded in part; wavy-bedded with internal cross-bedding in part; some Liesegang banding	11.0
4. Sandstone, very pale orange (10YR8/2) to grayish orange (10YR7/4) to moderate yellowish brown (10YR5/4); very fine grained, very thin to thin- to medium- to thick-bedded; wavy to swaly beds; many curved beds with 2- to 3-ft-thick convolute beds and dewatering features; ripple-marked on some surfaces; exhibits Liesegang banding and limonite-healed fractures; boxwork and pebble cavities and pits on some soles	23.0

3. Sandstone, grayish orange (10YR7/4) to dark yellowish orange (10YR6/6); very fine grained, mostly medium-bedded; bedding discontinuous planar to curved; cross-bedded; some folded, deformed layers; numerous pits on weathered surfaces; includes an ironstone pebble conglomerate near base; thick-bedded in lower part; outcrop of lower 3.5 ft slumped; base covered (lowest exposed unit of Cameron Sandstone Member)	8.5
2. Covered interval	60.0
1. Shale, medium dark gray (N4); flaky, silty; weathers grayish orange (10YR7/4) to dark yellowish orange (10YR6/6); contains abundant moderate yellowish brown (10YR5/4) siltstone nodules exhibiting bioturbation features; ~10 ft exposed in road cut just north of Highway 63; base covered	10.0
Total	155.0

Measured Section 2 (Pi-6-97-H)

(Gardner Creek dam section), Hartshorne SW 7.5′ Quadrangle

Measured in gully west of road, SW¼NE¼NW¼SE¼NW¼ sec. 26, T. 4 N., R. 15 E.; then southeast across road in shale pit; then southeast along strike to unnamed creek; then south through eroded area east of creek to abandoned railroad grade; then northeast along road on old grade to right turn in road; then in ditch along road to crest of ridge; southwest along road to east end of dam; in ridge southwest of dam at southeast edge of spillway; then back east to crest of ridge east of dam where new road runs southeast to State Highway 63; in new road ditch and in pasture west of new road; to small stream just north of Highway 63; in NW¼SW¼NW¼ sec. 25, T. 4 N., R. 15 E., by LeRoy A. Hemish.

Unit 2, units 4–9, part of unit 12, and units 18–31 of this measured section are used in the composite-stratotype (unit 11, units 14–19, unit 28, and units 43–56, respectively) for the McAlester Formation.

	Thickness (feet)
DESMOINESIAN SERIES	
KREBS GROUP	
SAVANNA FORMATION	
31. Sandstone, yellowish gray (5Y7/2); weathers light brown (5YR5/6; 5YR6/4) to moderate brown (5YR4/4); very fine grained, shaly; mostly thin- to medium-bedded (some thick beds); bedding slightly curved; internally contains low-angle cross-stratification; trace fossils and load casts abundant on soles; contact with underlying unit sharp	11.0
MCALESTER FORMATION	
30. Shale, light olive gray (5Y5/2); contains dark reddish brown (10R3/4) to light brown (5YR5/6) clay-ironstone concretions about 1–3 in. thick and 2–6 in. in diameter, notably concentrated in upper 6 in. of unit; includes some 2-in.-thick layers of medium dark gray (N4), blocky shale; contact with underlying unit sharp	38.6
29. Sandstone and siltstone, light olive gray (5Y6/1) with dark yellowish orange (10YR6/6) staining; very fine grained, shaly, micaceous; thin- to very thin bedded; low-angle cross-stratification; bioturbated; includes some obscure wavy bedding and poorly preserved ripple marks; base sharp; thickness variable	0.7
28. Shale, light olive gray (5Y6/1); weathers to tiny flakes; fissile; contains light brown (5YR5/6) and dark yellowish orange (10YR6/6), discoid clay-ironstone concretions that break into resistant fragments on the outcrop; in-	

	cludes at base of unit a 1-in.-thick, moderate brown (5YR4/4) and light brown (5YR5/6) continuous layer of silty clay ironstone	11.0
27.	Shale, olive gray (5Y4/1); weathers moderate yellowish brown (10YR5/4); silty; includes thin, flaky, light brown (5YR5/6) and dark yellowish orange (10YR6/6) clay-ironstone concretions	12.2
26.	Sandstone and siltstone; banded grayish orange (10YR7/4), light olive gray (5Y5/2), and dark yellowish orange (10YR6/6); shaly; micaceous; wavy-bedded; ripple-marked; trace fossils abundant; in places at base includes a 0.8-ft-thick, well-indurated layer of wavy-bedded sandstone with an irregular base (Keota Sandstone Member)	22.0
	Offset to abandoned shale pit ~70 yards east.	
25.	Shale, very silty; banded moderate yellowish brown (10YR5/4), light gray (N7) and moderate brown (5YR4/4); sharp color change at contact with underlying shale (exposed near eastern end of shale pit)	20.0
	Offset to creek bank ~100 yards east.	
24.	Shale, medium dark gray (N4); flaky; includes distinctive light brown (5YR5/6) and dark yellowish orange (10YR6/6), brittle, flaky stringers of clay ironstone about 1–10 ft apart, as well as irregularly shaped, banded clay-ironstone concretions that contain rare, calcareous crinoid ossicles and brachiopod valves	144.0
23.	Shale, brownish black (5YR2/1); carbonaceous, flaky; includes near base of unit, a moderate yellow (5Y7/6), unidentified mineral occurring as small irregular nodules and flakes	0.8
22.	Shale, olive gray (5Y4/1); weathers moderate yellowish brown (10YR5/4); flaky; contains irregularly shaped clay-ironstone concretions and thin stringers, which include plant fossils such as fern leaves and ribbed plant fragments; contact with underlying unit sharp	10.2
21.	Coal, brownish black (5YR2/1); impure, shaly, highly weathered; contains the same moderate yellow (5Y7/6) mineral described in unit 23 (Tamaha coal)	0.8
20.	Shale, medium gray (N5); weathers dark yellowish brown (10YR4/2) to light gray (N7); contains abundant, scattered, dark yellowish orange (10YR6/6) clay-ironstone concretions about 1–3 in. in diameter	6.0
19.	Shale, olive gray (5Y4/1); weathers grayish orange (10YR7/4) to yellowish gray (5Y7/2); very silty and sandy; includes widely spaced 1- to 2-in.-thick layers of thin-laminated, ripple-marked, lenticular sandstone with trace fossils; also includes layers of dark yellowish orange (10YR6/6) and light brown (5YR5/6) clay-ironstone concretions so abundant that their fragments almost obscure the outcrop (Tamaha Sandstone Member)	11.0
18.	Shale, light olive gray (5Y5/2) with pale red (5R6/2) shadings; weathers grayish orange (10YR7/4); very silty; includes some olive gray (5Y4/1) layers as well as some dark yellowish orange (10YR6/6) clay-ironstone layers	80.0
17.	Covered interval	117.0
16.	Shale, same description as unit 18. Measured in road cut south of gravel road built on abandoned railroad grade	5.0
15.	Covered interval (to flat-bedded, ripple-marked Cameron Sandstone Member in rib just north of lake)	106.0
	Offset along road eastward to outcrop of Cameron Sandstone Member on north side of road.	
14.	Sandstone, grayish orange (10YR7/4); very fine grained, thin- to very thin bedded in places; very shaly in middle part of exposure; mostly plane-, parallel-	

	bedded, but some low-angle cross-bedding and some ripple-marked beds; trace fossils common—notably invertebrate tracks; top of unit covered (Cameron Sandstone Member)	10.5
13.	Shale, light brownish gray (5YR6/1) with dark gray (N3) and light brown (5YR5/6) streaks; some siltstone stringers in upper 6 in.	1.0
	Offset along road eastward to bend in road.	
12.	Covered interval	320.0
11.	Sandstone, moderate brown (5YR4/4) to grayish orange (10YR7/4); very fine grained, siltstone in part, shaly, thin-bedded; wavy, parallel-bedded; ripple-marked (this unit is well-exposed ~1,500 ft to the northeast along strike, just west of the bend in State Highway 63) (upper unit of Warner Sandstone Member)	16.0
10.	Shale, olive gray (5Y3/2); weathers moderate yellowish brown (10YR5/4); fissile; includes some dark yellowish orange (10YR6/6) stringers of clay ironstone	160.0
9.	Shale, olive black (5Y2/1); clayey; weathers to small flakes on the outcrop; includes 2–3-in.-thick, light brown (5YR5/6) and dark yellowish orange (10YR6/6) discoid clay-ironstone concretions up to 1 ft in diameter	15.0
8.	Sandstone, grayish orange (10YR7/4); very fine grained, very thin bedded, wavy-bedded, ripple-marked; interbedded with grayish orange (10YR7/4) to light brown (5YR5/6) silty shale; contact with underlying unit sharp (lower unit of Warner Sandstone Member)	2.0
7.	Sandstone, grayish orange (10YR7/4) to very pale orange (10YR8/2) to light brown (5YR5/6); very fine grained, medium- to thick-bedded; plane-, parallel-bedded with current lineations, to wavy-bedded and marked by current ripples; some curved beds with soft-sediment deformation in places; includes nodular and boxwork ironstone concretions; flute marks and grooves on some soles; blocky to slabby (lower unit of Warner Sandstone Member)	5.0
6.	Sandstone and shale, interbedded; sandstone is pale yellowish brown (10YR 6/2) and light brown (5YR5/6); very fine grained, micaceous, thin-bedded, wavy-bedded, bioturbated, trace fossils abundant; occurs as 1–5-in.-thick layers; shale is moderate yellowish brown (10YR5/4) to light brown (5YR 5/6); silty, highly weathered; coarsening-upward sequence; unit forms resistant ridge (lower part of lower unit of Warner Sandstone Member)	56.0
5.	Shale, light olive gray (5Y5/2); weathers grayish orange (10YR7/4); silty, flaky, contains stringers of light brown (5YR5/6) and dark yellowish orange (10YR 6/6) clay-ironstone concretions (McCurtain Shale Member)	205.0
4.	Sandstone, moderate orange pink (5YR8/4) to light brown (5YR6/4; 5YR5/6); very fine grained, medium- to thick-bedded; mostly parallel-, wavy-bedded; symmetrical current ripples abundant; some low-angle cross-stratification; locally fills channels cut into same unit; ironstone concretions common in nodules, in boxwork, in ripple infillings, and in interbedded lenses; trace fossils abundant on some soles; slabby to blocky (unnamed sandstone in McCurtain Shale Member)	7.5
3.	Shale, olive gray (5Y4/1); weathers grayish orange (10YR7/4); flaky; contains ovoid and discoid light brown (5YR5/6) and dark yellowish orange (10YR 6/6) clay-ironstone concretions—mostly 1–2-in.-thick and 2–6-in. in diameter (McCurtain Shale Member)	306.0
2.	Shale, medium gray (N5); clayey; contains light brown (5YR5/6) clay-ironstone concretions; locally, near base of unit, contains very light gray (N8), small calcareous brachiopod valves and fossil fragments (at edge of small	

pond) (McCurtain Shale Member) 80.0

1. Siltstone interlaminated with very fine grained sandstone, moderate yellowish brown (10YR5/4) and moderate brown (5YR3/4); some light gray (N7) layers, very thin bedded, parallel-bedded, wavy-laminated, micaceous; black carbonaceous macerated plant material on some surfaces; some layers iron-stained; trace fossils rare (unnamed siltstone-sandstone in McCurtain Shale Member) 10.0

Total 1,790.3

Measured Section 3 (Pi-7-97-H)

(Highway 63 section), Hartshorne SW 7.5′ Quadrangle

Measured in ditches on both sides of State Highway 63, E½NW¼NW¼ sec. 25, T. 4 N., R. 15 E., starting at north edge of sec. 25, and continuing due southwest to just south of small stone bridge, by LeRoy A. Hemish.

Units 3–4 and units 8–15 of this measured section are used in the composite-stratotype (units 12–13 and units 20–27, respectively) for the McAlester Formation.

Thickness (feet)

DESMOINESIAN SERIES

KREBS GROUP

MCALESTER FORMATION

15. Shale, dark yellowish orange (10YR6/6) silty; highly weathered, blocky; contains thin siltstone laminae in lower part; lower contact gradational 3.0
14. Sandstone, grayish orange (10YR7/4) to dark yellowish orange (10YR6/6), silty, shaly, very thin bedded; interlaminated with siltstone; parallel, wavy-bedded; ripple-marked; micaceous; contains rare carbonized macerated plant fragments on some stratification surfaces; includes scattered trace fossils, many with bulbous forms; also contains scattered, light brown (5YR5/6), ironstone concretions; uniform-appearing throughout unit (upper unit of Warner Sandstone Member) 18.0
13. Shale, olive gray (5Y4/1); fissile; silty; contains very thin light brown (5YR5/6), silty layers of ironstone 1–6 ft apart; upper contact sharp 67.0
12. Shale, medium gray (N5); fissile to nodular; contains scattered, discontinuous layers of ovoid and discoid light brown (5YR5/6) clay ironstones 30.0
11. Sandstone and shale, interbedded; sandstone is very pale orange (10YR8/2) to grayish orange (10YR7/4); very fine grained, very thin bedded; wavy, parallel-bedded, contains small ironstone concretions; shale is yellowish gray (5Y7/2); silty and sandy 5.0
10. Shale, grayish orange (10YR7/4); very silty; contains small clay-ironstone concretions and two 1-in.-thick sandstone stringers 32.0
9. Sandstone, grayish orange (10YR7/4); weathers moderate brown (5YR4/4); very fine grained; occurs as 1–2-in.-thick beds interbedded with grayish orange (10YR7/4), sandy shale containing ironstone concretions 4.0
8. Shale, grayish orange (10YR7/4) to dark yellowish orange (10YR6/6); silty and sandy; contains small, dark yellowish orange (10YR6/6) clay-ironstone concretions 88.0
7. Sandstone, grayish orange (10YR7/4); weathers light brown (5YR5/6) and moderate reddish brown (10R4/6); very fine grained; occurs as a single unit ~1 ft thick with ripple marks, trace fossils, vertical burrows, and some cross-bedding (lower unit of Warner Sandstone Member) 1.0

6.	Shale, light olive gray (5Y6/1); weathers grayish orange (10YR7/4); silty and sandy in upper part; contains abundant light brown (5YR5/6) clay-ironstone concretions (McCurtain Shale Member)	192.0
5.	Sandstone, very pale orange (10YR8/2) to grayish orange (10YR7/4); very fine grained, mostly thin-bedded, shaly; wavy-, parallel-bedded, ripple-marked; trace fossils abundant; some cross-laminations; borings common; contains some light brown (5YR5/6) and moderate brown (5YR4/4) ironstone concretions (unnamed sandstone in McCurtain Shale Member)	7.5
4.	Shale, medium gray (N5); fissile; contains abundant 1-in.-thick, light brown (5YR5/6) clay-ironstone stringers (McCurtain Shale Member)	9.0
3.	Shale, light olive gray (5Y5/2); weathers pale yellowish brown (10YR6/2); very silty; contains rare, small, light brown (5YR5/6) ironstone concretions (McCurtain Shale Member)	250.0
2.	Covered interval (McCurtain Shale Member)	80.0
1.	Siltstone and sandstone, interlaminated, very pale orange (10YR8/2) and dark yellowish orange (10YR6/6); very thin bedded; parallel-, wavy-bedded; micaceous; contains rare carbonized plant remains (unnamed siltstone-sandstone in McCurtain Shale Member) (exposed just southeast of small stone bridge under State Highway 63)	10.0
	Total	796.5

Measured Section 4 (Pi-8-97-H)
(Coker Ranch section), Hartshorne SW 7.5′ Quadrangle

Measured in dip slope of ridge and in eroded gully along trail, from outcrop of sandstone at sharp bend in trail, northeastward down hill to barren slope just west and east of fence, in NE¼NE¼SW¼SE¼ and NW¼NW¼SE¼SE¼ sec. 5, T. 3 N., R. 15 E., by LeRoy A. Hemish.

Units 1–10 of this measured section are used in the composite-stratotype (units 1–10) for the McAlester Formation.

Thickness (feet)

DESMOINESIAN SERIES

KREBS GROUP

MCALESTER FORMATION

10.	Siltstone and sandstone, dark yellowish brown (10YR4/2) to light brown (5YR6/4); very thin bedded, fissile; plane-, parallel-bedded; subtly lenticular bedded in part; micaceous; minor carbonized plant fragments on some stratification surfaces; shaly, with light brown (5YR5/6) clay-ironstone stringers in upper part (unnamed siltstone-sandstone in McCurtain Shale Member)	10.0
9.	Shale, medium light gray (N6); fissile; contains abundant thin stringers of light brown (5YR5/6) and dark yellowish orange (10YR6/6) clay ironstone that weather out and litter the outcrop; contact with underlying unit sharp and conformable (McCurtain Shale Member)	28.0

HARTSHORNE FORMATION

8.	Coal, black (N1) with light brown (5YR5/6) iron-oxide staining; soft, weathered (Upper Hartshorne coal)	0.7
7.	Shale, dark gray (N3); fissile, carbonaceous; contains abundant plant compressions such as seed fern leaves and other ribbed plant fragments; also contains 1–2-in.-thick discoid, light brown (5YR5/6) clay-ironstone con-	

	cretions up to 1 ft in diameter; grades into overlying unit	4.0
6.	Shale, medium light gray (N6) to light gray (N7); fissile; contains abundant thin stringers of light brown (5YR5/6) clay ironstone	40.0
5.	Shale, dark gray (N3) with light brown (5YR5/6) streaks; contains thin coal streaks; carbonaceous, with abundant ribbed plant compressions	5.0
4.	Coal, brownish black (5YR2/1); soft, highly weathered (Lower Hartshorne coal)	2.3
3.	Underclay, dark gray (N3) with light brown (5YR5/6) mottling; blocky	2.0
2.	Shale, very pale orange (10YR8/2) with light brown (5YR5/6) mottling; silty; contains very thin stringers of very fine grained sandstone	10.0
1.	Sandstone, very pale orange (10YR8/2) to grayish orange (10YR7/4); weathers moderate brown (5YR4/4); very fine grained, mostly medium- to thin-bedded; parallel-, wavy-bedded, with some soft-sediment deformation; ripple-marked; becomes shaly in upper 5 ft (Hartshorne sandstone)	15.0
	Total	117.0

Measured Section 5 (Pi-9-97-H)

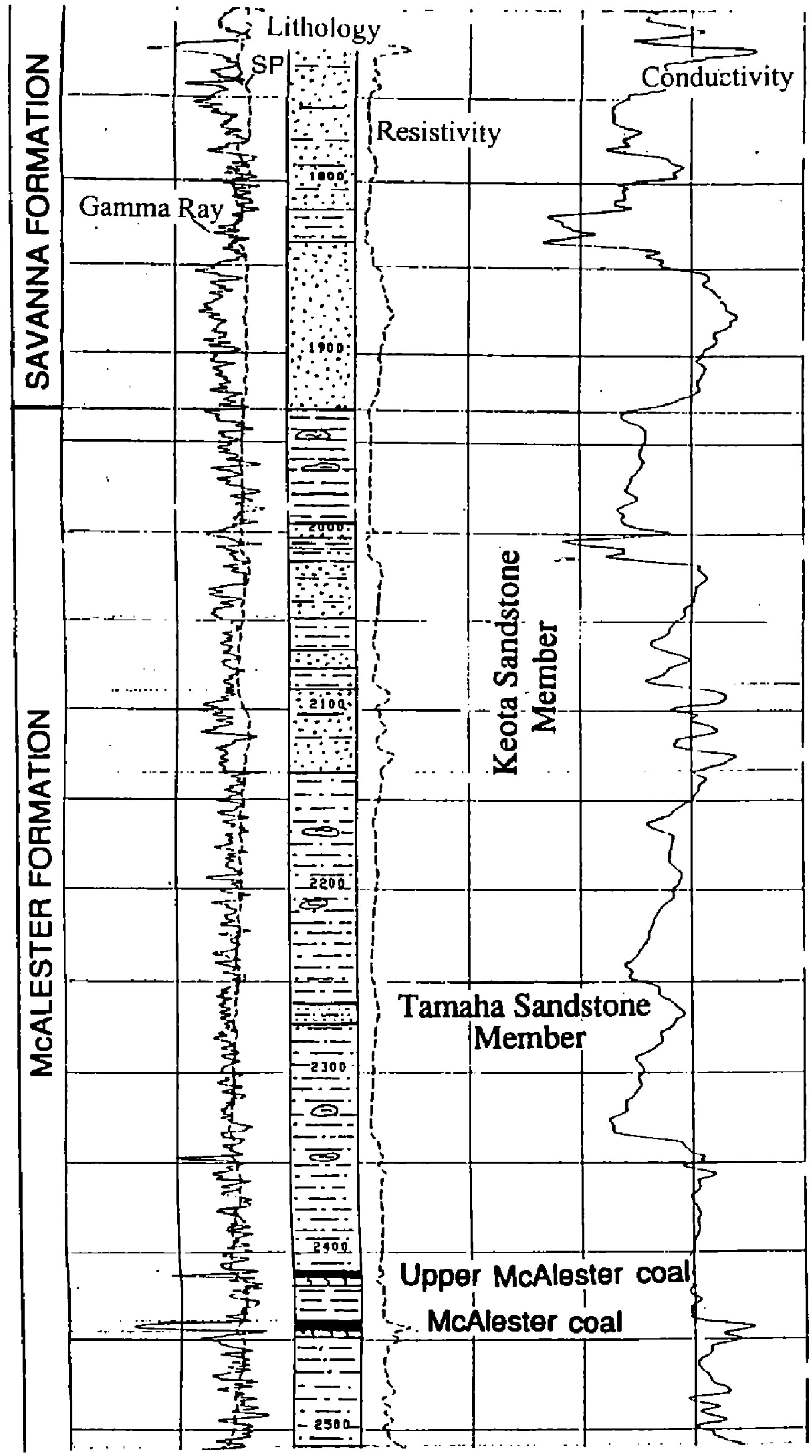
(Blanco section), Savanna 7.5′ Quadrangle

Measured in gully used as spillway for large pond, SW¼NE¼SE¼ sec. 6, T. 3 N., R. 15 E., starting at abandoned railroad grade, then down gully due southwest to first, thick-bedded, resistant unit of the Cameron Sandstone just north of breached ridge, by LeRoy A. Hemish.

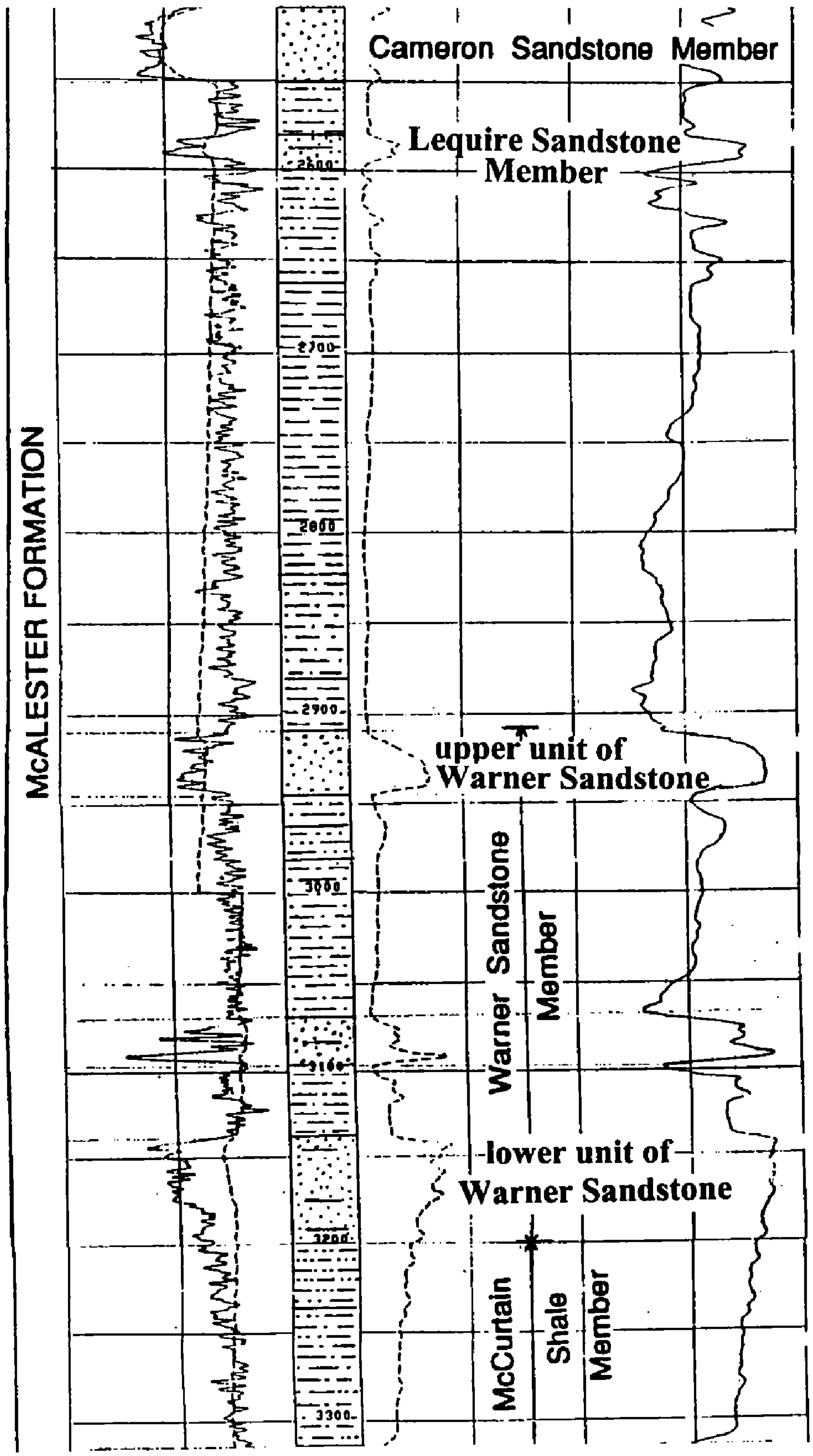
Units 2–6 of this measured section are part of the composite-stratotype (units 38–42) for the McAlester Formation.

		Thickness (feet)
	DESMOINESIAN SERIES	
	KREBS GROUP	
	MCALESTER FORMATION	
6.	Shale, medium gray (N5) to light gray (N7); silty; weathers yellowish gray (5Y 7/2); fissile to irregularly blocky in part; contains abundant discontinuous layers of dark yellowish orange (10YR6/6) and moderate brown (5YR4/4) clay-ironstone concretions 0.5–1.5 in. thick	92.0
5.	Coal, black (N1); soft, weathered; finely cleated where less weathered (McAlester coal)	2.0
4.	Underclay, dark gray (N3) with light brown (5YR5/6) mottling; plastic, slickensided; grades into underlying unit	1.2
3.	Shale, light olive gray (5Y5/2); silty; weathers grayish orange (10YR7/4) to dark yellowish orange; contains minor dark yellowish orange (10YR6/6) clay-ironstone concretions	38.0
2.	Siltstone, grayish orange (10YR7/4) with thin, moderate yellowish brown (10YR5/4) bands; weathers very pale orange (10YR8/2); shaly, very thin bedded, micaceous; plane-, parallel-bedded; includes some 0.5-in.-thick, very fine grained, wavy-bedded sandstone layers in lower half of unit; fining-upward sequence	6.0
1.	Sandstone, light brown (5YR6/4; 5YR5/6); very fine grained; mostly medium-bedded; blocky; upper surface irregularly ripple marked; contact with overlying unit sharp (top unit of Cameron Sandstone)	1.0
	Total	140.2

APPENDIX 3: Part of electric-log from Oxley No. 1-28 Crowl well, 1,320 ft from the south line and 1,320 ft from the east line of sec. 28, T. 4 N., R. 15 E., Pittsburg County, Oklahoma

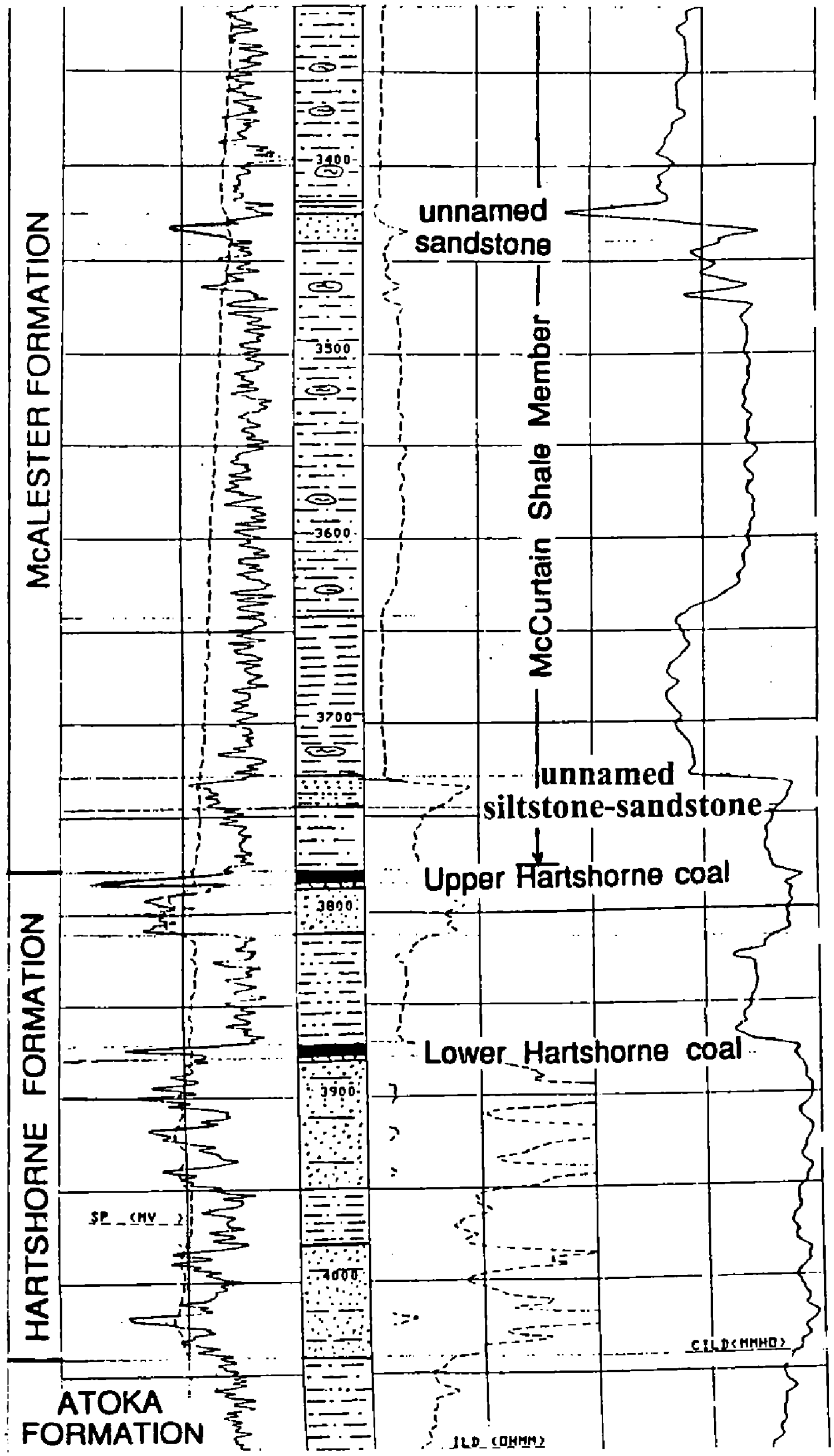


APPENDIX 3: Part of electric-log from Oxley No. 1-28 Crowl well *(continued)*



(continued on next page)

APPENDIX 3: Part of electric-log from Oxley No. 1-28 Crowl well *(continued)*



Stratigraphic and lithologic interpretations by LeRoy A. Hemish. Explanation of lithologic symbols given in Appendix 1.

APPENDIX 4. — Geologic map showing outcrop area of the McAlester Formation in the study area, as well as the underlying bedrock units (Atoka and Hartshorne Formations) and the overlying bedrock unit (Savanna Formation)

Excerpted and modified from Suneson and Hemish (1996) and Suneson (1997).

Description of units for map shown on p. 242–243

af ARTIFICIAL FILL—Material used for dams.

Qa ALLUVIUM (QUATERNARY)—Gravel, sand, silt, and clay on flood plains of present-day streams. Thickness: variable, but generally <20 ft where observed.

Qt TERRACE DEPOSITS (QUATERNARY)—Subangular to subrounded cobbles, gravel, sand and silt forming a veneer on the surfaces of terraces that stand about 15–50 ft above the beds of present-day streams. Thickness: variable, but generally <20 ft.

Qg GERTY SAND (QUATERNARY)—Unconsolidated gravel, sand, silt, and clay in abandoned river channel found at elevations well above modern flood plains. Main constituents of the gravel are rounded cobbles and pebbles of quartz, quartzite, chert, flint, jasper, and silicified wood. Thickness: varies from a thin veneer to an estimated maximum of 50 ft.

Psv SAVANNA FORMATION (PENNSYLVANIAN)—Predominantly pale yellowish brown (10YR6/2) to olive gray (5Y3/2) to medium dark gray (N4) shales (Psv) with several mappable moderate brown (5YR4/4) to grayish orange (10YR7/4) to moderate reddish brown (10R4/6), fine- to very fine grained, noncalcareous sandstone units (Psvss). The sandstones are massive to thin-bedded and shaly. They commonly are cross-bedded and ripple marked and in places contain abundant soft-sediment deformation features. Sole marks (trace fossils; brush and prod marks; flute, groove, and load casts) at the base of some sandstone beds are locally common. Most shales in the Savanna include thin, unmappable sandstone units. Coal beds may be present locally, but none were observed in outcrop. In the southwestern part of the map area, where beds dip more steeply, sandstone and shale units are undifferentiated and labeled Psv(un). Thickness: 1,250–1,450 ft.

Pm McALESTER FORMATION (PENNSYLVANIAN)—Consists of six named members, of which three are mappable, including (oldest to youngest): the McCurtain Shale Member (Pmm), the Warner Sandstone Member (Pmw), and the Cameron Sandstone Member (Pmc). A fourth named sandstone member is present (the Keota Sandstone Member), but it is not mappable in the area. Unnamed shale, labeled Pm, separates the named sandstones.

The McCurtain Shale Member (Pmm) predominantly is a poorly exposed, olive gray (5Y3/2 to 5Y4/1), laminated, silty shale that is subject to spheroidal weathering. Ironstone concretions are common; marine fossils and trace fossils are present but uncommon. Carbonized plant material locally occurs on bedding planes. Included are a 10-ft-thick silty sandstone bed near the base, and, near the middle, a 6–12-ft-thick, light brown (5YR6/4; 5YR5/6), very fine grained, parallel, wavy-bedded, unnamed sandstone mapped as Pmmss. Thickness: ~600 ft.

The Warner Sandstone Member (Pmw) predominantly is a relatively well exposed, grayish orange (10YR7/4) to yellowish gray (5Y7/2), fine- to very fine grained, noncalcareous, silty sandstone. Beds typically weather to slabs or flagstones and less commonly to equidimensional blocks. Individual sandstone beds vary from <1 ft to >3 ft in thickness and occur as isolated beds separated from others by covered intervals that probably are shale and siltstone. Ripple marks, cross-stratification, and wavy or

(Description of units continued on p. 244)

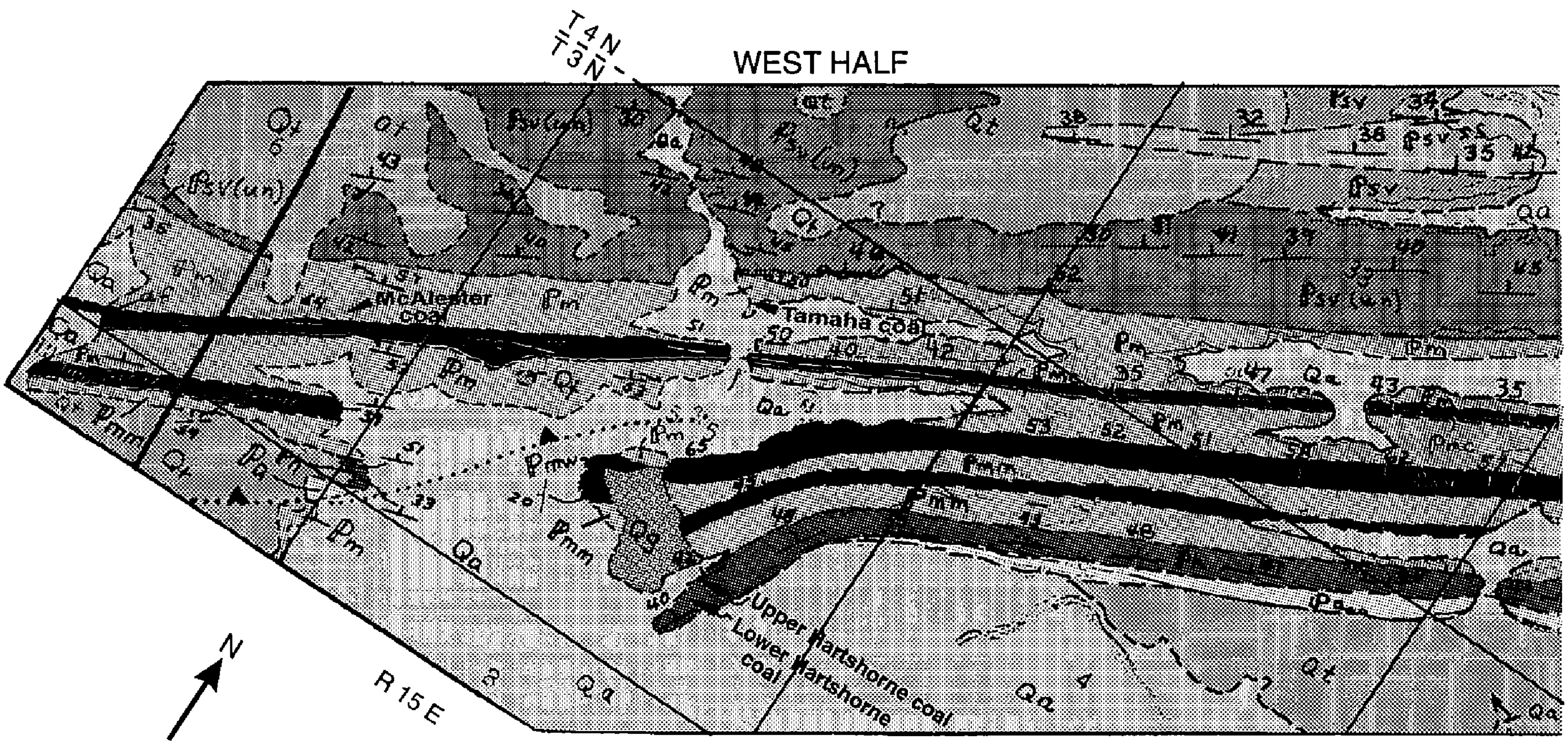
APPENDIX 4. — Geologic map showing outcrop area of the McAlester Formation in the study area, as well as the underlying bedrock units (Atoka and Hartshorne Formations) and the overlying bedrock unit (Savanna Formation)

SYMBOLS

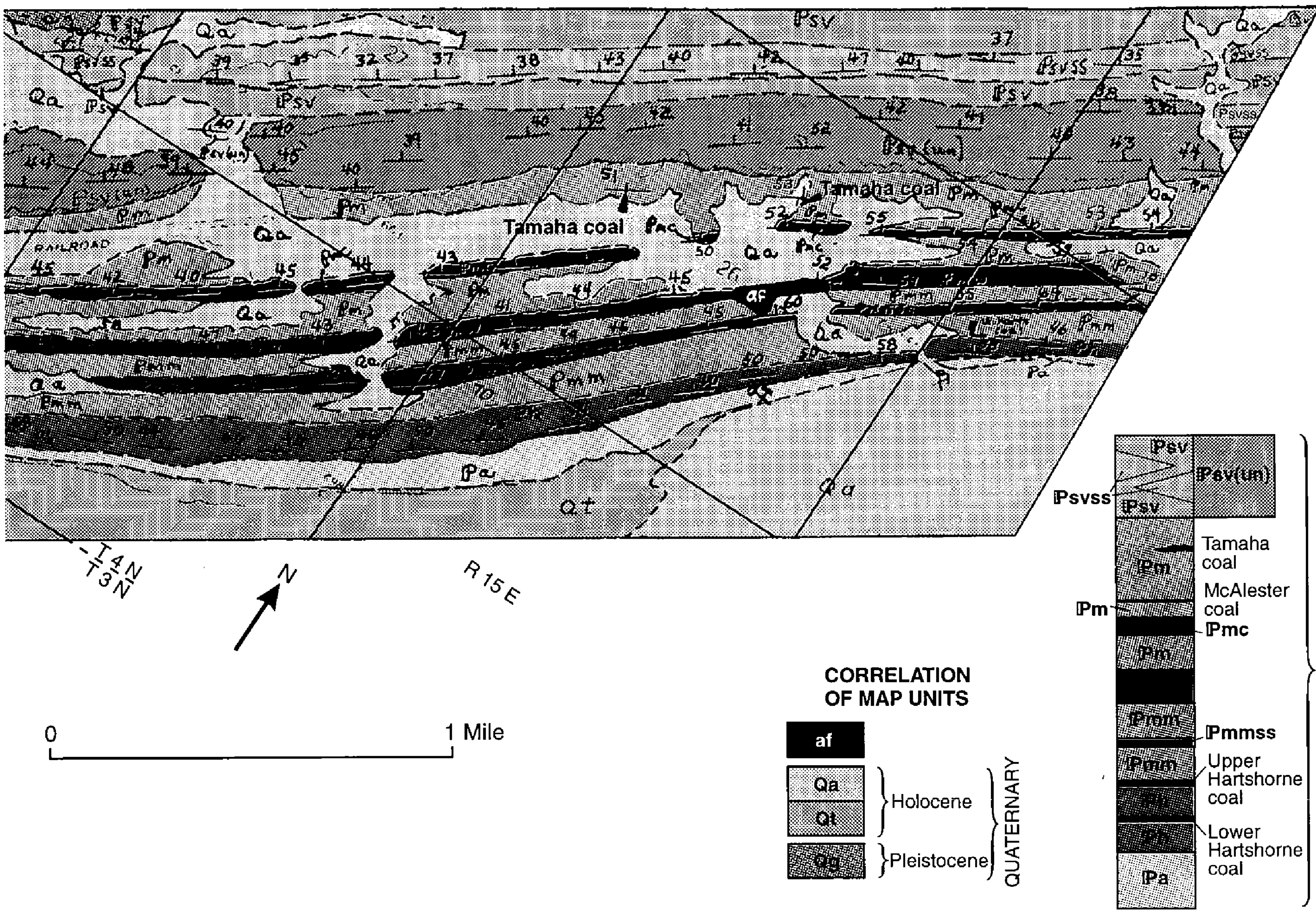
- CONTACT - Dashed where approximately located; queried where uncertain
- THRUST FAULT - Sawteeth on upper plate; dashed where approximately located; dotted where concealed; queried where uncertain
- COAL EXPOSURE
- ABANDONED STONE QUARRY OR OPEN SHALE PIT

STRIKE AND DIP OF BEDS

- Leader to location of measurement
- Strike and dip of beds, upright (50)



EAST HALF


Tamaha coal
Tamaha coal
RAILROAD
T4N
T3N
N
R 15 E
0
1 Mile
CORRELATION
OF MAP UNITS
af
Qa
Qt
Qg
Holocene
Pleistocene
QUATERNARY
Psv
Psv(un)
Psvss
Psv
Pm
Tamaha coal
McAlester coal
Pm
Pmc
Pm
Pmm
Pmmss
Pmm
Upper Hartshorne coal
Lower Hartshorne coal
Pa
PENNSYLVANIAN

Description of units *(continued from p. 241)*

swaly bedding characterize most beds; some beds are unstratified, and some show plane-parallel stratifications and/or soft-sediment-deformation features. Sole marks are rare. Sandstone beds locally appear to grade into flaser-bedded siltstone-sandstone sequences as thick as several tens of feet. As much as 50 ft of sandstone and covered intervals separating sandstone beds is exposed, but the unit is probably thicker and is shown that way on the map. The Warner is fossiliferous in the SW¼ sec. 26, T. 4 N., R. 15 E., and includes marine fauna consisting predominantly of brachiopods. Although it is mapped as a single unit, the Warner Sandstone Member consists of several moderately continuous to discontinuous sandstone beds separated by covered intervals. Thickness: ~300 ft.

The Cameron Sandstone Member (Pmc), is a relatively well exposed, yellowish gray (5Y7/2) to dusky yellow (5Y6/4), very fine grained, noncalcerous, silty sandstone that typically weathers to flagstones that are ripple marked. Individual outcrops vary from isolated sandstone beds 1–2 ft thick to stacked sandstones 85 ft thick. Although mapped as a single unit, the Cameron Sandstone Member includes covered intervals (probably shale and siltstone) that separate sandstone beds. Locally, the Cameron Sandstone Member weathers to blocks or slabs. Common sedimentary structures, in addition to ripple marks, include cross-stratification and wavy beds. Lenticular bedding (pinch and swell) and soft-sediment deformation features are rare. The sandstone locally appears to grade both updip and downdip and along strike into flaser-bedded siltstone-sandstone sequences. Outcrop thickness does not exceed 85 ft.

Shale in the McAlester Formation (Pm) predominantly is olive gray (5Y3/2 to 5Y4/1) to olive black (5Y2/1) to grayish black (N2). It is silty shale that contains rare, thin, siltstone beds. This shale typically weathers to thin flakes or chips and locally contains iron-oxide-stained concretions and carbonized plant debris. The McAlester coal occurs a few feet above the Cameron Sandstone Member in the map area. A thin, impure coal occurs ~260 ft below the top of the formation. Thickness of the McAlester Formation is 1,800–1,850 ft in the composite-stratotype area.

Ph HARTSHORNE FORMATION (PENNSYLVANIAN)—Predominantly grayish orange (10YR7/4) to dark yellowish orange (10YR6/6) to yellowish gray (5Y7/2), fine-grained, silty, ripple-marked, mostly thin-bedded (1–6-in.-thick beds) relatively well exposed, noncalcareous sandstone interbedded with poorly exposed, platy-weathering, flaser- to lenticular-bedded siltstone and shale. Outcrops form 0.5–2-ft-thick tombstone topography, ledges 2–10 ft high, and more rarely cliffs as high as 40 ft. The formation is characterized by sandstone outcrops separated by covered intervals that probably overlie shale and siltstone. Ridges underlain by the Hartshorne Formation typically are littered with slabs and flagstones. Some sandstone beds are continuous for hundreds of feet; others show pronounced lenticularity and thickening and thinning. Channel-form structures are rare. Common sedimentary structures include ripple marks, wavy bedding, trace fossils, and large- (1–4 ft) and small- (inches) scale cross-stratification. Cross-stratification is typically unidirectional and generally east to west; locally, herringbone cross-stratification shows two opposing current directions. The sandstone is quartzose and typically contains rare mica. Iron oxide generally coats individual grains. Carbonized plant debris locally occurs on bedding planes. The Hartshorne Formation contains two named coal beds, the Lower and Upper Hartshorne coals. The base of the Hartshorne Formation appears to be a disconformity. Thickness: individual outcrops rarely more than 50 ft. thick, but maximum thickness of formation is ~300 ft.

Pa ATOKA FORMATION (PENNSYLVANIAN)—Predominantly very poorly exposed, grayish black (N2) to olive gray (5Y3/2), slightly to very silty, fissile to platy, noncalcareous shale. Locally contains sparse concretions and layers and is subject to spheroidal weathering.

Listings of Model Values for the Simulation of Ground-Water Flow in the Cimarron River Alluvium and Terrace Deposits from Freedom to Guthrie, Oklahoma

Prepared by G. P. Adams in cooperation with the Oklahoma Geological Survey, this USGS open-file report includes a 111-page booklet and a 3½-in. DS/HD IBM-compatible computer diskette. The report contains MODFLOW input and output listings for the simulation of ground-water flow in alluvium and terrace deposits associated with the Cimarron River from Freedom to Guthrie, Oklahoma. The values are to be used in conjuction with USGS Water Resources Investigations Report 95-4066, *Geohydrology of Alluvium and Terrace Deposits of the Cimarron River from Freedom to Guthrie, Oklahoma* (for a description, see "Notes on New Publications," ***Oklahoma Geology Notes***, p. 224, October 1996).

The simulation used a digital ground-water flow model and was evaluated by a management and statistical program.

Order OF 95-0735 from: U.S. Geological Survey, Information Services, Box 25286, Denver Federal Center, Denver, CO 80225, telephone (303) 202-4210. Cost is $25.50, plus $3.50 per order for handling. The report is also available for viewing at the Oklahoma Geological Survey main office at 100 E. Boyd, Room N-131, Norman, Oklahoma, telephone (405) 325-3031 or (800) 330-3996; ask for file no. 2061.

Annual Yield and Selected Hydrologic Data for the Arkansas River Basin Compact, Arkansas–Oklahoma, 1995 Water Year

Compiled by J. E. Porter, with cooperation from the Arkansas River Compact Commission, Arkansas–Oklahoma, this report contains 64 pages.

Order OF 96-0441 from: U.S. Geological Survey, Information Services, Box 25286, Denver Federal Center, Denver, CO 80225, telephone (303) 202-4210. Cost is $10.25 for a paper copy or $4 for microfiche, plus $3.50 per order for handling.

Schlumberger Soundings at the Norman Landfill, Norman, Oklahoma

In 1995 the U.S. Geological Survey made 17 dc electrical soundings at the Norman, Oklahoma, landfill using the Schlumberger array. An additional 23 Schlumberger soundings were made in 1996. The soundings were made to determine the extent of the subsurface spread of the conductive leachate, and to assist in determining the alluvial aquifer geometry. This 44-page report, by R. J. Bisdorf, presents the new data and its automatic interpretation, as well as the original 17 soundings.

Order OF 96-0668 from: U.S. Geological Survey, Information Services, Box 25286, Denver Federal Center, Denver, CO 80225, telephone (303) 202-4210. Cost is $6.75 for a paper copy or $4 for microfiche, plus $3.50 per order for handling.

INDEX[1]

Volume 57, 1997

[1]Reference is to first page of article containing indexed item.

E–F

I–K

N–O

T–U

W