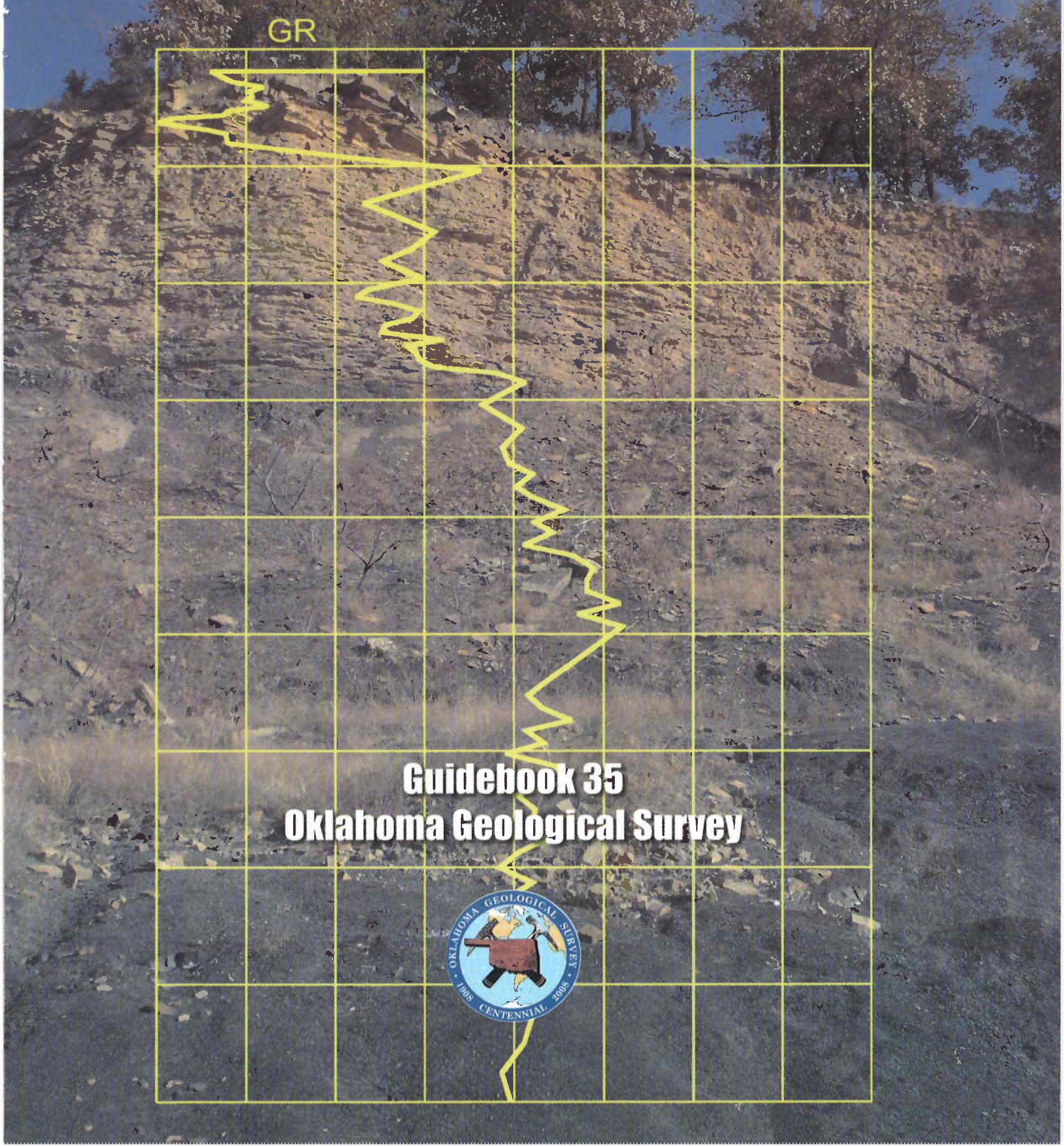
Guidebook to the Booch Sandstones: Surface to Subsurface Correlations

by
Neil H. Suneson and Dan T. Boyd



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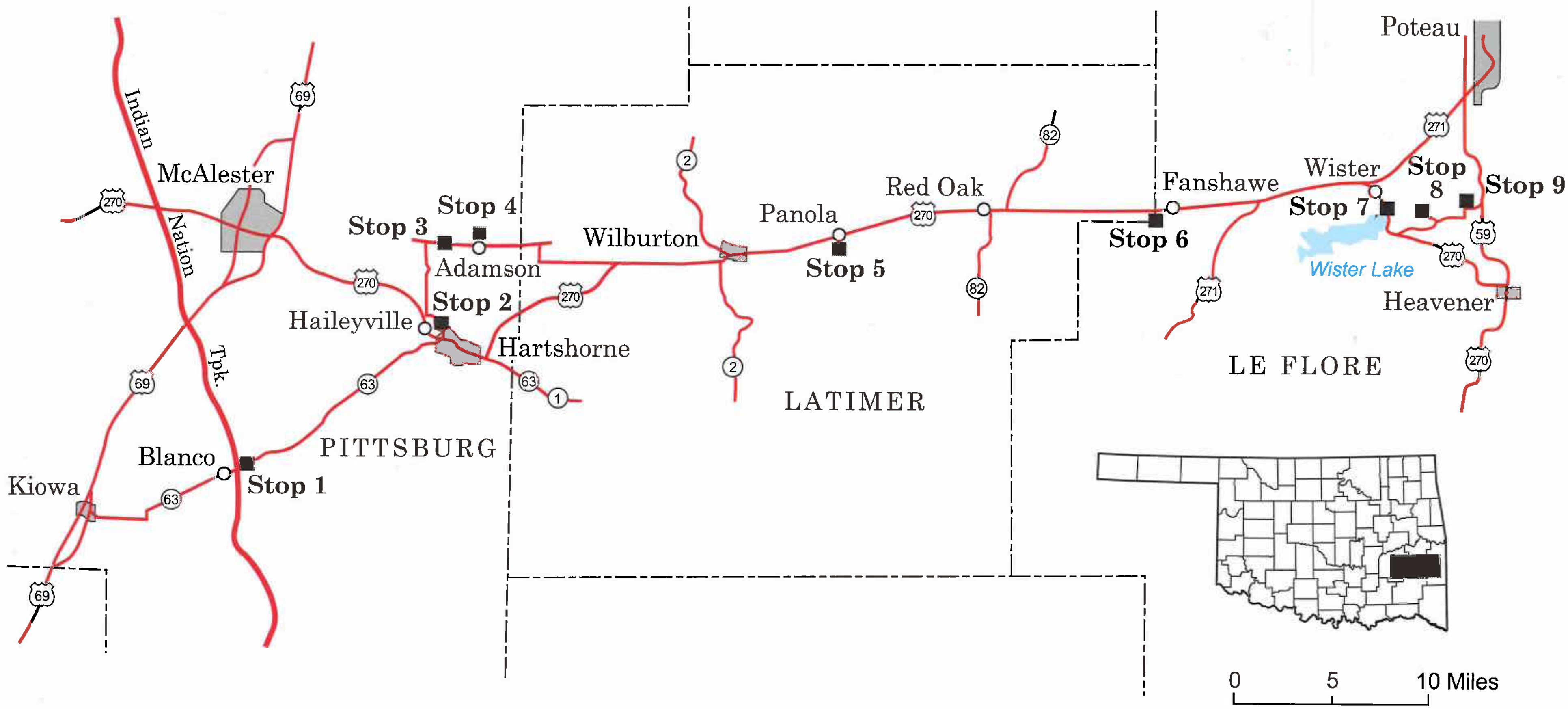
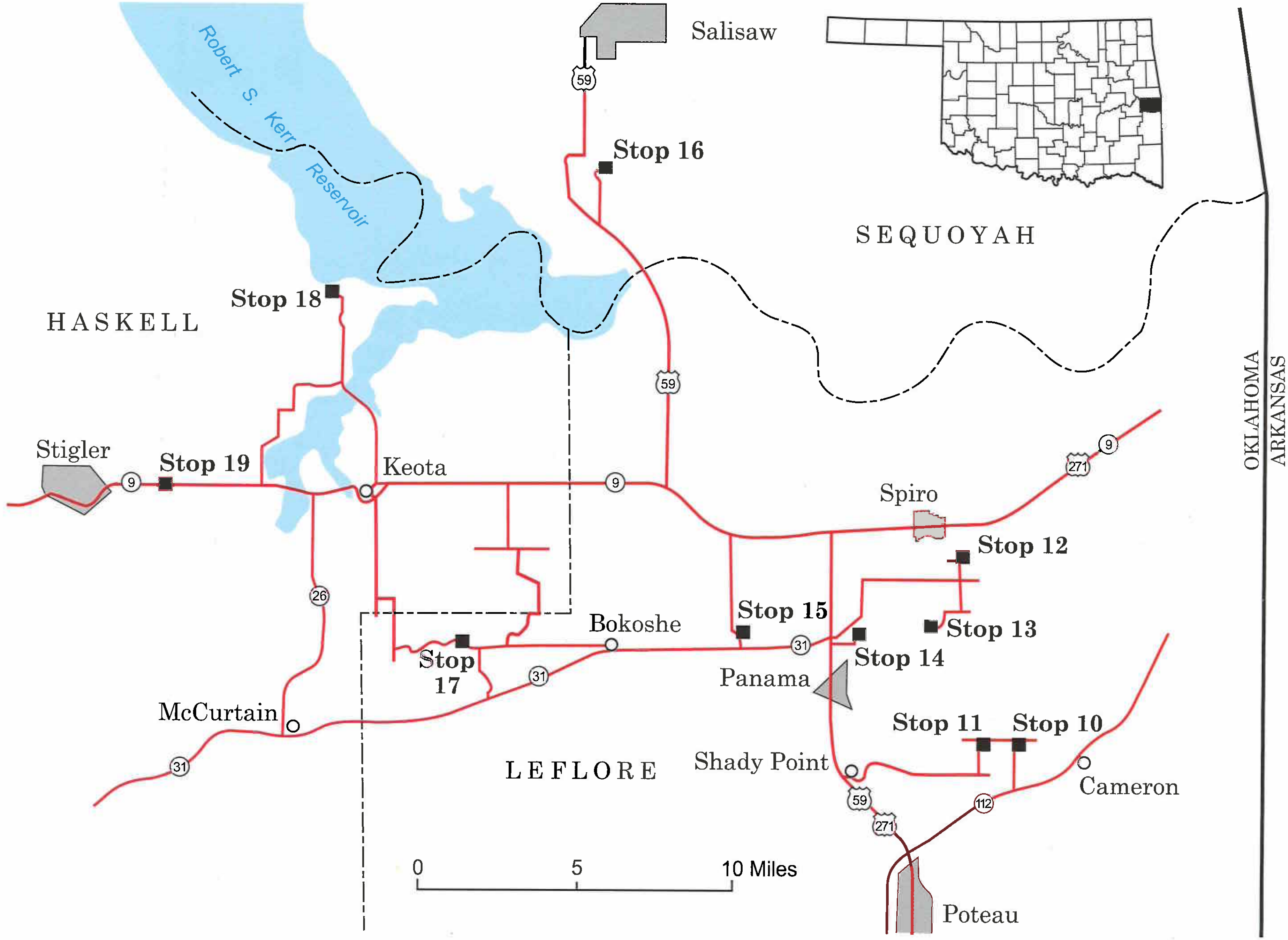

Poteau
Stop 9
Stop 8
Wister
Stop 7
Wister Lake
Heavener
Fanshawe
Stop 6
LE FLORE
Red Oak
Panola
Stop 5
LATIMER
Wilburton
Stop 4
Stop 3
Adamson
Stop 2
Haileyville
Hartshorne
PITTSBURG
McAlester
Indian
Nation
Tpk.
Blanco
Stop 1
Kiowa
0
5
10 Miles

Day 1


Salisaw
Robert S. Kerr Reservoir
Stop 16
SEQUOYAH
HASKELL
Stop 18
59
OKLAHOMA
ARKANSAS
Stigler
Stop 19
9
Keota
Spiro
271
Stop 12
26
Stop 15
Stop 13
Bokoshe
31
Stop 14
Stop 17
Panama
McCurtain
Stop 11
Stop 10
LEFLORE
Shady Point
Cameron
112
0
5
10 Miles
Poteau

Day 2

Oklahoma Geological Survey
G. Randy Keller, *Interim Director*

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GUIDEBOOK TO THE BOOCH SANDSTONES: SURFACE TO SUBSURFACE CORRELATIONS

Neil H. Suneson and Dan T. Boyd

Oklahoma Geological Survey
Norman, Oklahoma

Prepared for a two-day field trip (October 2-3, 2008) to the Arkoma Basin of southeastern Oklahoma. Held as part of the Oklahoma Geological Survey Centennial celebration (2008) and in conjunction with the annual meeting of the Geological Society of America in Houston, Texas, on October 5–9, 2008.

Mewbourne College of Earth and Energy
The University of Oklahoma
2008

Front Cover

Carter Lake measured section (Stop 15), Le Flore County, Oklahoma. The Warner Sandstone (Booch Sandstone, parasequence 3/3A) is exposed at the top of a borrow pit along a county road. The base of the outcrop consists of dark marine shale which grades upward into interbedded shale, siltstone, and thin sandstone. Nested trough-crossbeds and rip-up clasts in the sandstone at the top of the outcrop are evidence that the sandstone is a channel deposit, possibly a tidal or distributary channel. The sequence represents progradation of a delta complex over marine mud.

Photograph by Dan Boyd, Gamma-Ray overprint by Jim Anderson

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Guidebook to the Booch Sandstones: Surface to Subsurface Correlations

Neil H. Suneson and Dan T. Boyd
Oklahoma Geological Survey

Introduction

This guidebook is a companion to Oklahoma Geological Survey (OGS) Special Publication 2005-1: The Booch Gas Play in Southeastern Oklahoma: Regional and Field-Specific Petroleum-Geological Analysis (Boyd, 2005). The Booch gas study is the latest in the series of play-based workshops jointly sponsored by the OGS and the Petroleum Technology Transfer Council that are designed to aid State oil and gas operators.

The Booch (pronounced Boke, the same as "coke") stratigraphic interval is the informal subsurface term used by the oil and gas industry to identify certain sandstones contained in the Desmoinesian (Middle Pennsylvanian) McAlester Formation. The term "Booch sand" was first used in 1906 to describe the producing reservoir in two wells drilled in Okmulgee County (sec. 20, T. 13 N., R. 14 E.) on the Booch farm in the Morris Oil Field (Clark, 1930; Jordan, 1957). Jordan (1957) correlated the productive sandstone on the Booch farm with the Warner Sandstone, a formally named member of the McAlester Formation. In sequence stratigraphic terms, the Warner Sandstone typically correlates with middle Booch PS-3/3A (Boyd, 2005). (The correlation of surface-named sandstones with subsurface-identified sequences is one of the themes addressed in this guidebook). In the broader sequence-stratigraphic framework, the Lower and Middle Pennsylvanian sediments, of which the Booch is a part, were deposited in an overall transgressive regime during which smaller magnitude regressions occurred (see Boyd, 2005, fig. 11, after Ross and Ross, 1988).

The purpose of this guidebook is multifold. It locates, identifies, and describes the best Booch sandstone outcrops in the Oklahoma part of the Arkoma Basin. It interprets the depositional environments of the strata in those outcrops based on lithologies, sedimentary structures, stratal disconformities, and textural changes. It presents gamma-ray profiles of the outcrops that approximate wireline gamma-ray logs in the subsurface. Parts of wireline logs from nearby wells are presented to show that, in some cases, the logs closely match the outcrop profiles; in other cases, the logs may differ greatly from the outcrop. Finally, the logs and outcrops are placed in the sequence-stratigraphic framework established for the entire Booch interval.

This guidebook is based on regional and detailed subsurface and surface studies. Figure 1 shows the location of the 19 outcrops described in this guidebook and the area in which the Booch is recognized in the subsurface. Figure 1 also shows the locations of the wells in which logs, cores, and/or core analyses were utilized in Boyd's (2005) study of the Booch and the surface geologic maps that show the distribution of the Booch sandstones.

McAlester Formation field mapping (which includes all of the Booch stratigraphic interval) is difficult, especially in structurally complex areas, because outcrops usually are widely spaced, poorly exposed, and restricted to relatively thin intervals within and immediately below erosionally resistant sandstones and siltstones. This limits the interpretation of a stratigraphic interval that is composed mostly of easily eroded shale. However, this limitation can be overcome by utilizing the subsurface data provided by thousands of closely spaced wells. Measured sections, surface gamma-ray profiles, and analysis of subsurface data makes it possible to place Booch outcrops into a regional depositional framework. This not only helps explain anomalies that are difficult to address on the surface, such as variations in thickness and the stratigraphic placement of unnamed (or misnamed) sandstones, but also puts a "face" on wireline-log signatures recorded in the subsurface.

Nomenclature

Surface (McAlester Formation)

The McAlester Formation, named by Taff (1899) who called it the McAlester shale, is the second oldest of the four formations that make up the Desmoinesian Krebs Group in the Arkoma Basin of Oklahoma and Arkansas. For the most part, it conformably overlies the Hartshorne Formation and conformably underlies the Savanna Formation (Fig. 2). The base of the McAlester generally is recognized as the top of the highest Hartshorne coal. The top of the McAlester Formation

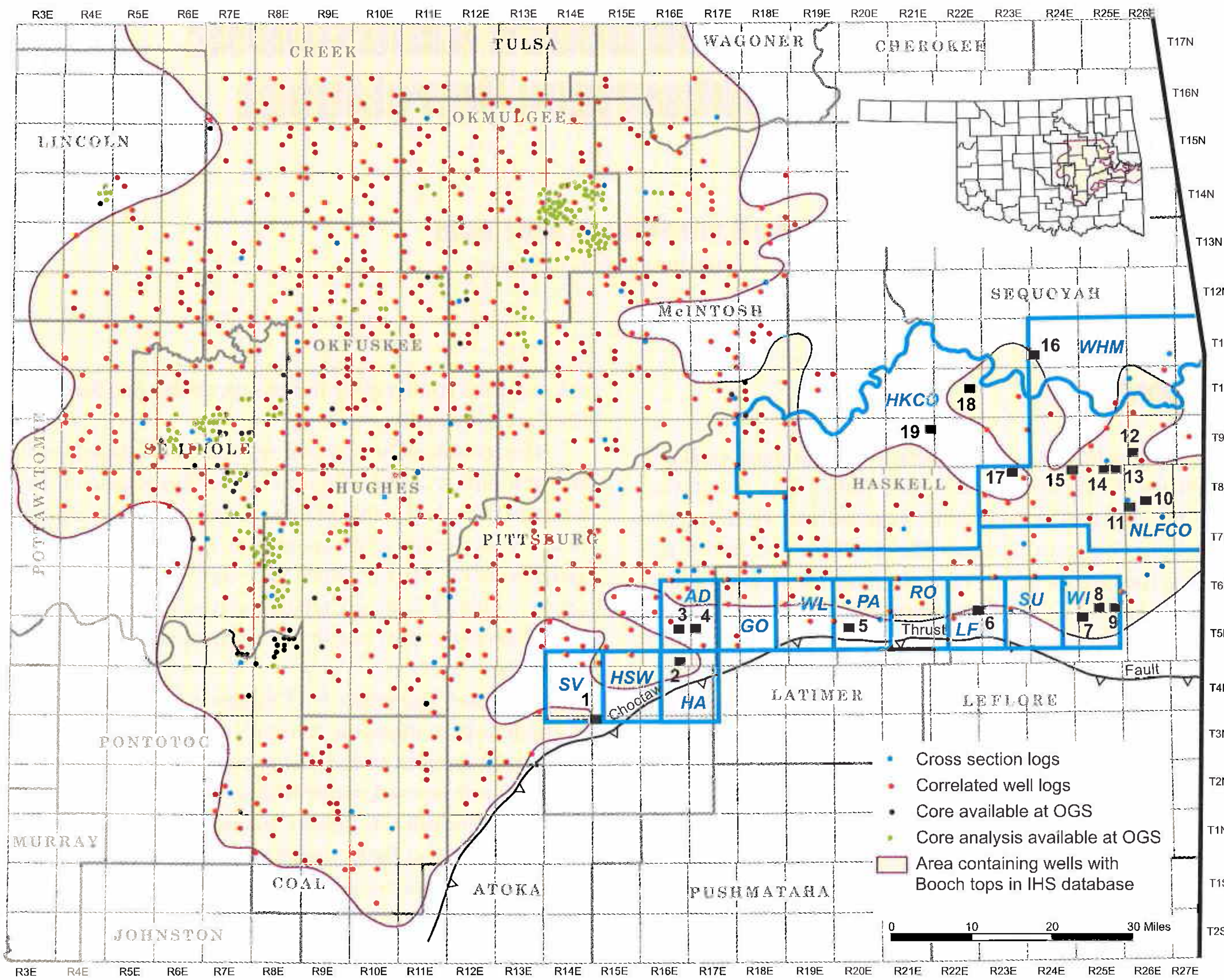

Figure 1. Map showing location of field-trip stops (numbers 1 through 19) and data used in Boyd's (2005) regional subsurface study of the Booch interval, including wells, cores, and core analyses. Geologic maps used in field studies of the Booch are outlined and labeled as follows: SV - Savanna 7.5' quadrangle (Suneson, 1997); HSW - Hartshorne SW 7.5' quadrangle (Suneson and Hemish, 1996); HA - Hartshorne 7.5' quadrangle (Suneson, 1996); AD - Adamson 7.5' quadrangle (Hemish, 1995); GO - Gowen 7.5' quadrangle (Hemish, 1992); WL - Wilburton 7.5' quadangle (Hemish and others, 1990a); PA - Panola 7.5' quadrangle (Hemish and others, 1990b); RO - Red Oak 7.5' quadrangle (Hemish and others, 1990c); LF - LeFlore 7.5' quadrangle (Hemish, 1991); SU - Summerfield 7.5' quadrangle (Hemish and Mazengarb, 1992); WS - Wister 7.5' quadrangle (Hemish and Suneson, 1993); NLFCO (northern Le Flore County) – Knechtel (1949); WHM (area near Wildhorse Mountain) – Crumpley (1949); HKCO (Haskell County) – Oakes and Knechtel (1948).

is placed at the base of the lowest massive sandstone of the Savanna Formation. In most places the contact with the Savanna is gradational and conformable; locally, however, the basal sandstone unit of the Savanna Formation is deposited in channels eroded into the McAlester. Where this occurs, the contact is a paraconformity.

Most of the McAlester Formation consists of poorly exposed shale that typically forms valleys between ridges underlain by the sandstone-rich Hartshorne and Savanna Formations. The formation includes several moderately to poorly exposed sandstone beds of varying thickness and continuity which form low ridges or hills in otherwise relatively flat valley floors. In the extreme southern part of the Arkoma Basin, chert conglomerate beds are present. Several coal beds are also present and, like the sandstones, vary greatly in character. The McAlester coal (and locally, Upper McAlester coal) has been extensively strip-mined. Other named (e.g., Keefton) and unnamed (e.g., Mile 0.0, Day Two) coals have been mined locally.

The McAlester Formation is divided into six named members (from bottom to top): the McCurtain Shale, the Warner Sandstone, the Lequire Sandstone, the Cameron Sandstone, the Tamaha Sandstone, and the Keota Sandstone (Fig. 2). These were first "named and assigned member status in 1927 by Thom (1935)" (in Russell, 1960, p. 14), but this work evidently was unpublished. Wilson (1935) and Wilson and Newell (1937), acknowledging Thom's work, recognized the same sandstone members and also named the Stigler coal. These authors, however, included the Tamaha and Keota in the overlying Savanna sandstone and the Upper Hartshorne coal in the McAlester shale. Oakes and Knechtel (1948) and Knechtel (1949) formally raised the rank of the McAlester shale to McAlester Formation. They also included the Tamaha and Keota Sandstone Members, as well as the unnamed shale immediately overlying the Keota, in the McAlester Formation. The McAlester Formation in the Arkoma Basin also contains five named coal beds; from bottom to top, these are the Keefton coal (within the Warner Sandstone Member), the McAlester (Stigler) coal, the Upper McAlester (Stigler Rider) coal, the Tamaha coal, and the Keota coal. Recent OGS mapping in the southern part of the Arkoma Basin shows the Warner Sandstone as locally subdivided into lower and upper parts; the names lower Warner sandstone and upper Warner sandstone, however, are informal.

Subsurface (Booch sandstones)

Formal stratigraphic nomenclature is based on strata that can be described and mapped in outcrop. Industry terminology, however, is keyed to productive reservoirs and typically is not related to formal surface terminology. A local name may be given to a productive reservoir that, over time, is extended to include a much thicker stratigraphic interval. Eventually a consensus is reached in which certain stratigraphic markers on well logs are understood to define the limits of a given productive interval. The industry-defined Booch is not the subsurface equivalent of the McAlester Formation but represents the lower three quarters of this formation between the tops of the McAlester and Hartshorne coals. Fortunately, Hartshorne and McAlester coals are among the most widespread coals in the Arkoma Basin and both have been extensively mapped and mined; therefore, they provide excellent markers in both the surface and subsurface. Within the Booch, the Warner Sandstone (PS-3/3A) is the most widespread, allowing it to form a relatively continuous ridge throughout the mapped extent of the McAlester Formation. In terms of oil and gas production the upper part of the McAlester Formation, between the Brown Limestone (equivalent to the surface Spaniard Limestone) and the McAlester coal, is relatively unimportant. Thus, the Keota and Tamaha Sandstones are not included in what the petroleum industry considers to be the Booch stratigraphic interval (Fig. 2).

Wireline logs from throughout the Arkoma Basin (Fig. 1) show the Booch stratigraphic interval to be composed of eight, generally coarsening-upward depositional cycles (Fig. 3). These cycles, or parasequences, represent a relatively conformable succession of genetically related beds that are bounded by marine flooding surfaces or their correlative surfaces (Jackson, 1997). In the Booch interval each parasequence represents a shallowing-upward sedimentary cycle that is interpreted as a progradation of Booch deltas into the marine Arkoma Basin. Each parasequence begins with a flooding surface that marks the deposition

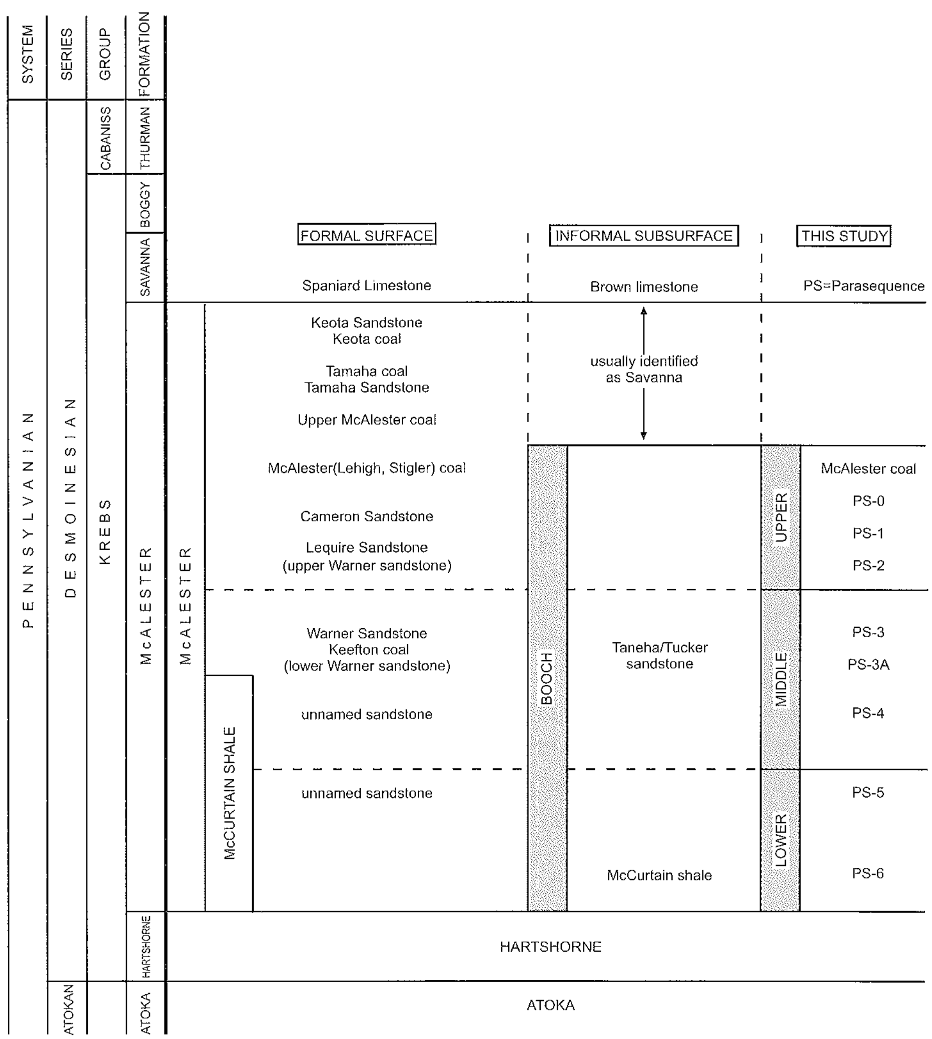

Figure 2. Booch stratigraphic-nomenclature chart (modified from Boyd, 2005, fig. 1). The chart compares formal surface and informal subsurface (industry) names with parasequence designations from Boyd (2005). Locally, the Warner Sandstone has been subdivided on some surface geologic maps into upper and lower (informal) sandstones.

of distal marine muds. These are overlain by progressively more nearshore marine muds, silts and sands that can include fluvial-deltaic sands and muds that may be interbedded with peat. The tops of each parasequence typically are sharp and represent marine transgression, with distal marine shale of the next flooding surface deposited on relatively shallow-marine, deltaic, or non-marine strata.

The eight Booch parasequences are based on regional subsurface stratigraphic markers. They are combined into three intervals termed the lower, middle and upper Booch. These three subdivisions were defined using the period of maximum progradation and sand deposition, here called the middle Booch, to separate the shale-dominated upper and lower Booch intervals. Boyd (2005) describes the individual Booch parasequences in detail.

Surface – Subsurface Correlation (Fig. 2)

In outcrop the base of the McAlester Formation is the top of the highest Hartshorne coal. On wireline logs, the base of the McAlester Formation (and Booch interval) occurs where relatively high-resistivity siltstones and shales above the coal are overlain by low-resistivity, high-gamma ray shales. In outcrop (e.g., Stop 5), this contact occurs where light brown, fossiliferous (plants), interdistributary-bay shale in the Hartshorne is overlain by distal marine shale at the base of the McAlester. The subsurface contact between the Hartshorne and McAlester Formations can be several tens of feet above the coal. Thus, the surface-defined contact can be much lower than the subsurface-defined contact.

On the surface the McCurtain Shale Member of the McAlester Formation extends from the top of the (Upper) Hartshorne coal to the base of the Warner Sandstone, which is the most extensive and best-exposed sandstone in the McAlester. In the subsurface, the McCurtain shale is the lowest parasequence in the McAlester Formation (PS-6) (Boyd, 2005). Thus, the subsurface-defined McCurtain shale is always thinner than that defined at the surface.

In general, parasequences PS-6, PS-5, and PS-4 contain little or no sandstone (Boyd, 2005). This contrasts with parasequences PS-3 and PS-3A which contain abundant sandstone. Based on surface-to-subsurface correlations throughout the Booch outcrop area, subsurface parasequences PS-3 and 3A contain what is mapped on the surface as the Warner Sandstone or, in places, the lower Warner Sandstone. This relation is supported by the sandstone-dominated character of PS-3 and 3A in the subsurface and the widespread occurrence of the Warner on the surface. Locally, various workers have mapped discontinous sandstones below the Warner; these are mapped either as "sandstone lenses within the McCurtain Shale" (e.g., Oakes and Knechtel, 1948) (see Stop 17, this guidebook) or as unnamed sandstones within the McCurtain Shale (e.g., Hem-

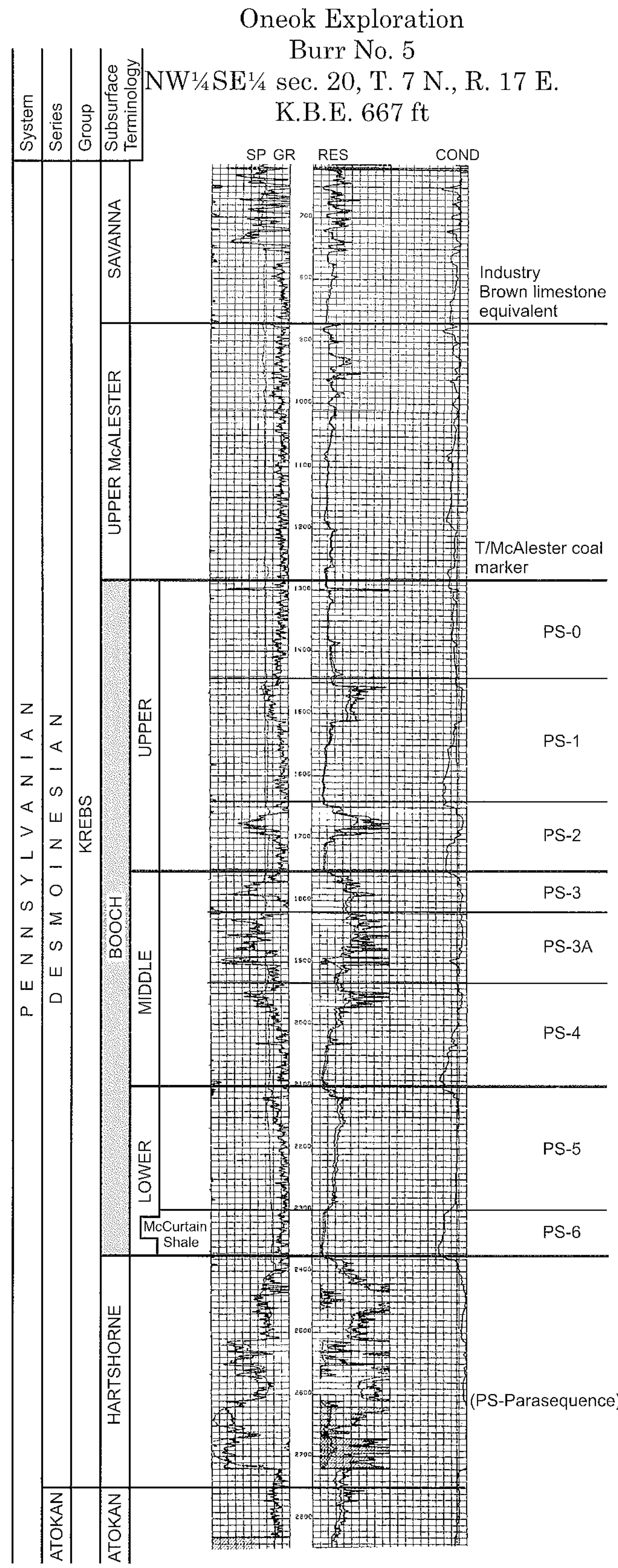

Figure 3. Regional Booch type log (Oneok Exploration No. 5 Burr, Pittsburg County, Oklahoma) showing eight, generally coarsening-upward parasequences (from Boyd, 2005, fig. 9). The parasequences are numbered (from oldest to youngest) 6, 5, 4, 3A, 3, 2, 1, and 0.

ish and Suneson, 1993) (see Mile 83.1, Day One, this guidebook). The parasequence (PS-4, PS-5) to which these unnamed sandstones are assigned varies.

Several relatively widespread and well-developed sandstones have been mapped in the McAlester Formation above the Warner Sandstone (PS-3/3A). From oldest to youngest, these include the upper Warner sandstone, Lequire Sandstone, and Cameron Sandstone. Based on correlation of the sandstones mapped on the surface with nearby down-dip wireline logs, PS-2 includes either the upper Warner or Lequire Sandstones, PS-1 either the Lequire or Cameron Sandstones, and PS-0 the Cameron Sandstone. The McAlester coal occurs near the top of PS-0. Some of the names applied to the McAlester sandstones cropping out in the Arkoma Basin may be incorrect, but renaming them based on sequence stratigraphy is beyond the scope of this study.

Depositional Environments

Hemish and Suneson (1997) reviewed the history of McAlester (Booch) sandstone interpretations. Most modern studies of the Booch begin with the classic studies by Busch (1953, 1959, 1971, 1974). Based on isopach maps of the middle Booch sandstone (Warner Sandstone), Busch showed that the unit has the form and character of a series of anastomosing distributary channels (Fig. 4). (It is important to note that Busch's studies focused on the Cherokee Platform area of eastern Oklahoma and extended only into the northwestern-most part of the Arkoma Basin.) He observed that where the channel sandstones are thickest, the underlying beds had been eroded. He interpreted some of the smaller distributary sandstones as deposited in a crevasse-splay environment. Busch also recognized that the upper Booch sandstone locally was deposited in a deltaic environment, but he did not address the

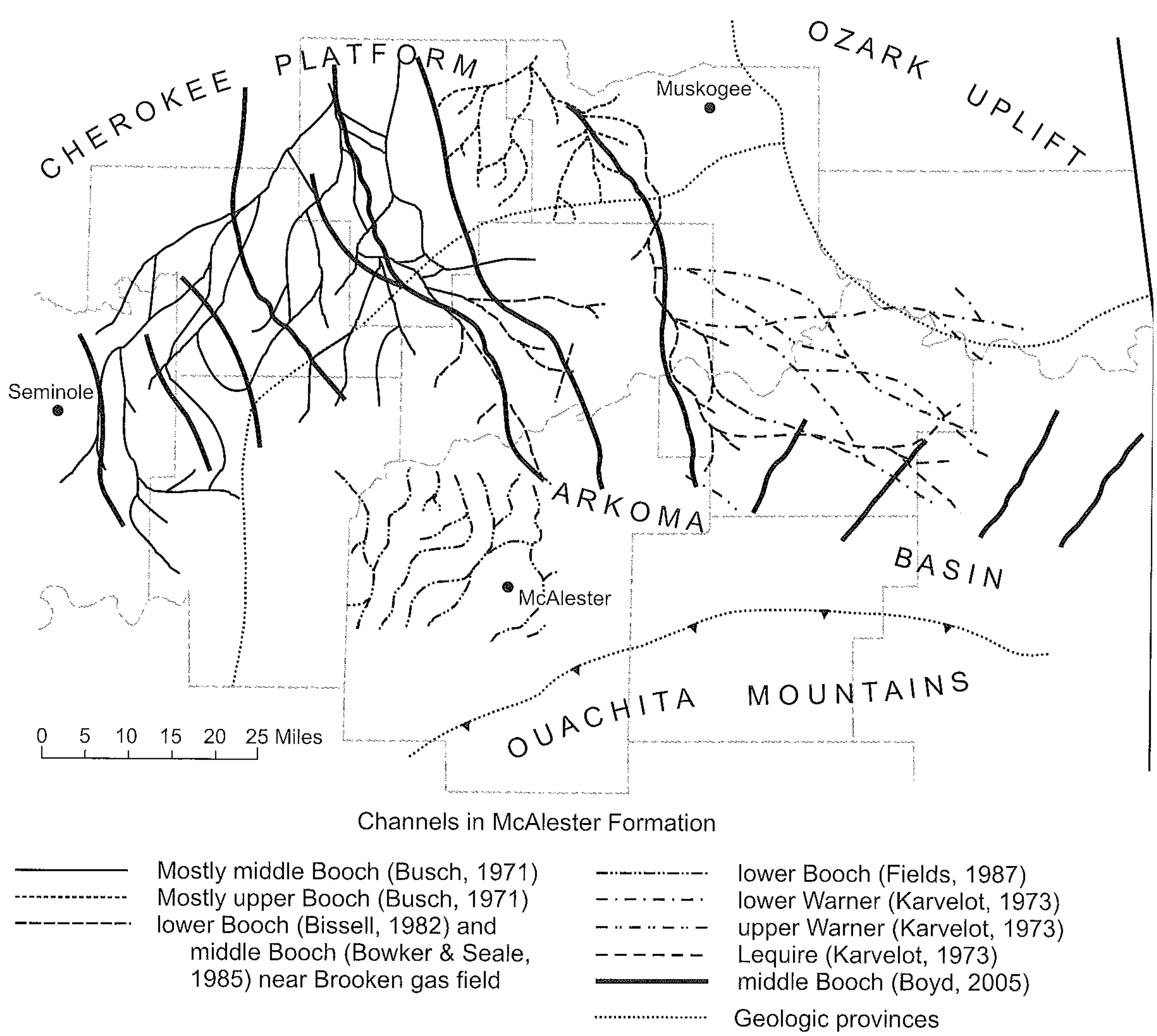

Figure 4. Map showing distribution of Booch channels in the Arkoma Basin and on the southern part of the Cherokee Platform (modified from Hemish and Suneson, 1997, fig. 12). Channel locations are based on Busch (1971), Bissell (1982), Bowker and Seale (1985), Fields (1987), Karvelot (1973), and Boyd (2005).

Figure 5. Paleogeographic reconstruction of part of Middle Pennsylvanian southern mid-continent (modified from image by R.C. Blakey, http://jan.ucc.nau.edu/~rcb7/namPP315.jpg, retrieved July 5, 2006). The reconstruction shown here differs from Blakey's reconstruction of the Early Pennsylvanian in the following ways: the Nemaha Uplift extends south through most of Oklahoma, the large "bay" in southeastern Kansas is filled, and the Ouachita Mountains are considerably lower.

origin of the lower or lower middle Booch sandstones. Bissell (1982) recognized prodelta, delta-front, and shoreline sandstones in parts of the Booch interval. Regardless of the details of nomenclature, a deltaic origin for the Booch sandstones is firmly established.

More recently, Northcutt (1995, p. 14) identified what he considered to be "Booch sediments" which include shales "deposited in marine, delta-front, lagoonal, and coastal-plain environments," as well as sandstone, the greatest thicknesses of which "were deposited in distributary channels on the delta plain." The Booch also includes coal deposited in lagoons on the delta plain. Northcutt (1995) combined all published maps of the Booch on the Cherokee Platform into a single map showing the Booch delta and interpreted areas of fluvial, upper delta-plain, and lower delta-plain deposition. But, as in most studies of the Booch, Northcutt's (1995) map covered only the extreme northern part of the Arkoma Basin.

Boyd (2005) studied the subsurface character of the Booch interval in the Arkoma Basin and put it into a sequence-stratigraphic framework based partly on modern paleogeographic reconstructions of North America (Fig. 5). He concluded that Booch strata could be divided into three basic types: (1) distal marine and prodelta shales, (2) various types of deltaic sediments and coals (including delta-front and delta-plain strata), and (3) fluvial sediments related to incised valleys (Fig. 6). For each cycle of Booch progradation, marine shales are deposited first. They are deposited in a low-energy environment over a large area. Although deposited in a distal marine environment, this does not imply deep water; rather, they are deposited beyond the reach of shoreline processes. Thickness variations in these units occur gradually, and minor variations in the composition of marine shales (discernible on wireline logs) can be correlated over tens of miles. Thus, they are reliable subsurface stratigraphic markers.

The economically important Booch sandstones overlie marine shales and are typically near the top of parasequence depositional cycles. Evidence observable in outcrops and in cores for a prograding delta includes thin siltstone laminations within the marine shale; the frequency, grain size, and thickness of these laminations gradually increase upsection as the delta progrades over the marine shale. With continued progradation tidal winnowing progressively removes the clay-sized fraction until only silt and fine-grained sand remain. The upper part of the coarsening-upward parasequence typically is a fine-grained sandstone deposited in a tidally winnowed distributary-mouth bar environment. The coarsening-upward pattern that characterizes the Booch parasequences marks the transition from distal marine shale, to prodelta siltstone and shale, to delta-front distributary-mouth bar, although not all environments are preserved everywhere.

Locally, distributary-channel-fill sandstones occur on top of and incise into the mouth bars that they sourced (Fig. 6). Distributary-channel sandstones are usually single-story channel-fills, are never more than 30 ft thick, and typically less than 20 ft. Because these are narrower than the mouth bars that they feed, feeder channels are not always observed on wireline logs or in outcrop. Where channel-fill deposits are not present, the distributary-mouth bar deposits may be overlain by interdistributary sediments of the delta plain, including fossiliferous (plants) bay-fill shales, crevasse-splay sandstones, tidal-channel sandstones, and/or coal.

In places a much thicker sandstone may be present that can be more than two hundred feet thick. These are interpreted as stacked channel-fill sandstones filling valleys that were incised when the paleoshoreline was located far to the south. In places, these valleys are eroded deep into the underlying marine shales or completely through them and into the underlying parasequence. These sandstones, which represent the main feeder system bringing sediment to the delta during a period of maximum progradation, become thicker in the updip direction. Although incised-valley sandstones are the highest quality reservoirs in the Booch, the individual channel-fill components vary in their log response. This probably reflects variations in grain size, the amount of disseminated plant material, and/or the presence of shale rip-up clasts that are frequently present in these sandstones.

Guidebook Format

This guidebook is divided into two parts. Day One is a road log starting in Blanco and ending in Poteau, Oklahoma (Fig. 7). The road log goes through the towns of Haileyville, Adamson, Wilburton, Panola, Red Oak, Wister, and Howe. Eight Booch sandstone stops and one (Stop 5) showing the Hartshorne Formation – McAlester Formation contact comprise the first day. Day Two starts in Poteau, ends in Stigler, Oklahoma, and goes through the towns of Shady Point, Panama, Cartersville, and Keota (Fig. 8). Nine of the stops on Day Two are at Booch sandstones and one (Stop 18) is a McAlester sandstone above the Booch.

The guidebook is based, in part, on several guidebooks previously published by the Oklahoma Geological Survey. The road log from Blanco (Day One, Mile 0.0) to Bond (Day One, Mile 8.7) is modified from Suneson and Andrews (2005). Stop 2 (AOK Railroad, Haileyville measured section) was described by Hemish and Suneson (1997, p. 56-59). The road log from the small village of Bowers (Day One, Mile 31.3) to State Highway 82 on the east side of Red Oak (Day One, Mile 55.4) is modified from Suneson and others (2005). Stop 5 (Panola measured section) was visited as part of a field trip on the Hartshorne Formation (Suneson, 1998). The road log from State Highway 82 (Day One, Mile 55.4) to the Wister Lake spillway (Day One, Mile 80.1) and the description of the Cameron Sandstone at Stop 6 is modified from Suneson and Hemish (1994). All the guidebooks are based on 1:24,000 geologic maps of the southern part of the Arkoma Basin published by the

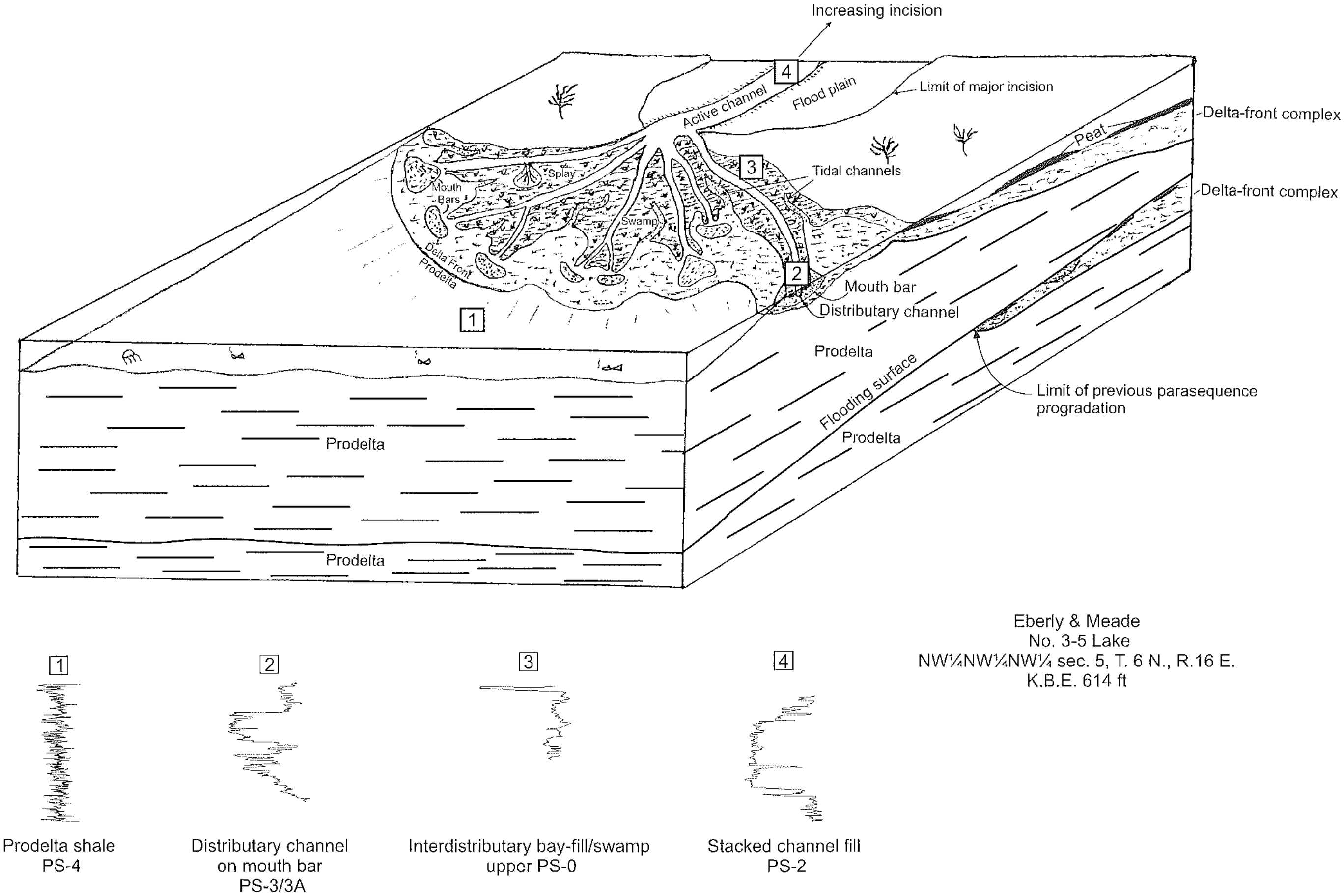

Figure 6. Schematic Booch tidally-influenced delta. This diagram shows the major depositional environments encountered in the Booch and their appearance on wireline logs (from Boyd, 2005, fig. 16).

Oklahoma Geological Survey as part of the U.S. Geological Survey-supported COGEOMAP and STATEMAP programs (Fig. 1).

Most of the road log for Day Two is new. The only part that was previously described is the first 3.7 miles from Poteau (Day Two, Mile 0.0) to the east along State Highway 112. The most recent geologic maps of this part of the Arkoma Basin are those of Knechtel (1949) and Oakes and Knechtel (1948).

Throughout this guidebook sites of historical interest are noted. These sites are included because most geologists are interested "in anything and everything they see in the field." Furthermore, geologists are also historians; we simply tend to be more interested in what others call "really old things."

In the interest of simplicity, but in keeping with some degree of nomenclatural correctness, the names of formal stratigraphic units are capitalized; however, "Warner Sandstone Member of the McAlester Formation" is typically simplified to "Warner Sandstone." Informal stratigraphic units (e.g., upper Warner sandstone, Booch sandstones) are shown in lower case. Coal beds, although formal stratigraphic units, are shown in lower case (e.g., Lower Hartshorne coal). All subsurface units are also shown in lower case. Throughout the guidebook the names sandstones that are exposed on the surface are named as shown on the geologic maps. Where we have determined that a sandstone has been misnamed on a map (e.g., Day One, Stop 3 – Lequire Sandstone) we use the correct name and document our reasons for the change.

Thickness calculations between sandstone beds or from a sandstone to an underlying or overlying coal bed are based on dip measurements shown on geologic maps. Where numerous dip values were recorded an average dip value was used. In some cases very few dip values were recorded and single, possibly distant values had to be used. Thickness calculations from wireline logs are not corrected for possible dip. In most cases the strata dip gently and the wells are close enough to vertical that dip corrections would be small.

Acknowledgments

We would like to thank a number of individuals who have made this guidebook possible. First and foremost, we thank the various landowners who have allowed us access to key outcrops. Their names are given at the appropriate stops in the guidebook. Rick Andrews, wireline-log guru at the OGS, kept our interpretations of the well logs honest. Rod Tillman reviewed an early version of the manuscript and made many helpful suggestions, nearly all of which significantly improved the final version. Jim Anderson, head of cartography at the OGS, drafted many of the figures. Susan Cogan, University Printing Services, kept our grammar and syntax within reason and is responsible for the graphic design. We also appreciate Interim Director Randy Keller's interest in publishing this guidebook as an Oklahoma Geological Survey Centennial contribution. It truly has been a pleasure working with these individuals to complete this publication on the Booch sandstones in the Arkoma Basin.

ROAD LOG

DAY ONE

Start field trip in small town of Blanco, Oklahoma, along Oklahoma State Highway (S.H.) 63. The road log for the first 8.7 miles is modified extensively from Suneson and Andrews (2005).

cum interval
miles

0.0 0.0 Blanco, Oklahoma. A post office was established here in 1901. Proceed east on S.H. 63.

Blanco Gas Field

Section 12, T. 3 N., R. 14 E., immediately to the southwest, is the one-well Blanco Gas Field, discovered in 1979 by Hamiton Brothers Oil Company in their No. 1-12 Hamilton Sweetin well (E½E½E½NW½). Production is from the Wapanucka Limestone which was perforated from 10,915 to 11,055 ft. Hardie (1988, p. 237, cross section C-C', well 15) shows a small south-vergent anticline to be the trapping structure. The well has produced ~900 MMcf gas and is still producing ~61 Mcf gas per day (IHS Energy, 2006).

For the next ~11 mi the highway parallels an old railroad grade that serviced a number of mines in the McAlester coal. The Choctaw, Oklahoma, and Gulf Railroad Company built the railroad west from near Hartshorne in 1900-1901; it originally extended to Ardmore and closely followed the outcrop of the coal (Taff, 1904; Gunning, 1975). The railroad was bought by the Chicago, Rock Island, and Pacific Railway Company in 1904 (George and Wood, 1943), and this company played a major role in developing the coal resources of southeastern Oklahoma. The line was abandoned in 1950.

0.6 0.6 S.H. 63 passes underneath the Indian Nation Turnpike. Continue east.

0.8 0.2 Excellent outcrop of shale in McAlester Formation (PS-1) in bar ditch on left (north) side of road immediately west of bridge.

0.9 0.1 Excellent outcrop of Cameron Sandstone Member, McAlester Formation in small creek on left (north). Stop 1.

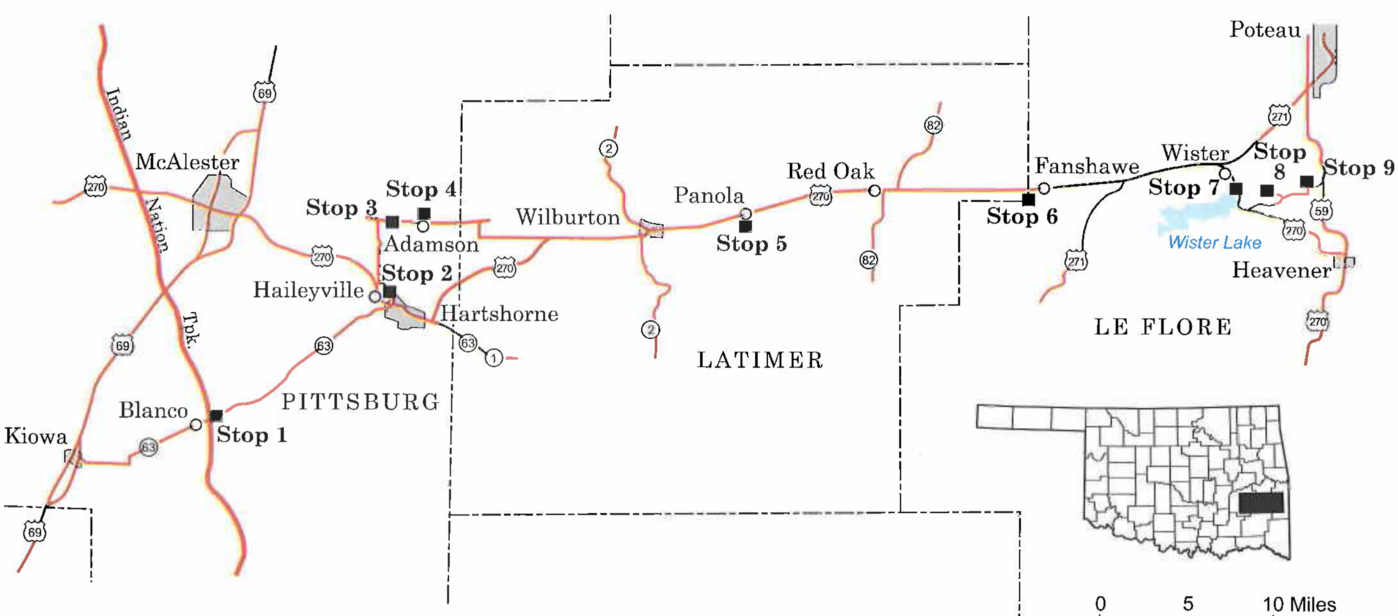

Figure 7. Map showing route for Day One, including highways, county lines, towns, and stop locations.

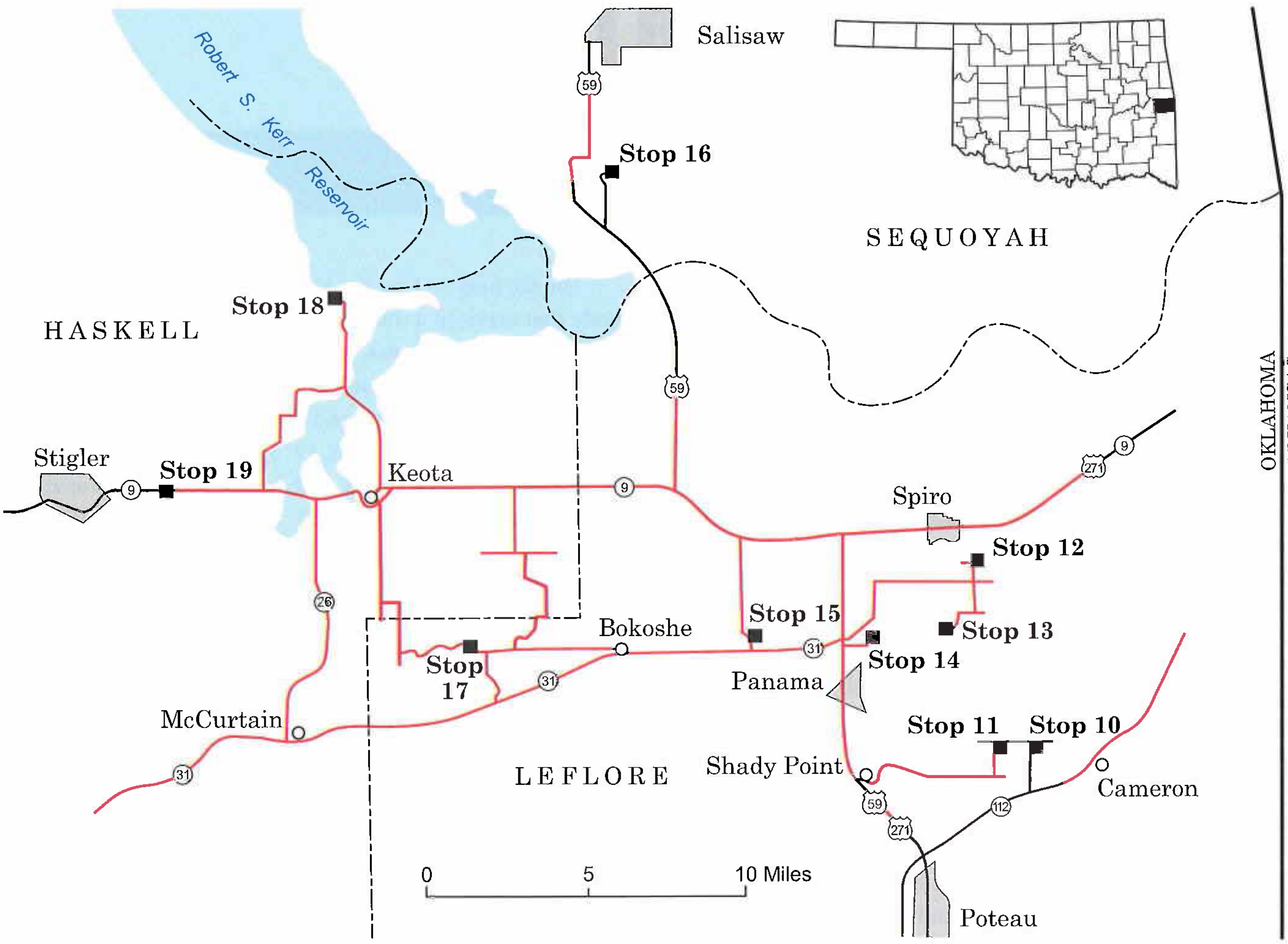

Figure 8. Map showing route for Day Two, including highways, county lines, towns, and stop locations.

Stop 1. Cameron Sandstone Blanco Measured Section

Location: Exposure along creek immediately north of Oklahoma State Highway 63, ~0.3 mi east of bridge under Indian Nation Turnpike and ~1 mi east-northeast of Blanco, Oklahoma. Center E½SE¼ sec. 6, T. 3 N., R. 15 E., Savanna 7.5′ quadrangle. UTM: 15S 247205 E 3849355 N.

Discussion and Interpretation:

Suneson (1997) mapped this outcrop as the Cameron Sandstone Member of the McAlester Formation. Here, it dips steeply (53°) to the northwest on the southeastern flank of the Kiowa Syncline (trough ~2.5 mi to north-northwest). The trace of the Blanco Fault, a relatively small south-southeast-directed backthrust, is ~0.5 mi to the southeast and the trace of the Choctaw Fault is ~1.5 mi to the southeast. This outcrop is near the southern margin of the Arkoma Basin, the edge of which is marked by the Choctaw Fault.

Hendricks (1937a) placed the Cameron Sandstone (although not named as such in his report) into his "middle" part of the McAlester Formation. His descriptions are not helpful for interpreting the depositional environment of sandstone.

Suneson (1997) described the Cameron Sandstone (Fig. 9) in the Savanna quadrangle as follows:

> The Cameron Sandstone Member ... is a relatively well exposed, yellowish gray to dusky yellow, fine- to very fine grained noncalcareous silty sandstone that typically weathers to ripple-marked slabs and flagstones. Individual outcrops vary from isolated 4- to 8-ft-thick sandstone beds to stacked sandstones over 100 ft thick. In the southeastern corner of the map, the Cameron shows rapid thickening and thinning. Although mapped as a single unit, the Cameron Sandstone Member includes covered intervals that separate sandstone beds and are probably shale and siltstone. Common sedimentary structures, in addition to ripple marks, include wavy bedding, large-scale cross-stratification, soft-sediment deformation features, and sole marks. The sandstone locally appears to grade both up- and down-section and along strike into flaser-bedded siltstone/sandstone sequences.

The top of the Cameron Sandstone here is ~80 ft below the McAlester coal (Suneson, 1997). To the northeast, this sand-

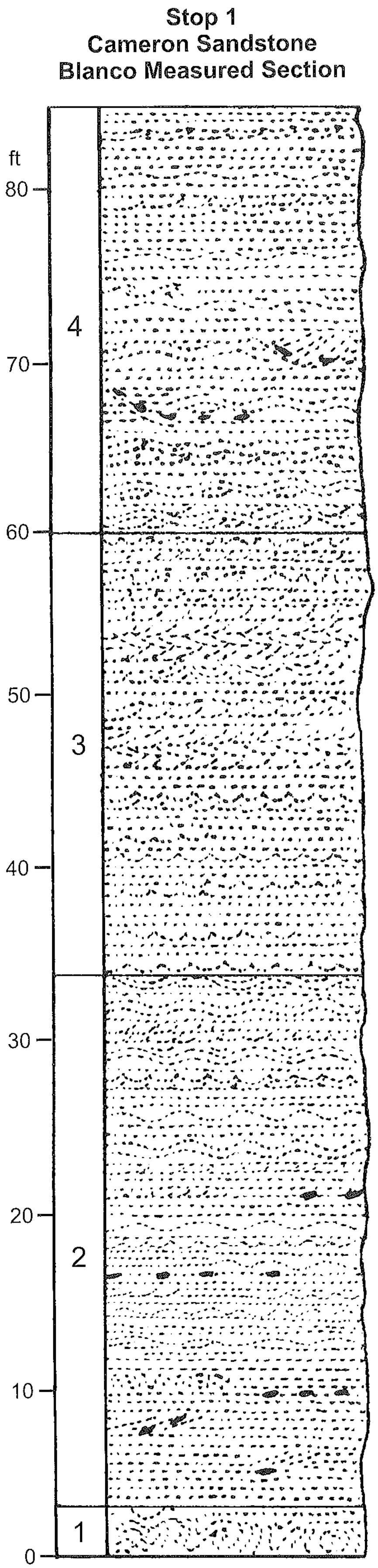

Figure 9. Graphic columnar section of the Cameron Sandstone exposed at Stop 1, Blanco measured section. The McAlester coal crops out ~80 ft above the top of this sandstone.

stone ranges from ~280 ft to 690 ft below what is mapped as the McAlester coal (Hendricks, 1937a; Suneson and Hemish, 1996). Hendricks (1937a, p. 63) notes that there are "several" coal beds greater than 1 ft 2 in. thick in the McAlester Formation; he also notes that "numerous thin coal beds are present a short distance above the McAlester coal, and some of these beds are present over considerable areas" (p. 15).

Boyd (2005) notes that the McAlester coal is a useful marker bed for identifying his parasequence PS-0, which usually immediately overlies the Cameron Sandstone. It is likely that any coals more than ~100 ft above the Cameron are not the McAlester coal.

Hemish and Suneson (1997, Stop 7) described the Cameron Sandstone in detail at an outcrop ~0.9 mi east-northeast of here (Fig. 10). They measured 85 ft of sandstone, which is identical to that in this outcrop. Many of the sedimentary structures they measured and described are similar to what Suneson (1997) noted and that are present here. They interpreted the Cameron as having been deposited in a "marginal marine" environment, but admitted that their interpretation was "open for discussion."

Two nearby well logs show the variable thickness and character of the Cameron Sandstone. The Hamilton Brothers No. 1 Sweetin (E½E½E½NW¼ sec. 12, T. 3 N., R. 14 E.) is located ~1.5 mi west-southwest of this outcrop. The McAlester coal was penetrated at 830 ft and the Upper McAlester coal at 800 ft (Fig. 11). The top of the Cameron Sandstone is ~75 ft below the McAlester coal; this is similar to what Suneson (1997) mapped at the surface. In the well, the Cameron Sandstone is ~35 ft thick – about half of what was measured at the outcrop. The Oryx No. 1 Cable (CN½ sec. 1, T.3 N., R. 14 E.) is ~1.5 mi west-northwest of this outcrop. The McAlester and Upper McAlester coals are at 2,335 and 2,314 ft deep, respectively, and the Cameron Sandstone is represented by a ~65-ft-thick sandstone-rich interval from ~2,425 to 2,490 ft (Fig. 12). As in the Sweetin well, the top of the Cameron is ~75 below the McAlester coal.

The absence of siltstone and shale (except as rip-up clasts), the abundance of truncated cross-stratification at many scales, and probable abrupt basal contact (Fig. 9) are evidence that the Cameron Sandstone was deposited in a relatively high-energy environment. The sharp base of unit 1 suggests incision followed by channel filling. Many features, including the draping in units 2 and 3 and the herringbone cross-stratification in unit 3 suggest a tidal influence. Based on the sedimentary structures in the measured section, units 1, 2, and 3 probably represent tidal deposits or tidally reworked distributary-channel deposits. By contrast, the depositional environment of unit 4 is relatively straightforward – the truncated beds, channelform features, and zones of rip-up clasts are evidence that it is a channel-fill sandstone, probably filling a distributary channel. The origin of these deposits is open to interpretation because most Booch sandstones this thick are interpreted to be primarily incised-valley fill.

The Hamilton Brothers No. 1 Sweetin and Oryx No. 1 Cable logs show the Cameron Sandstone to have relatively sharp base that is about the same distance below the McAlester coal as in the outcrop. However, the log character of this interval in the two wells is different. The variability seen between the Sweetin and Cable wells is especially common in the upper Booch where pervasive marine shales are rare and most sediments are deltaic. As discussed throughout this guidebook, the Booch sandstones exhibit significant lateral and vertical facies changes, suggestive of a dynamic and complex depositional environment. Except for the incised-valley fills, all Booch sandstones were deposited in and around tidally influenced deltas.

Description of units (Fig. 9):

McALESTER FORMATION:

Cameron Sandstone Member:

Note: 0-11 ft measured and described on west side of creek; 11-25 ft on east side; 25-41 ft on west side; 41-49 ft on east side; 49 ft – top in creek bed.

4. Sandstone. Beds 1 – 3 ft thick; locally internally stratified. Large-scale, low-angle wavy-bedded showing low-angle truncations. Common local small-scale soft-sediment deformation; slight slump features; good dish-and-pillar (dewatering) structures. Channels common, many with thin zones of unsupported shale rip-up clasts at base. Pinch-and-swell common due to channeling (Fig. 13).

3. Sandstone. Very fine grained, well sorted. Individual beds vary in thickness. Plane-parallel- and trough-cross-stratified; tops of many beds ripple-marked. Finely stratified organic-rich sandstone locally draped across ripple-bedded sandstone. Well-developed herringbone cross-stratified sandstone beds 1-3 in. thick separated by plane-parallel-stratified sandstone with organic-rich layers near top. Minor soft-sediment deformation, possibly slumped beds, at top. Trace fossils absent. Contact between units 3 and 4 conformable.

2. Sandstone. Fine-grained, poorly sorted to rarely well sorted, very abundant comminuted carbonaceous organic debris and mica on bedding planes. Mostly plane-parallel stratified, locally low-angle cross-stratified. Thicker beds appear unstratified or show low-amplitude wavy-bedding; some pinch and swell, draping common. Some large-scale wavy-bedding shows truncation of beds (Fig. 14). Ripple-marks moderately common. Thin zones with shale or siltstone rip-up clasts, flattened parallel to bedding planes, moderately common. Trace fossils uncommon. Upper part: Wavy-bedding, low-angle cross-stratification, truncated beds more common than below. Also sandstone fine- to very fine grained, only trace of organic debris.

1. Sandstone. Fine-grained, poorly sorted, abundant comminuted carbonaceous organic debris. Mostly highly soft-sed-

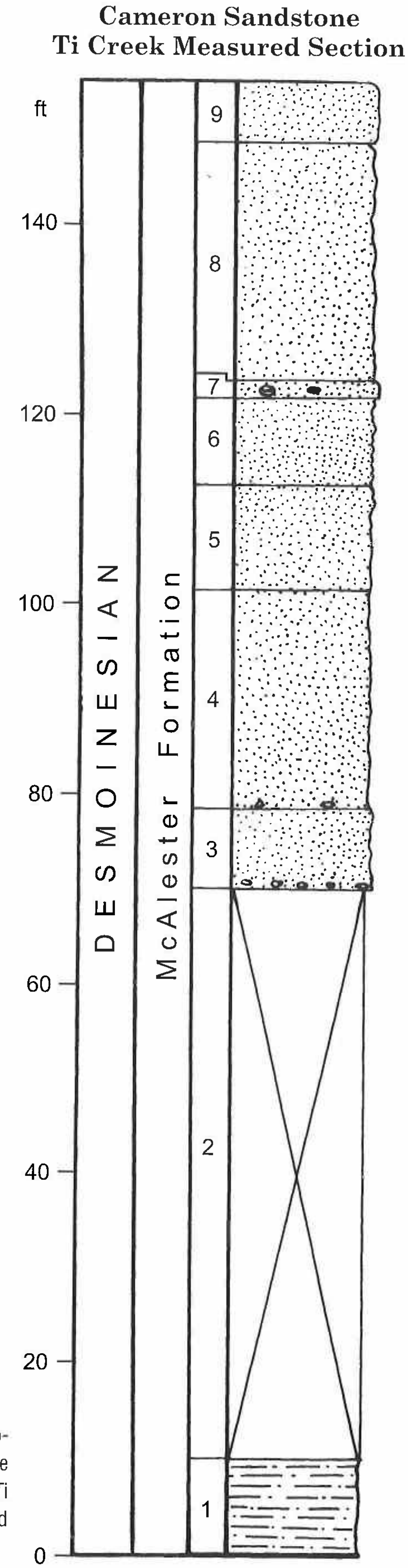

Figure 10. Graphic columnar section of the Cameron Sandstone at Ti Creek (from Hemish and Suneson, 1997, fig. 38).

iment deformed with rolled sandstone masses. Locally highly plane-parallel stratified.

1.7 0.8 Cross Ti Creek. Hemish and Suneson (1997) measured an outcrop of the Cameron Sandstone in the stream cut immediately north of the highway (Fig. 10). Some old and impressive bridge abutments from the Choctaw, Oklahoma, and Gulf Railroad are still present on either side of Ti Creek.

Leave Savanna 7.5' quadrangle, enter Hartshorne SW 7.5' quadrangle. The geology of the Hartshorne SW quadrangle is shown by Suneson and Hemish (1996).

2.8 1.1 Low ridge is upper Warner sandstone of the McAlester Formation.

3.4 0.6 Highway passes through a ridge underlain by sandstone of the Hartshorne Formation dipping ~45° northwest. For the next couple of miles, the highway parallels the Hartshorne ridge to the left (north).

Haileyville Southwest Gas Field

Enter Haileyville Southwest Gas Field (Boyd, 2002) which was discovered by the Oxley No. 1 Whiting (SW¼NE¼SW¼ sec. 25, T. 4 N., R. 15 E.) in 1975. The well was perforated in the Red Oak sandstone from 8,341 to 8,693 ft.

The field produces primarily from Atoka Formation sandstones, including the Atoka (undivided), Spiro, Brazil, Red Oak, and Fanshawe; minor production is from the Hartshorne and Wapanucka. The field has 76 active wells, has produced 162 Bcf of gas, and continues to produce 23 MMcf gas per day (IHS Energy, 2006).

4.5 1.1 Section-line road to right (south).

The broad valley to the southeast is underlain by the Atoka Formation; the trace of the Choctaw Fault is in the valley, but is difficult to locate precisely because it juxtaposes easily eroded, poorly exposed shale of the Atoka Formation in the hanging wall (south) against equally easily eroded and poorly exposed shale of the Springer Formation in the footwall (north) (Hendricks and others, 1947).

5.5 1.0 The large borrow pit on the left (northwest) exposes shale in the uppermost part of the Atoka Formation.

6.0 0.5 S.H. 63 crosses Gardner Creek. Suneson (1998, p. 35-39) measured and described the outcrop of Hartshorne sandstone immediately east of the highway.

7.6 1.6 Entrance to the small Berlin Coal Mine (McAlester coal) to left (north). This mine was abandoned prior to 1930 (Hendricks, 1937a).

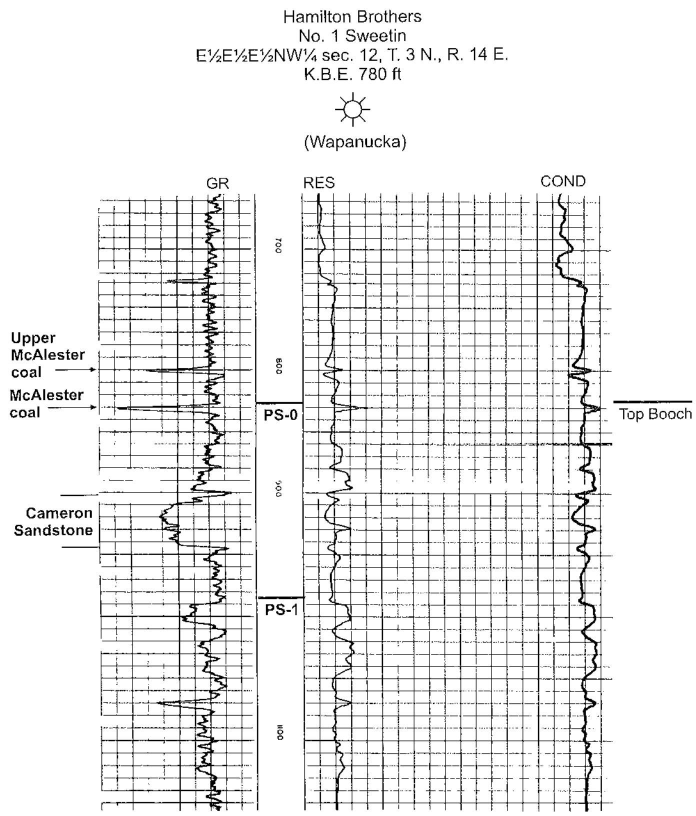

Figure 11. Part of wireline log from Hamilton Brothers No. 1 Sweetin well showing the log character of the Cameron Sandstone. The McAlester and Upper McAlester coals are characterized by sharp-peaked gamma-ray lows. The Cameron Sandstone on this log and at the outcrop at Stop 1 is characterized by a sharp basal contact.

8.0 0.4 Entrance to the small Messina Coal Co. No. 1 Craig Mine (McAlester coal) to right (south); some remnants of the mine workings are still present. This mine was active in 1930 (Hendricks, 1937a). The Oklahoma Conservation Commission reports that the slope entrance is open but partly blocked with concrete debris.

The low ridges just north of the highway are underlain by northwest-dipping sandstone beds in the lower part of the Savanna Formation.

8.7 0.7 Intersection with county road NS414. This intersection is shown as "Bond" on some maps of this area.

The structural geology immediately south of here is complex and includes, from north to south, the Craig Anticline, the Haileyville Syncline, and the north-dipping Berlin Fault. These probably are flexural-slip structures on the south flank of the Kiowa Syncline.

Leave Haileyville Southwest Gas Field, enter Wilburton Gas Field (Boyd, 2002).

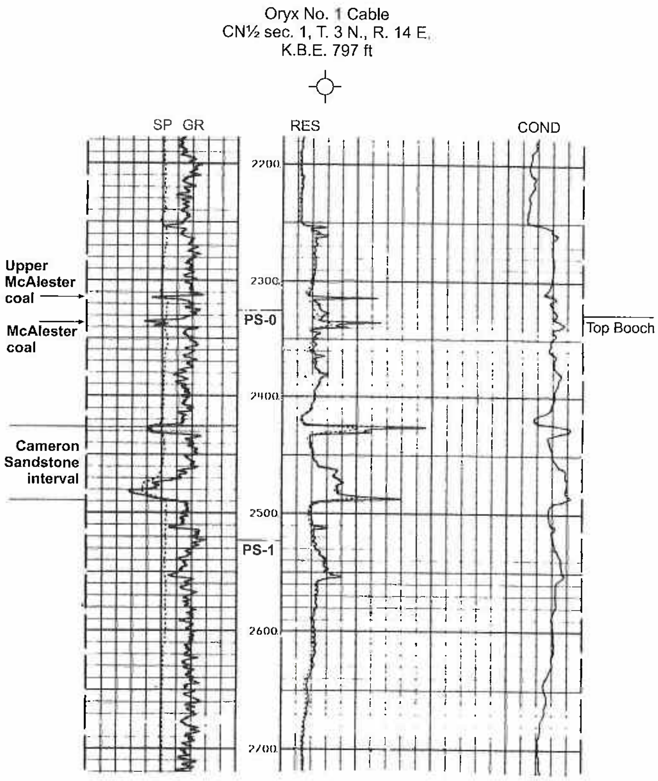

Figure 12. Part of wireline log from Oryx No. 1 Cable. The log character of the Cameron Sandstone in this well is different from that in the Sweetin well and the outcrop. This illustrates the variability of the Booch sandstones deposited in various deltaic environments.

Wilburton Gas Field

The Wilburton Gas Field is the third largest gas field in the Arkoma Basin, extending from here ~30 mi east-northeast through north-central Latimer County, and varying from 2 to 8 mi wide. The field has produced 2,023 Bcf gas and continues to produce ~109 MMcf gas per day (230 Mcf gas per day per well, average). 597 wells were drilled in the field and 480 remain active. The Cromwell Sandstone; Wapanucka Limestone; Spiro, Red Oak, Fanshawe, and Atoka (undivided) sandstones; and Hartshorne Formation are the primary producing units (IHS Energy, 2006).

The Wilburton Field includes the former Wilburton North, Wilburton Northwest, and Hartshorne Fields. Prior to 1987 this part of the Wilburton Field was the Hartshorne Gas Field (Burchfield, 1985) which was discovered by the Public Service Company No. 1 Craig (NE¼SE¼NE¼ sec. 9, T. 4 N., R. 16 E.) in 1941. This well produced gas from the Hartshorne at a depth of 1,200 to 1,280 ft.

The subsurface geology of this part of the Wilburton Field is relatively well-studied. Wilkerson and Wellman (1993) and Valderrama and others (1996) have documented the triangle-zone geometry of this part of the Arkoma Basin and the location of many of the gas reservoirs at the leading edge of blind thrust plates. Gross and others (1995) and Forgotson and others (2000) emphasize the importance of depositional environment, diagenetic history, and thermal maturity for exploring for Spiro sandstone reservoirs. Detailed studies of the other reservoir units are not published.

For the next several miles S.H. 63 continues to parallel the Choctaw, Oklahoma, and Gulf railroad grade. The grade is still visible immediately to the left (northwest) of the highway.

10.8 2.1 S.H. 63 passes over a moderately extensive underground coal mine beginning here. Hendricks (1937a) shows five slope mines (including the Tatum, Stevenson, and Bolen-Darnall Coal Co. Nos. 4 and 5 Mines) in the northwest-dipping McAlester coal on the northwest flank of the Craig Anticline on the right (southeast) side of the highway. All the slope mines appear to extend into the underground mine and all were abandoned by 1930.

11.0 0.2 Leave Hartshorne SW 7.5' quadrangle, enter Hartshorne 7.5' quadrangle. Suneson (1996) mapped the geology of the Hartshorne quadrangle.

11.4 0.4 Road to abandoned village of Craig enters from left (northwest).

Figure 13. Large-scale trough cross-bedding and cut-and-fill structures in unit 4, Cameron Sandstone, Blanco measured section. Black comb for scale.

Extensive remains from coal-mining activity, probably from the Bolen-Darnall Coal Co. No. 5 Mine, on right (southeast). The ridge on the left (northwest) side of the highway is underlain by the Savanna Formation.

11.5 0.1 Northeastern extent of underground mine in McAlester coal.

11.8 0.3 S.H. 63 crosses Brushy Creek.

12.1 0.3 Ridge underlain by Cameron Sandstone dipping ~15° west near the crest of Craig Anticline.

12.5 0.4 Section-line road to right (south).

12.6 0.1 Road to left (north). The small outcrop on the left just past the road is the lower Warner sandstone. Here it dips ~35° west on the crest of the Craig Anticline.

Figure 14. Mostly plane-parallel stratified to slightly wavy-bedded sandstone typical of unit 2, Cameron Sandstone, Blanco measured section (structural dip 40° to right). Some beds show slight thickening and thinning. Hammer for scale.

Choctaw Coal and Railway Company Railroad

The railroad through Haileyville is part of the original Wister to McAlester line built by the Choctaw Coal and Railway Company. Here the line followed close to the present route of U.S. 270 / S.H. 1. The cut at Stop 2 is not part of the original line; it does not appear on Hendricks' (1937a) map of the coal fields nor on the 1948 1:250,000 U.S.G.S. topographic map. However, it is present on the 1967 1:24,000 topographic map.

The Choctaw Coal and Railway railroad was built in 1889 – 1890 from Wister to McAlester to connect the St. Louis – San Francisco ("Frisco") line (now Burlington – Northern) with the Missouri – Kansas – Texas ("Katy") line (now Union Pacific). It is shown on Taff's (1899) geologic map and probably was built to exploit the "coal measures" mapped by Chance (1890).

The railroad was sold to the Choctaw, Oklahoma, and Gulf Railroad Company in 1894, became the Choctaw, Oklahoma, and Western, and was bought by the Chicago, Rock Island, and Pacific in 1904. It is now operated by the Arkansas – Oklahoma (AOK) Railroad based in Wilburton, Oklahoma. The AOK operates ~70 mi of freight line (mostly coal) between Howe and McAlester. In the past, coal was one of the railroad's most important commodities, but flagstone recently has become significant.

13.0 0.4 Beginning here, S.H. 63 passes over extensive Hailey-Ola Coal Co. No. 1 Mine in Lower Hartshorne coal beginning here. This mine and the more extensive Rock Island Improvement Co. No. 8 Mine (also in Lower Hartshorne coal) underlie much of the northern part of the town of Haileyville.

13.1 0.1 Cross Blue Creek.

13.4 0.3 Road enters from right (south).

13.5 0.1 S.H. 63 turns left (north). Enter Haileyville, Oklahoma.

Haileyville, Oklahoma

Haileyville and its twin city Hartshorne were established in 1890 as a result of the construction of the Choctaw Coal and Railway Company railroad. Haileyville was named for Dr. David Morris Hailey, one of the early principal coal mine operators in the district (Fugate and Fugate, 1991).

13.55 0.05 Turn right (east).

13.6 0.05 Turn left (north). Haileyville Warriors football field on left (west).

13.7 0.1 Turn right (east). U.S. Highway 270 / State Highway 1 immediately to left (north).

14.0 0.3 Turn left (north) to intersection with U.S. 270 / S.H. 1.

14.1 0.1 Road forks. Take left fork past sewage disposal ponds on left (west).

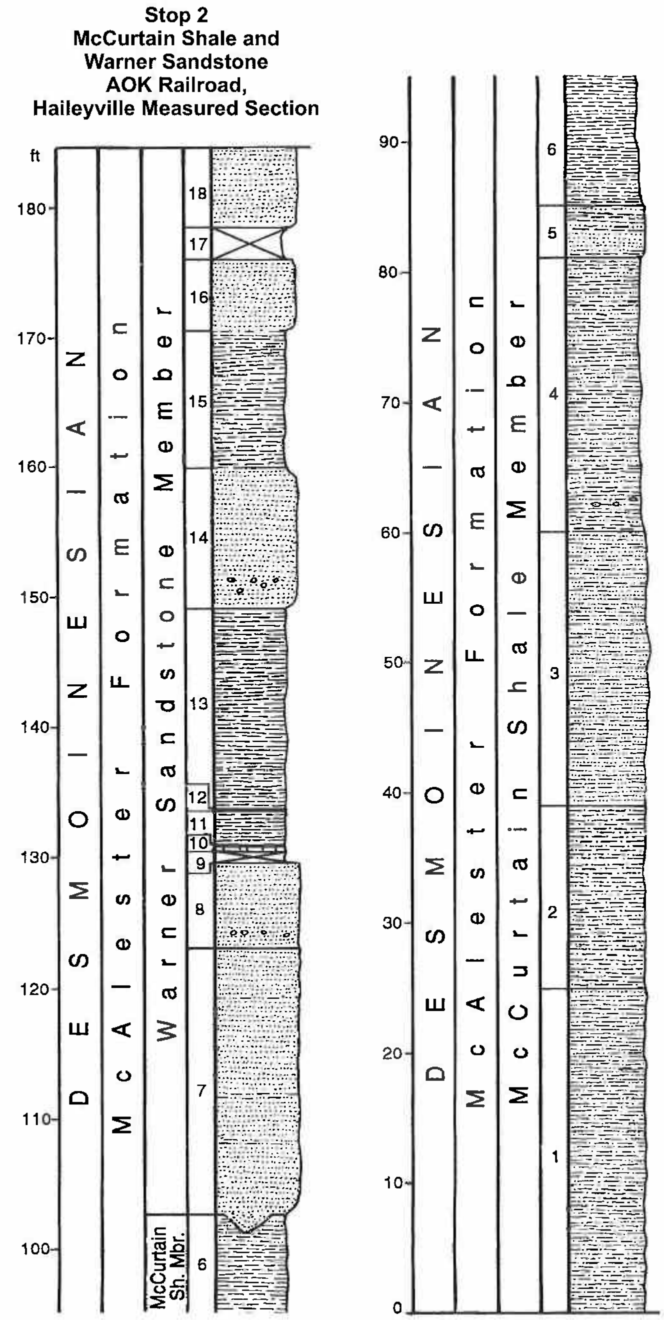

Figure 15. Graphic columnar section of Warner Sandstone and upper part of McCurtain Shale exposed at Stop 2, AOK Railroad, Haileyville measured section (from Hemish and Suneson, 1997, fig. 45).

14.2 0.1 Turn right (northwest).

14.3 0.1 Cross railroad tracks. Immediately after crossing tracks, turn left (northwest) on graded gravel road. The ridge immediately in front is underlain by the lower Warner sandstone. Stop 2 is the railroad cut through the ridge immediately to the left (southwest) of the road.

14.6 0.3 Turn left (southwest) on poor dirt track and park. Walk to railroad tracks, turn left, and walk back to large outcrop of lower Warner sandstone and Stop 2.

For permission to visit this outcrop (private property), please contact B. David Donoley, President/CEO, Arkansas - Oklahoma Railroad, Inc., 103 South Central, P.O. Box 485, Wilburton, OK 74578; or phone (918) 465-0299.

Stop 2. Warner Sandstone, AOK Railroad, Haileyville Measured Section

Location: Railroad cut along Arkansas - Oklahoma Railroad ~0.5 mi northwest of Haileyville, Oklahoma. NE¼NW¼SE¼ sec. 35, T. 5 N., R. 16 E., Hartshorne 7.5' quadrangle. UTM: 15S 263840 E 3860440 N.

Discussion and Interpretation:

This outcrop of the Warner Sandstone (Figs. 15 and 16) dips ~20° northwest towards the axis of the Kiowa Syncline, which is located ~1.3 mi to the northwest (Suneson, 1996). The crest of the Craig Anticline is ~1 mi to the southeast and the trace of the Choctaw Fault is ~2.5 mi to the south. Hemish and Suneson (1997) measured and described this section; their description and interpretation is reprinted below. Although mapped as the lower Warner sandstone by Suneson (1996), this outcrop is the Warner Sandstone based on subsurface regional data and the probable correlation of the coals in units 10 and 12 with the Keefton coal (Fig. 2). The low ridge to the north, mapped by Suneson (1996) as the upper Warner sandstone, probably is the Lequire Sandstone. Our reinvestigation of the outcrop largely confirms Hemish and Suneson's (1997) interpretations but adds some detail and puts the section into Boyd's (2005) sequence stratigraphic framework of the McAlester Formation.

The Warner Sandstone was logged in the Unit No. 1 Norris B (NE¼SE¼NE¼NW¼ sec. 31, T. 5 N., R. 16 E.) (Fig. 17), located ~4 mi west of this outcrop. The No. 1 Norris drilled the Warner Sandstone from 2,710 ft to 2,745 ft and although thinner than the Warner Sandstone exposed at Stop 2, both show the characteristic "shale break" within the unit.

Hemish and Suneson (1997, p. 56) described and interpreted this outcrop as follows:

> The Arkansas-Oklahoma Railroad section at Stop [2 (Fig. 15)] is the best exposure of the contact between the McCurtain Shale and Warner Sandstone Members of the McAlester Formation in the southern part of the Arkoma Basin. The McCurtain Shale Member typically forms valleys and is rarely exposed. Although the Warner Sandstone Member generally is well exposed, most outcrops are lichen covered, thus subtle (and, in some cases, gross) sedimentary structures commonly

are obscured. In addition, the more fine-grained rocks within the Warner Sandstone Member are rarely exposed. In this area, the Warner Sandstone Member is split into lower and upper sandstones; the upper sandstone is very poorly exposed where the railroad cuts through the low ridge ~700 ft northwest of this section. It is not worth visiting.

This section represents two very different sedimentary environments. The McCurtain Shale Member appears to have been deposited in a prodelta environment; the relatively high silt content of the shales, abundance of siltstone and fine-grained sandstone beds, and conspicuous slump features suggest a proximal prodelta setting. In contrast, the Warner Sandstone Member is characterized by a large number of sedimentary structures that suggest deposition in relatively shallow water. The most important of these features are diagnostic and include coal beds (units 10 and 12) and autochthonous plant fossils (units 8 and 16). Any interpretation of the depositional environments of the different units that make up the lower part of the Warner Sandstone Member at this locality should start with these four units.

Part of our interpretation of this section is that unit 8 was deposited in an interdistributary-bay environment; the gradational nature of the contact between units 8 and 7 suggests that unit 7 was deposited in a similar environment. Unit 7 clearly eroded into unit 6 (interpreted to be a prodelta deposit), which suggests that the contact between units 7 and 6 (the Warner Sandstone – McCurtain Shale contact) represents an abrupt lowering of sea level and could mark a sequence boundary.

An important aspect of this section is that there appear to be no sediments associated with distributary channels. Levees, channel-fill, and distributary-mouth-bar deposits are absent in this outcrop.

According to Hemish and Suneson (1997), the Warner Sandstone at this stop consists entirely of delta-plain deposits, including crevasse-splay sandstones, interdistributary-bay and bay-fill shales, and marsh-swamp coals. They noted some tidal-flat and tidal-channel deposits in unit 8.

An alternate interpretation of units 7 and 8 is that they are tidally reworked distributary-mouth bars that shoal upward into sandy tidal-flat deposits. One argument against Hemish and Suneson's (1997) interpretation of unit 7 as an interdistributary-bay deposit is the predominance of sandstone and evidence for a relatively high-energy environment (ripple marks, trough-crossbeds). The abundant sandstone suggests the unit represents a middle- or upper-bar deposit; the scarcity of lower-bar strata that would normally grade into the underlying prodelta shales of unit 6 is due to the erosional unconformity between units 7 and 6. Flaser beds and local repetition of strata are evidence for tidal reworking, and the presence of reddish beds may indicate subaerial exposure and weathering. Unit 8 is generally similar to unit 7; although evidence for tidal reworking is stronger and includes bidirectional cross-stratification. The presence of Stigmaria in the upper part of unit 8 is evidence for shoaling and the transition of the unit from delta-front to delta-plain deposits.

Figure 18 compares the graphic columnar section and surface gamma-ray profile of the Warner sandstone at this stop. The abrupt base of the sandstone units (7, 14, and 16) are clearly represented on the profile. The apparent fining-upward character of unit 14 may partly be due to the mostly soil-covered exposures available for gamma-ray measurements; unit 14 may, in fact, have an abrupt top. Despite the abrupt and clearly erosional base of unit 7, it is not a channel deposit as evidenced by the seriate character of the gamma-ray profile. As stated above, unit 7 is a tidally reworked distributary-mouth-bar deposit with an erosional base. In contrast, units 14, 16, and 18 are crevasse-splay deposits. The interdistributary-bay or bay-fill shales (unit 15 and parts of units 13 through 11) have higher gamma-ray readings than the marine shales (units 5 through 1) probably because of the high silt content in the marine shales. The presence of silt is evidence of a more proximal (probably a prodelta) deposit, as opposed to a distal marine shale. The seriate character of the entire unit above the prodelta shales is typical of delta-plain deposits, particularly the alternating crevasse-splay sandstones and interdistributary-bay shales.

Figure 18 is part of the well log of the Unit No. 1 Norris B (NE¼SE¼NE¼NW¼ sec. 31, T. 5 N., R. 16 E.) showing the Warner (this outcrop) and the Lequire (upper Warner sand-

Figure 16. Outcrop photo of units 7 through 13, AOK Railroad, Haileyville measured section. The base of unit 7 (marked) is partly in the shadow on right; the light-colored unit in the upper left is unit 8 (top marked).

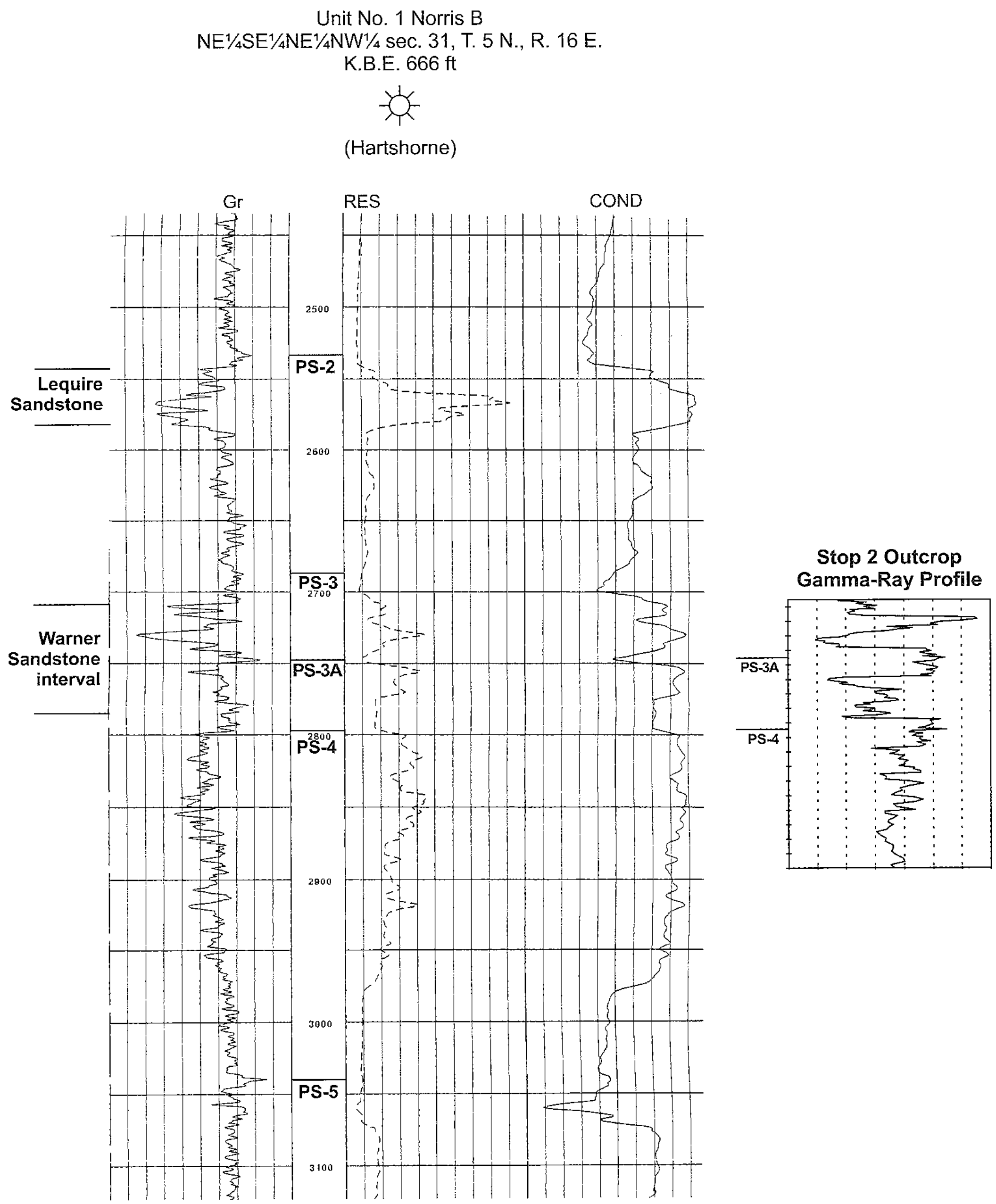

Figure 17. Part of wireline log of the Unit Petroleum No. 1 Norris B showing the log character of the Lequire and Warner Sandstones compared to the outcrop gamma-ray profile. Although the sandstones differ, the overall gamma-ray patterns are remarkably similar.

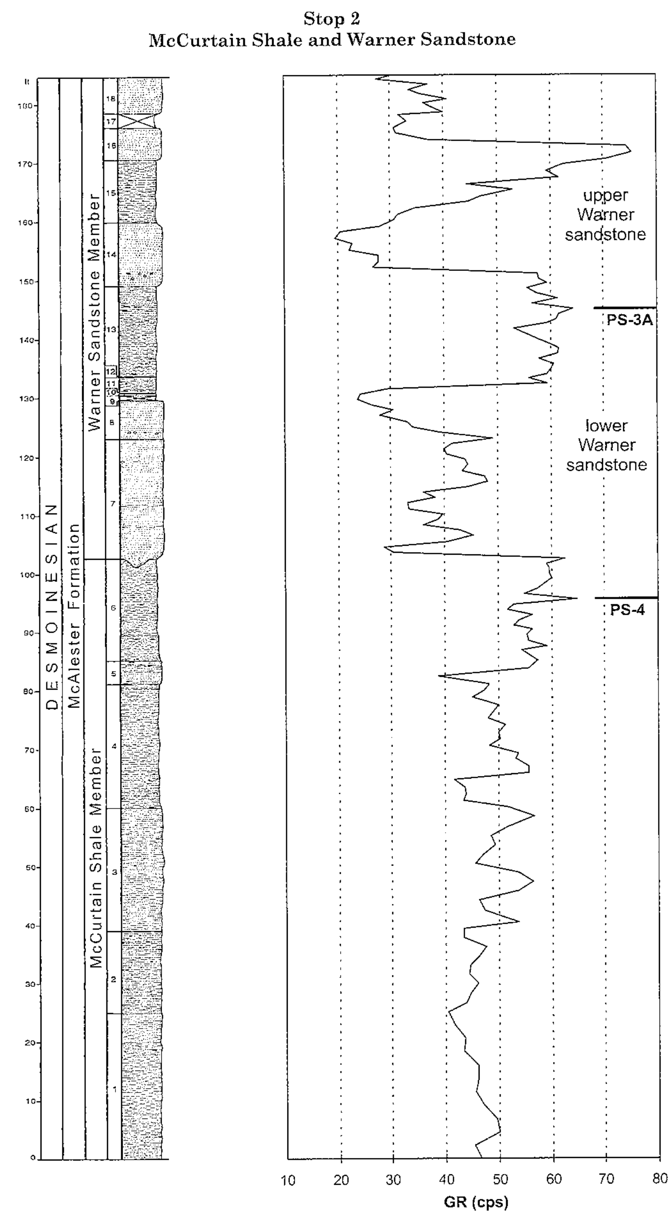

Figure 18. Graphic columnar section of the Warner Sandstone and McCurtain Shale at AOK Railroad, Haileyville measured section, showing the outcrop gamma-ray profile. Major lithologic changes in the outcrop correlate well with the log; however, subtle variations in gamma-ray response are difficult to discern in outcrop.

stone of Suneson, 1996) Sandstones. The highly seriate character of the Warner Sandstone, indicative of delta-plain deposits, is similar to that observed on the gamma-ray profile of the outcrop. Distributary channel-fill deposits are absent. Parasequences 3 and 3A typically do not have thick marine shales at their base, making the identification of their boundaries uncertain. This contrasts with the thick marine shales, generally beginning with a "hot" gamma-ray streak at the flooding surface, on the No. 1 Norris B log for parasequences 5, 4, 3, and 1 (Fig. 19).

Figure 19 shows the position of the Warner Sandstone within the sequence stratigraphic framework of the entire Booch interval developed by Boyd (2005). The Warner Sandstone is within the PS-3 and PS-3A intervals in the middle of the Booch. In this well the Lequire Sandstone (PS-2) is well-developed and the Cameron Sandstone (PS-1) is poorly developed. No Booch sandstones are present below the Warner, but the coarsening-upward trends are apparent.

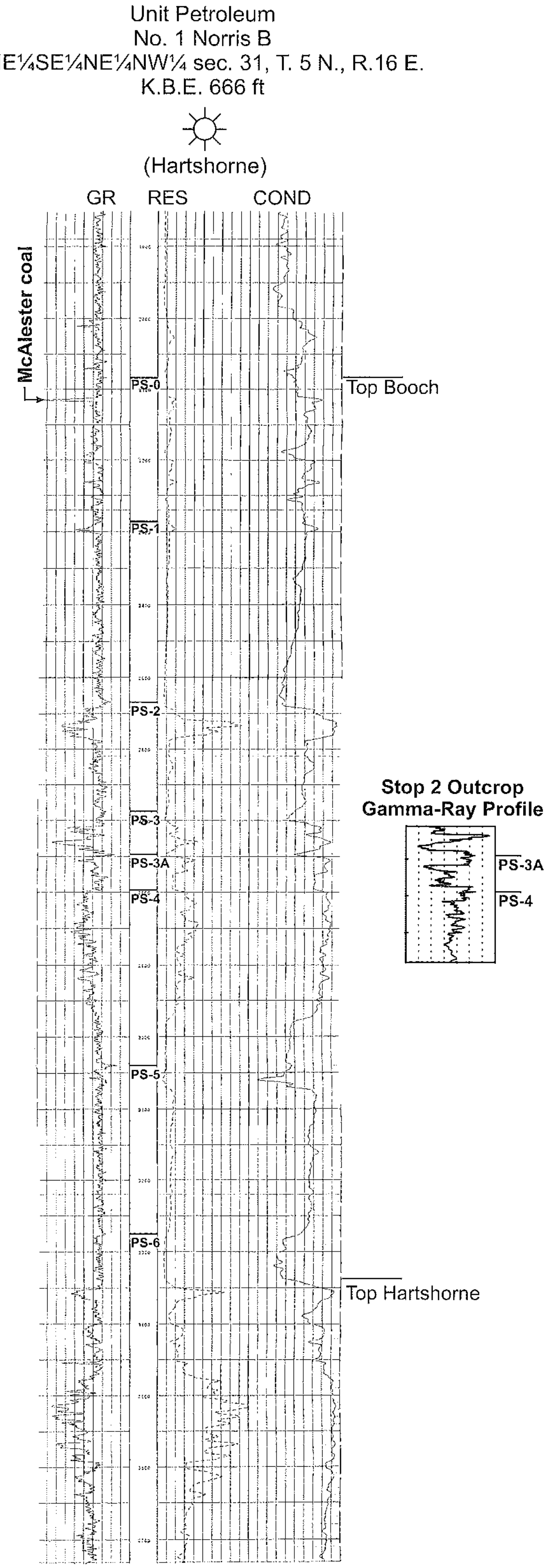

Figure 19. Wireline log of the entire Booch interval in the Unit No. 1 Norris B compared to the gamma-ray profile of the AOK Railroad, Haileyville outcrop. Although this outcrop is one of the thickest described, it represents only a small part of the Booch interval. The PS-2 sandstone underlies a topographic ridge mapped by Suneson (1996) as upper Warner sandstone but referred to in this report as the Lequire Sandstone.

Description of units

(modified from Hemish and Suneson, 1997) (Fig. 15):

McALESTER FORMATION:

Warner Sandstone Member:

(Note: Interpretations of depositional environments are those of the authors and some differ from those of Hemish and Suneson (1997).)

18. Sandstone. Very fine grained, yellowish gray (5Y 7/2). Abundant organic material on laminations. Slabby, consists of stacked, amalgamated sandstone beds. Cross-beds, pinch-and swell, soft-sediment deformation features common; scour-and-fill uncommon. Top irregular, wavy-bedded. Interpretation: crevasse-splay sandstone

17. Covered. Interpretation: interdistributary-bay or bay-fill deposit?

16. Sandstone. Very fine grained, light gray (N7), conspicuous mica on laminations. Slabby, consists of stacked 0.5–1-ft-thick beds (Fig. 20). Cross-beds, plane-parallel beds, pinch-and-swell, soft-sediment deformation features common. Contains an upright carbonized tree trunk ~3.5 ft tall, 4 in. in diameter in growth position (Fig. 21), extending through four individual sandstone beds with a base in unit 15. Conspicuous carbonized plant compressions, rarely well preserved, on bedding planes. Base abrupt, wavy, slightly undulatory. Interpretation: crevasse-splay deposit

15. Shale. Silty, fissile to platy, poorly exposed. Interpretation: interdistributary-bay or bay-fill deposit

14. Sandstone. Fine-grained, quartzose, light gray (N7), with conspicuous mica and organic material on laminations. Mostly plane parallel stratified, rarely cross stratified, locally with soft-sediment deformation features (Fig. 22). Abundant rounded shale rip-up clasts 3 in. in diameter in zone ~1 ft

Figure 20. Stacked, thick-bedded sandstone in unit 16, AOK Railroad, Haileyville measured section. A wide variety of sedimentary structures suggests that this unit is a crevasse-splay deposit. A coalified tree trunk in growth position is present immediately below hammer (Fig. 21).

thick, ~3 ft above base. Base sharp, with abundant load casts. Interpretation: crevasse-splay deposit

13. Shale. Fissile, grayish black (N2) to olive gray (5Y3/2), appears to be organic-rich. Small coal chips observed in float near lower part of unit, but no coal outcrop observed. Mostly poorly exposed. Rare 0.5–1-in.-thick silica-cemented shale layers thicken and thin slightly. Locally weathers spheroidally. Abundant ironstone concretions near top. Interpretation: marsh-swamp deposit and interdistributary-bay or bay-fill deposit overlain by marine or prodelta shale.

12. Coal. Weathers to 1–2-in. blocks. Keefton(?) coal. Interpretation: marsh-swamp deposit

11. Shale. Very dark colored, sooty, organic-rich. Soft, weathers easily. Yellowish clayey mineral on bedding planes. Poorly exposed. Interpretation: mixed marsh-swamp and interdistributary-bay or bay-fill deposit

10. Coal and underclay. Coal ~2 in. thick; underclay ~4 in. thick. Coal weathers to 1–2-in. blocks, iron-oxide-stained fractures. Well parted. Keefton(?) coal. Interpretation: marsh-swamp deposit

9. Covered. Probably shale. Interpretation: interdistributary-bay or bay-fill deposit

8. Sandstone. Very fine grained, quartzose, light olive gray (5Y6/1). Mostly cross bedded, rippleform-topped, and flaser bedded; locally repetitive (Fig. 23). Cross-beds mostly unidirectional, but locally bidirectional. Locally small-scale soft-sediment deformation and dewatering features. Beds locally lensoid with no evidence for erosion at base (Fig. 24). Upper 4 ft with abundant vertical burrows. Locally contains shale rip-up clasts as large as 2 in. in diameter. Autochthonous 2.5-ft-long Stigmaria ~14 in. below top of unit. Also prone plant cast with slightly carbonized exterior, upright cast at same level. Top of unit contains 1-ft-thick channelform deposits that truncate soft-sediment-deformations in underlying sandstone. Base gradational with unit 7. Interpretation: tidally influenced upper distributary-mouth-bar, locally tidal-flat and tidal-channel deposits

7. Sandstone, minor siltstone, very minor shale. Fine-grained to very fine grained, medium light gray (N6) to light olive gray (5Y6/1). Sandstone includes ripple-marked, wavy-bedded, trough cross-bedded, and flaser-bedded beds 0.5–6 in. thick, interbedded with plane-parallel laminated beds 0.5–3 in. thick (Fig. 25). Cross-bedded beds are unidirectional, locally show pinch-and-swell, lensing, pinching-out. Cut-and-fill structures

Figure 21. Close-up photograph of coalified tree trunk, AOK Railroad, Haileyville measured section (unit 16). Hammer for scale. See figure 20 for location.

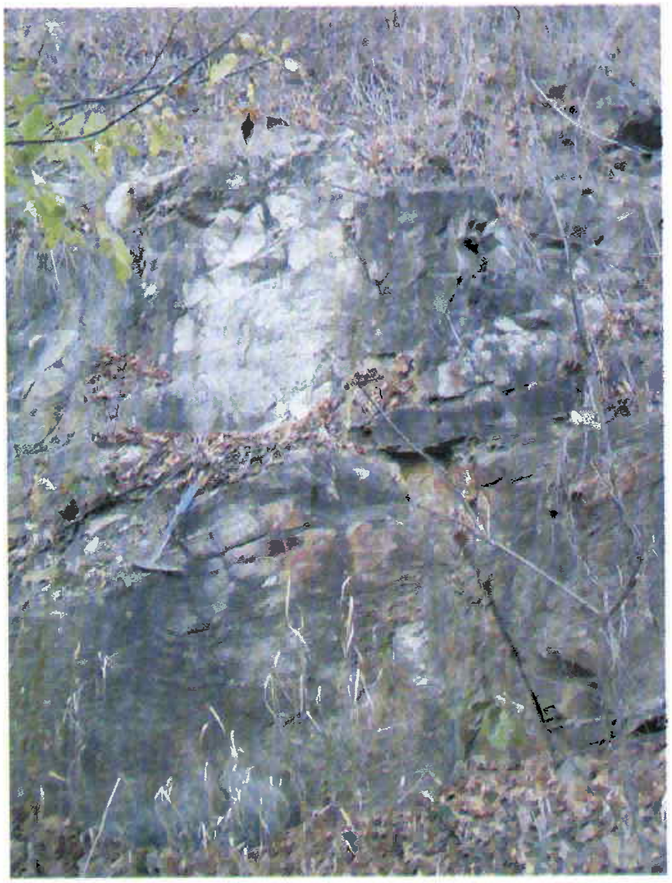

Figure 22. Soft-sediment deformation features in unit 14, AOK Railroad, Haileyville measured section. These structures indicate that the entire ~6-ft-thick bed was deposited extremely rapidly. This is consistent with a crevasse-splay origin for the unit. Hammer for scale.

McCurtain Shale Member:

6. Shale and very minor siltstone. Olive black (5Y2/1). Fissile, locally slightly calcareous, abundant carbonized organic debris on bedding planes in upper 1.5 ft. Shale locally exhibits pencil structure. Possibly slightly coarsening upward. Interpretation: proximal prodelta possibly grading upward to distal bar

5. Siltstone; minor shale; rolled sandstone, siltstone, and shale masses. Sandstone fine-grained, calcareous, locally with soft-sediment deformation features. Rolled siltstone masses with iron oxide stain. Rolled masses range from 2 in. to 3.5 ft long. Unit includes autochthonous, but detached and folded beds. Interpretation: proximal prodelta deposit

4. Siltstone and shale. Shale silty. Rare 1-in.-thick calcareous siltstone layers show pinch-and-swell, locally form alignment of concretions, elsewhere detached and folded. Soft-sediment deformation features common at base. Thickness approximate. Interpretation:
proximal prodelta deposit

3. Siltstone. Sandy, dark yellowish brown (10YR4/2). Platy to chippy, appears highly fractured and weathered. Mica, minor carbonized organic material, iron oxide stain conspicuous on bedding planes. Interpretation: proximal prodelta deposit

2. Shale. Silty, olive black (5Y2/1). Weathers chippy. Conspicuous 0.25–1-in.-thick iron-oxide-stained beds. Interpretation: prodelta deposit

1. Shale. Silty. Poorly exposed, weathers chippy. Mica conspicuous on bedding planes. 1-in.-thick fine-grained sandstone at top of unit. Hard, quartzose, calcareous cement, dis-

uncommon. Beds generally very continuous across length of outcrop; locally repetitive. Cross-bedded beds appear to be most common in lower part of unit; plane-parallel bedded beds most common in middle and upper parts of unit. Very minor soft-sediment slump structures in lower part. Unit locally includes some slightly reddish weathering, resistant, calcareous, sideritic, sandy siltstone layers ~1 in. thick. Very abundant carbonized plant trash on plane-parallel beds, some with extremely fine detail of plants preserved. Mica conspicuous on bedding planes. Shale rip-up clasts in basal 3 in. Contact with unit 6 sharp, erosional, marked by scoured channels as thick as 2 ft (Fig. 26), locally with groove casts oriented at N. 70°–75° E. and load casts. Shale locally deformed (compressed) beneath channels. Interpretation: Tidally influenced distributary-mouth-bar deposit.

Figure 23. Unit 8, AOK Railroad, Haileyville measured section, showing rippleform-topped crossbeds, flaser beds, and cyclic character of unit. Vertical burrows (immediately to left of penny) and soft-sediment deformation features (near center of photograph) are locally conspicuous. The abundance of sandstone and cyclicity are evidence that this unit is a tidally reworked upper-distributary-mouth-bar deposit.

Figure 24. Sandstone lens (possible tidal channel), unit 8, AOK Railroad, Haileyville measured section. Hammer for scale (from Hemish and Suneson, 1997, fig. 47).

continuous, locally appears detached and folded. Interpretation: prodelta deposit

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Return to graded gravel road and turn left (northwest).

14.7 0.1 Low ridge is upper Warner sandstone.

14.9 0.2 Road "T's." Turn right (north). Dow Lake is on right (east) side of road.

15.2 0.3 Road turns to left (west) and passes through some low outcrops of the Cameron Sandstone dipping ~15o west. This is the same Cameron ridge that the field-trip route crossed at Mile 12.1.

15.3 0.1 Road crosses Brushy Creek. Highly ripple-bedded bedding-plane outcrops of Cameron Sandstone dipping ~10o northwest exposed on southeast bank of creek.

15.5 0.2 Road crosses outcrop location of McAlester coal.

Most of the area between this location and the town of Dow overlies the Milby and Dow Coal and Mining Co. No. 1 Mine in the McAlester coal (Hendricks, 1937a). The No. 9 Mine, also an underground mine, is mostly west and southwest of Dow, and the underground No. 2 Mine is north and northwest of town. The McAlester coal is exposed in an old strip pit just south of the road (Suneson, 1996); this pit is not shown on Hendricks' (1937a) map, so it must have been active after 1930.

15.8 0.3 Road intersection. Turn right (north).

This flat topography immediately south of the town of Dow is underlain by a thin veneer of the Gerty Sand, an unconsolidated Pleistocene deposit that probably marks the former course of the Canadian River. This deposit is distinguished from Quaternary alluvial deposits by the abundance of Rocky Mountain-derived pebbles and cobbles, especially quartzite. Hendricks (1937a, 1937b) studied the Gerty Sand throughout Oklahoma and concluded that "it is probable that the original course of the Canadian River at the time of the deposition of the Gerty Sand was down Peaceable and Brushy Creeks to (near Haileyville)" (Hendricks, 1937a, p. 31).

16.0 0.2 Dow, Oklahoma.

Dow, Oklahoma

Dow was one of three small coal-mining towns (including Bache and Alderson) that were established along the Choctaw Coal and Railway Company line shortly after it was built. All

Figure 25. Highly rippled, crossbedded, and flaser-bedded sandstone typical of unit 7, AOK Railroad, Haileyville measured section. Sandstones are interbedded with plane-parallel-stratified siltstone and shale. Most ripples and crossbeds are unidirectional. Unit is interpreted as a tidally influenced distributary-mouth-bar deposit. Keys for scale.

were named after coal operators or coal company employees.

Leave Hartshorne 7.5' quadrangle, enter Adamson 7.5' quadrangle. Hemish (1995) mapped the geology of the Adamson quadrangle.

For the next couple of miles the surface geology mostly consists of a dissected veneer of Gerty Sand that is broken by "paleo-hills and -ridges" underlain by moderately south- to southwest-dipping McAlester (Booch) sandstones.

16.6 0.6 Section-line road to left (west). Continue straight. Leave area of underground mines in the McAlester coal.

17.6 1.0 Crossroads. Continue straight. Leave Wilburton Gas Field.

17.9 0.3 Strip mines in the Hartshorne coal are present on both sides of the road.

Figure 26. Base of unit 7, AOK Railroad, Haileyville measured section, showing channelform features and erosive nature of contact between units 7 and 6. Hammer for scale (from Hemish and Suneson, 1997, fig. 50).

Begin ascent up south side (and dip slope) of Pocahontas Mountain, which here is underlain by moderately (25°) south-dipping Hartshorne sandstone on the north flank of the Kiowa Syncline (south flank Adamson Anticline).

18.1 0.2 Top of Pocahontas Mountain.

Hemish (1995) mapped the contact between the Hartshorne Formation and underlying Atoka Formation ~140 ft (in elevation) below the top of the mountain.

18.4 0.3 Road straightens. The broad flat valley in front is underlain by very poorly exposed Atoka Formation which is mostly shale.

18.9 0.8 Approximate trace of Carbon Fault.

Here, the Carbon Fault dips steeply north and juxtaposes north-dipping shales in the Atoka Formation in its hanging wall against south-dipping shales in the Atoka Formation in its footwall. Many geological maps of this area also show the crest of the Adamson Anticline superposed on the fault. Hemish's (1995) cross section shows the triangle-zone geometry of this area.

Gaines Gas Field

Section 10 (T. 5 N., R. 16 E.) immediately to the west makes up the two-well Gaines Gas Field (Boyd, 2002). The discovery well for the field is the Hamilton Brothers No. 1-10 Bernardi-Jones (NE¼SW¼NE¼) which was completed in April 1980 in the Wapanucka Limestone from 10,192 – 11,278 ft. The cumulative production from this well is 587 MMcf gas (IHS Energy, 2006). Chesapeake Operating completed its No. 1-10 Fish Trap well (NW¼NE¼SE¼) in 2004 in the Brazil sandstone from 10,405 – 10,414 ft. This well is a poor producer having a cumulative production of 6 MMcf gas (20 months) and a current production rate of 7 Mcf gas per day. The field has a combined production from both wells of 55 Mcf gas per day (IHS Energy, 2006).

19.0 0.1 Begin ascent over Fish Trap Mountain.

19.1 0.1 Top of Fish Trap Mountain.

Fish Trap Mountain is underlain by steeply north-dipping (80°) Hartshorne sandstone. The Hartshorne – Atoka contact is just below the top of the mountain on its south side. Unlike the south flank of the Adamson Anticline, the Hartshorne coal was rarely mined on the north flank because its dip was too steep.

The valley immediately north of Fish Trap Mountain is underlain by the McAlester Formation.

19.2 0.1 Road turns left (north) and follows section line.

19.5 0.3 Hemish (1995) mapped this low ridge as underlain by the upper Warner sandstone. Stop 3 is the same unit exposed 1 mi to the east. Correlation of the McAlester Formation in this area, as determined by Boyd (2005), suggests this ridge probably is underlain by the Lequire Sandstone which is discussed at Stop 3.

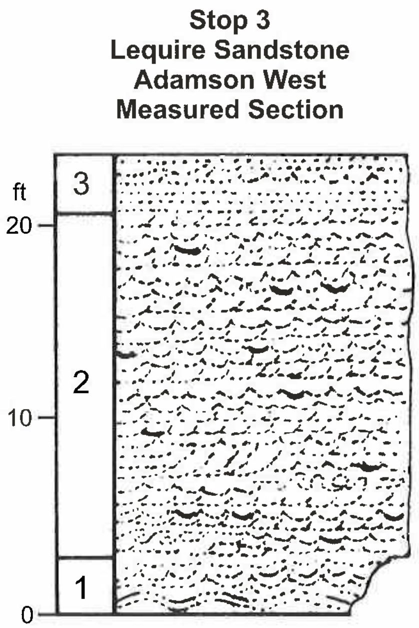


Figure 27. Graphic columnar section of Lequire Sandstone exposed at Stop 3, Adamson West measured section.

19.6 0.1 Low ridge underlain by the Cameron Sandstone. Stop 4 is the same unit ~2.5 mi to the east.

Turn right (east) on major paved county road.

For the next 6.4 mi (to Mile 26.0), the road parallels and is just south of an old railroad grade shown on the 1908 1:250,000 topographic map of the area as the Missouri, Kansas, and Texas Railroad, Wilburton Branch. (Taff (1904) does not mention the line.) The railroad was built to serve the many coal mines in the area, exploiting mostly the McAlester coal to the west and the Hartshorne coal to the east. The line was reclassified as a siding in 1922 and abandoned in 1950 (George and Wood, 1943).

20.6 1.0 Turn right (south) into small parking area opposite the Pittsburg County Water Authority plant. Park near the water pump. Gaines Creek arm of Lake Eufaula is ahead. Walk down steep and rubbly dirt road to examine large outcrop of Lequire Sandstone.

Stop 3. Lequire Sandstone Adamson West Measured Section

Location: Immediately south of county road opposite water treatment plant and road to Hickory Point Recreation Area, just above edge of Gaines Creek arm of Eufaula Lake. About 1.75 mi west of Adamson, Oklahoma. CSE¼NE¼NE¼ sec. 11, T. 5 N., R. 16 E., Adamson 7.5' quadrangle. UTM: 15S 264480 E 3867560 N.

Discussion and Interpretation:

The Adamson West measured section (Fig. 27) is located ~0.5 mi north of the steeply north-dipping Carbon Fault on the south flank of the San Bois Syncline (trough ~2.25 mi to north) (Hemish, 1995). The Carbon Fault is a backthrust that forms the northern margin of a triangle zone in the southern part of the Arkoma Basin; the southern margin of the triangle zone is the Choctaw Fault and the floor is a regional detachment that rises from the Devonian Woodford Chert to the lower part of the Atoka Formation from south to north (Çemen and others, 2001). The Carbon Fault also forms the core of the Adamson Anticline. The Lequire Sandstone at this outcrop dips 25° north.

Hemish (1995) and Hemish and Suneson (1997) mapped the sandstone exposed here as Warner Sandstone. Hemish (1995) described it as a "resistant, moderate reddish brown (10R4/6) to grayish orange (10YR7/4) to moderate yellowish brown (10YR5/4), find-grained, cross-bedded sandstone of variable thickness."

Boyd (2005) mapped a prominent sandstone in the subsurface nearby and correlated it with his parasequence PS-2. This sandstone is 450 ft to 475 ft below the McAlester coal (Boyd, 2005, Pl. 1, wells 15 and 16). He also showed that the Warner-equivalent PS-3A and 3 were poorly developed in this area. Boyd's (2005) observations, the stratigraphic position of this sandstone ~425 ft below the McAlester coal based on surface exposures, and the prominent topographic expression of the ridge underlain by this sandstone suggest this sandstone is the Lequire Sandstone (PS-2) and not the Warner Sandstone (PS-3A and 3).

Figure 28 shows logs from two nearby wells that show the character of the Lequire Sandstone. The Jay No. 1-32 Eddie (CNE¼NE¼ sec. 32, T. 6 N., R. 16 E.) is located ~3.7 mi northwest of this outcrop and the Jay No. 1 Harper (CE½ sec. 3, T. 5 N., R. 16 E.) ~1.4 mi northwest. The gamma-ray logs from both wells show conspicuous "hot" shales immediately above well-developed sandstones. The logs also show that the Warner Sandstone, ~150 ft to 200 ft below the Lequire Sandstone, is poorly developed. The poor development of the Warner Sandstone on the logs is consistent with the poor topographic expression in this area of the lower Warner sandstone as mapped by Hemish (1995).

The Lequire Sandstone exposed along this ridge was measured in detail by Hemish and Suneson (1997, stop 6) a few hundred yards to the east (Fig. 29). There the lower contact of the sandstone and strata above the sandstone are exposed. Although their description of the units is quite good, our interpretation of the Lequire Sandstone (their units 4 and 5) differs from theirs. Hemish and Suneson (1997) suggested the Lequire Sandstone is a delta-plain deposit consisting of "a series of distributary channels," whereas we believe it is an upper-delta-front deposit (see below).

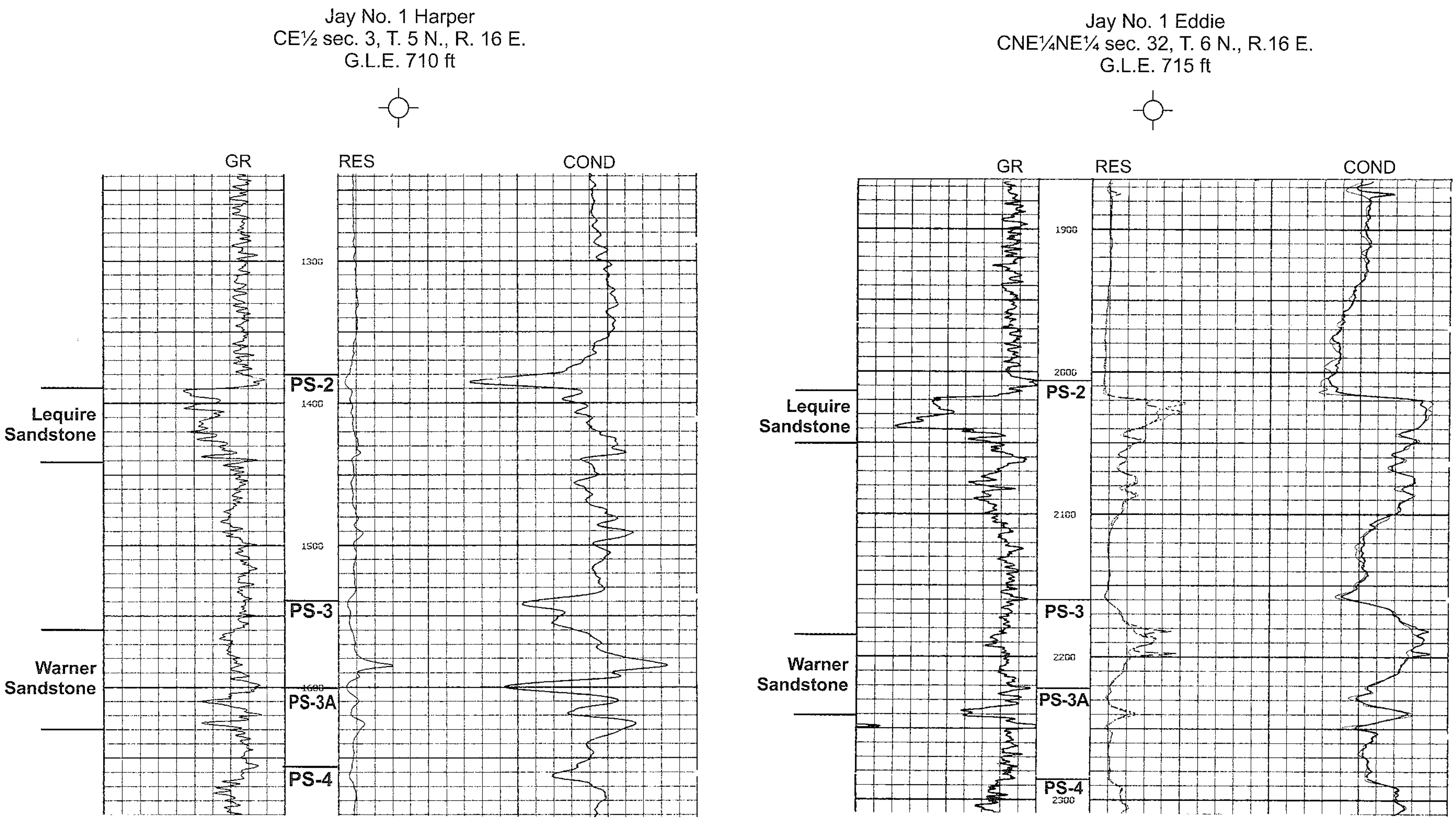


Figure 28. Part of wireline logs from Jay Petroleum No. 1 Harper and Jay Petroleum No. 1 Eddie showing character of Lequire and Warner Sandstones. The sandstone content of the Warner in both logs is less than that in the Lequire, causing the Warner to form less prominent topographic ridges than the Lequire. The sandstone in the No. 1 Eddie is significantly cleaner than that in the No. 1 Harper, illustrating the lithologic variability of the Lequire in the area.

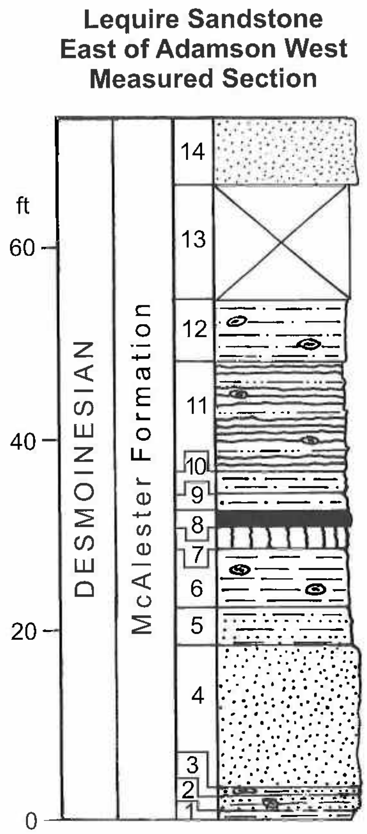


Figure 29. Graphic columnar section of the Lequire Sandstone located just east of the Adamson West measured section (Stop 3, this guidebook) (from Hemish and Suneson, 1997, fig. 35). Hemish and Suneson (1997) called this the Warner Sandstone, but correlation with well logs to the north shows this to be the Lequire Sandstone (PS-2).

At this outcrop, strata underlying the Lequire Sandstone are not exposed; to the east, the sandstone grades into the underlying shale (Hemish and Suneson, 1997, p. 51). The coarsening-upward character of the sandstone at this outcrop is suggested by the gradational contact between units 2 and 1, and the gradational fining downward may extend down-section to the underlying strata as occurs to the east. Evidence that the sandstone (Hemish and Suneson's (1997) units 3 and 4) (this report units 1, 2, and 3) was deposited in a high-energy environment includes cross-stratification, ripple marks, and low-angle truncations; flaser bedding suggests the sediments were influenced by tides. The gradational lower contact and high-energy environment suggests that the Lequire Sandstone here was deposited in a shoaling distributary-mouth-bar environment; the channelform features may be tidal in origin or indicative of periodic erosion related to distributary channels altering course during flood events.

The overlying strata are delta-plain sediments (Hemish and Suneson, 1997) and represent deltaic progradation. The coal probably is not the Keefton coal within the Warner Sandstone as identified by Hemish and Suneson (1997), but is a coal at the top of Boyd's (2005) PS-2.

The coarsening-upward character of the log from the No. 1 Harper supports a distributary-mouth-bar origin for the Lequire Sandstone. In addition, the density log (not shown) suggests that the gamma-ray low at 1,404 ft is a thin coal. The Lequire interval on this log is interpreted to be a 30-ft-thick distributary-mouth bar overlain by ~20 ft of delta-plain strata, including a coal. This shoaling sequence is generally similar to that proposed by Hemish and Suneson (1997). In contrast, the density log from the No. 1 Eddie (not shown) shows a coal at 2,042 ft, below the principal sandstone. Although coals typically occur above these sandstones, the general delta-plain environment that concludes the depositional cycle of each parasequence has coal swamps, bay fills, overbank splays, and distributary channel-fills in close proximity. This allows these environments to occur in almost any order, or even to be repeated, as at Haileyville (Stop 2).

Description of units (Fig. 27):

McALESTER FORMATION:

Lequire Sandstone Member:

3. Sandstone. Fine-grained, slightly silty. Plane-parallel stratification grades laterally into wavy- and ripple-bedded. Poorly exposed.

2. Sandstone and very minor shale. Sandstone fine to very fine grained, moderately sorted, quartzose. Beds 1 to 8 in. thick, generally very continuous along strike (Fig. 30). Some large-scale trough-cross-stratification and very low angle truncated crossbeds. Highly cross-stratified, tops typically ripple-marked. Flaser-bedding common; sideritized shale preserved in troughs. Some beds locally show soft-sediment deformation, contain rolled and/or slumped sandstone masses 1 – 2 ft. thick. Individual beds may thicken upward. Contact with unit 1 sharp and conformable (Fig. 31).

1. Sandstone and minor shale. Sandstone fine-grained, moderately sorted, quartzose. Comminuted carbonaceous organic debris and mica on abundant partings. Lower part: Lenticular- and wavy-bedded sandstone interbedded with sideritized shale. Sandstone cross-stratified, exhibits much pinch-and-swell. Individual beds continuous. Amount of sandstone increases upward.

Return to paved county road, turn right and continue east.

21.0	0.4	Cross Gaines Creek arm of Lake Eufaula.
22.1	1.1	Enter Adamson, Oklahoma. The following brief history of Adamson is modified from http://www.adamsonancestry.com/place-names/adamson-okla.html, retrieved April 15, 2005.
22.2	0.1	Turn left (north) immediately and drive up hill.

Eufaula Lake and Dam

(the following is modified from the U.S. Army Corps of Engineers website: http://www.swt.usace.army.mil/PROJECTS/civil/civil_projects.cfm?number=10, retrieved August 2, 2006).

Eufaula Lake is the largest lake in Oklahoma, with more than 600 mi of shoreline and 102,000 surface acres (~ 160 sq mi). Eufaula dam was built between 1956 and 1964 ~9 mi below the confluence of the Canadian and North Canadian Rivers (originally just east of the present-day town of Eufaula). The lake now extends well up those rivers, as well as the Brushy Creek / Gaines Creek drainages to the south near McAlester and the Coal Creek / Deep Fork drainages to the northwest just east of Henryetta. The lake and dam were built for flood control, water supply, hydroelectric power, and navigation.

The lake now covers several trails and towns of historical significance, including the Texas Road, a branch of the California Road (see Mile 75.0, Day Two), and North Fork Town. The Texas Road was a major wagon route for Texas immigrants crossing Indian Territory in the 1830s. U.S. Highway 69 approximately parallels the old road through much of Oklahoma, and the Missouri, Kansas, and Texas (Katy) Railroad – the first rail line built (1872) across Indian Territory – also follows the Texas Road. "The Texas Road and a branch of the California Road crossed at North Fork Town, making it a major intersection of traffic. This important tribal community was the scene of the treaty signing between the Confederates and the Creeks, Choctaws, and Chickasaws in 1861."

22.4 0.2 Park in driveway at private residence near top of hill.

Mr. Jim Whiting has kindly granted us permission to visit this excellent outcrop of the Cameron Sandstone. For permission to visit this outcrop, please contact Mr. Whiting at (918) 297-2913.

Stop 4. Cameron Sandstone Adamson Measured Section

Location: Private residence on north side of Adamson, Oklahoma. Center N½N½NW¼NE¼ sec. 7, T. 5 N., R. 17 E., Adamson 7.5'quadrangle. UTM: 15S 267155 E 3867705 N.

Discussion and Interpretation:

This outcrop of the Cameron Sandstone (Figs. 32, 33) is located on the south flank of the San Bois Syncline (trough ~2.5 mi to north) and ~0.7 mi north of the trace of the steeply north-dipping Carbon Fault. This fault forms the north side of a triangle zone that separates the Arkoma Basin and Ouachita fold-and-thrust belt in this part of Oklahoma. The strata dip ~25° north. Hemish (1995) mapped the McAlester coal ~150 ft above the base of this sandstone. Because the coal is easily identified on well logs, this outcrop can be confidently correlated with well-log signatures in nearby wells. The Cameron Sandstone at this locality underlies a ridge with ~100 ft of relief. Along strike this ridge is a much less prominent feature, in some places disappearing altogether. This is evidence that the sandstone content of the Cameron interval varies widely, in some places probably containing little more than thin-bedded siltstones.

The Coquina No. 1 Tobe (E½E½W½NE¼ sec. 5, T. 5 N., R. 17 E.) (Figs. 34 and 35) is located ~1.2 mi northeast of this outcrop. The McAlester coal is distinctive on the gamma-ray, resistivity, and density logs and the Upper McAlester coal is ~47 ft above it. The first sandstone is ~80 ft below the coal and is ~80 ft thick. This thickness, combined with its sharp upper and

Figure 30. Unit 2 of Lequire Sandstone at Stop 3, Adamson West measured section, showing cliff-forming sandstone with continuous partings. Minor large-scale cross-bedding locally present. Sharp basal contact of unit 2 is overhang near bottom of photograph.

Adamson, Oklahoma

Named for Peter Adamson, mine owner
Post Office March 1, 1906 – unknown

Adamson developed first as a coal mining camp, then in the early 1900's as a town. Within the four-square-mile area in which it served as the trading center were fifteen mines, four of which were considered major producers. The town reached its peak during World War I, when coal formed the chief source of energy for railroads, electricity generation, and general manufacturing activities. At that time the population in the area was estimated at more than 5,500 persons, including 700 living in Adamson. The Rock Island & Katy Railroads both built tracks into the community to serve the mines. From 1913 to 1919 Adamson was known as a "live town." There was fighting and dancing, Choc beer drinking, and intermarriage between the people that moved here from various parts of the world. The four major mines were worked twenty-four hours a day, with each employing about two hundred men. Railroads carried out trainloads of coal daily. Money flowed freely. Holidays of a dozen different European countries were celebrated. One merchant of the time records: "We had a busy city then. It was gay and happy and something happened all of the time."

All of the mines in the Adamson area were slope mines, and most had a dip of about 35 degrees northward. Coal was taken from both the McAlester and Hartshorne outcrops. The deepest was the Hartshorne, which was workable in most of the area where it averaged about four feet in thickness. The McAlester bed, approximately one thousand feet above the Hartshorne, varied in thickness from three feet to a maximum of five feet. On September 4, 1914, one of the major mine disasters in Oklahoma occurred at Mine No. 1, one quarter mile south of the principal business district of Adamson. At about 3:30 p.m. a miner reported that he had heard a cracking noise in the mine. All men were ordered out of the mine at once. The trips carried the men up a sixteen-hundred foot incline, set on a 45 degree angle, to the tenth level about eight hundred feet below the surface. All were up to this level except fourteen still in the bottom room. The underground tunnels and rooms of the mine, almost without warning, began to "squeeze" and collapse. "Increasing creaking noises, a groan from the earth, and a splintering of supports foretold the carnage." Several stated there was one great noise like an explosion far beneath the ground; at the same time the surface the earth dropped eight to ten feet. The bodies of the fourteen men were never recovered.

Today about ten small homes, largely occupied by retirees, remain north of the old main street. Two small grocery stores remain, but much of their business is from visitors to nearby Lake Eufaula. All the mines are now closed and filled with water. About one quarter mile south of the former business area the land between mine pillars continues to settle gradually, and a series of somewhat elongated ponds is forming. Water flowing from the old mines now presents a problem to conservationists. The water is highly mineralized and contaminates nearby streams, sometimes killing large numbers of fish.

One person now living in the area stated that Adamson was a ghost town with fourteen ghosts watching over it.

(From the book by John W. Morris, *Ghost Towns of Oklahoma*. (Norman: University of Oklahoma Press, 1977))

especially lower contacts, strongly suggests a multi-story channel-fill (incised valley) with an erosive base. Based on surface-mapped stratal thicknesses, this 80-ft-thick sandstone, although thicker, is the same as that seen in this outcrop.

The Hamilton Brothers No. 1 Winship-Browne (W½E½NE¼ sec. 31, T. 6 N., R. 17 E.) (Fig. 35) is located ~1.8 mi north. The McAlester coal is clear on the log, but the upper McAlester coal is absent and the Cameron Sandstone is poorly developed. Although both of these wells have sandstones roughly the same distance below the McAlester coal, these are not stratigraphic equivalents. Given that both should have a similar thickness of prodelta shale above the top of PS-2, one can infer that the original PS-1 flooding surface, defined in the No. 1 Winship-Browne, has been removed due to incision in the No. 1 Tobe. This would place the original PS-1 flooding surface (dotted line on Fig. 35) in the middle of the sandstone and the actual top at the base of the sandstone. If true, the Cameron Sandstone in the No. 1 Tobe was deposited during middle PS-0 time as an incised-valley fill, whereas the Cameron Sandstone in the No. 1 Winship-Browne was deposited during maximum progradation (at the end of PS-1 time) on the extreme edge of a delta complex (Fig. 35). The markedly different e-log character of these wells highlights the lateral variability of the Cameron Sandstone over short distances.

The Cameron Sandstone at this stop consists of a basal 32 ft (units 5 and 6) that is mostly sandstone overlain by 16.5 ft of interbedded sandstone and probable shale (covered) (units 7 through 14) (Fig. 32). The shaley strata below the sandstones are unlike those exposed beneath the Warner Sandstone at Stop 2, being siltier and not the dark gray characteristic of marine and prodelta shales in the McAlester Formation. The lithology and well-preserved megaflora (unit 2) of these units are evidence they probably are bay-fill deposits. The abrupt, erosional base of the sandstone (unit 5) is similar to the lower

Figure 31. Well-stratified sandstone and minor shale of unit 1, Lequire Sandstone at Stop 3, Adamson West measured section. Contact between unit 1 and overlying unit 2 is sharp and conformable. Hammer for scale.

Warner sandstone at Stop 2 and the Warner Sandstone at Stop 14. Many features observed here, such as cross-stratification and ripple marks, suggest a moderately high-energy environment of deposition. Flaser-bedding and herringbone cross-stratification are strong evidence for tidal reworking. These strata, like the lower part of the lower Warner sandstone at Stop 2 and the Warner Sandstone at Stop 14, probably represent tidally reworked distributary-mouth-bar deposits. The thin sandstone beds (units 8, 10, 12, and 14) are more difficult to interpret because the intervening shales are not exposed. As the scour marks on the base of units 12 and 14 are evidence for deposition from an initially high-velocity flow, they may represent overbank/crevasse-splay deposits.

Description of units (Fig. 32):

McALESTER FORMATION:

Cameron Sandstone Member:

14. Sandstone. Very fine grained. Highly silica-cemented. Sharp base and top; top flat, scour marks on base. Slight pinch and swell. Poorly exposed.

13. Covered.

12. Sandstone. Slightly wavy-bedded. Sharp base and top; scour marks on base. Poorly exposed.

11. Covered.

10. Sandstone. Very fine grained. Plane-parallel- and cross-stratified. Poorly exposed.

9. Covered.

8. Sandstone. Very fine grained, poorly sorted. Very ripple-cross-stratified. Poorly exposed.

7. Covered.

6. Sandstone. Fine-grained to less commonly very fine grained, moderately sorted, moderately porous. Conformable with unit 5. Plane-parallel- and ripple-cross-stratified. Bidirectional foreset beds and herringbone cross-stratification present locally (Fig. 36). Individual beds very continuous, although some show minor pinch and swell. Minor flaser-bedding (Fig. 37). Soft-sediment deformation/incipient slumping near top; minor crumpling. Unit forms top of cliff.

5. Sandstone and minor siltstone. Fine-grained, quartzose, iron-oxide coatings on grains. Unconformable with unit 4; erodes 4 ft into shale in unit 4. Channelform; similar to base of unit 7, Haileyville Railroad outcrop, Stop 2. Mostly plane-parallel stratified, uncommonly cross-stratified, flaser-bedded, and ripple-marked. Some large, low-angle crossbeds. Partings formed by abundant mica, comminuted carbonaceous organic debris, some with fine detail preserved. Some plant compressions as large as 2 in. on bedding planes.

4. Shale. Conformable with unit 3. Silty. Fissile, Very abundant comminuted carbonaceous organic debris.

3. Sandstone. Medium-fine grained, poorly sorted. Conformable with unit 2. Plane-parallel stratified, very slightly wavy-bedded near top.

2. Shale and minor siltstone. Conformable with unit 1. Increase in siltstone toward base. Abundant well-preserved leaf fragments.

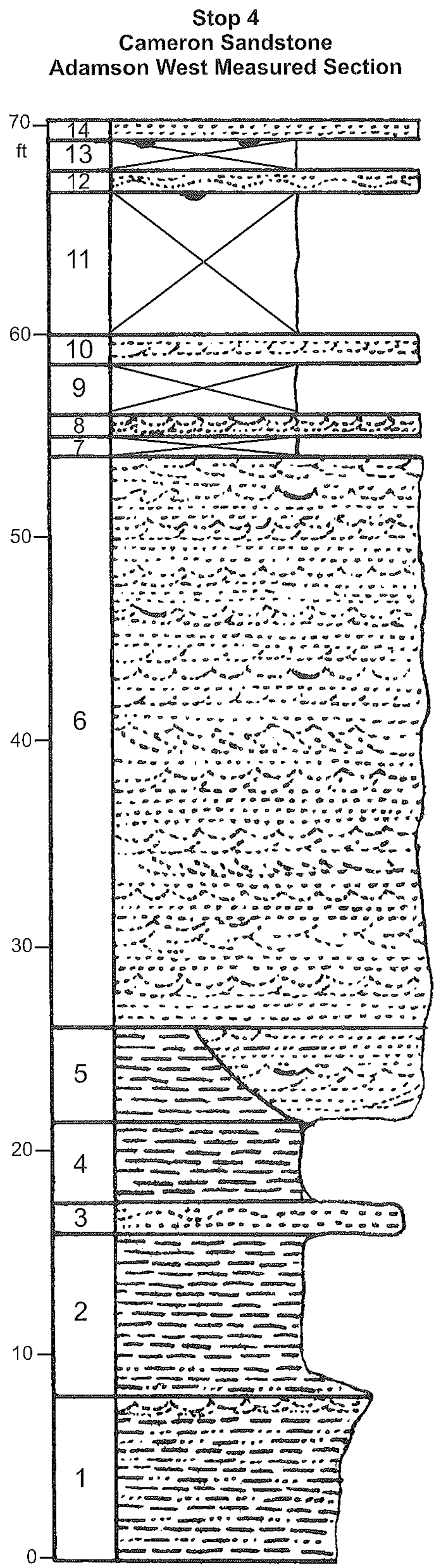
1. Siltstone, shale, and minor sandstone. Laminated, plane-parallel stratified. Minor ripple-cross-stratified very fine grained sandstone near top in beds as thick as 0.5 in.

Stop 4 is located ~1 mi south of the southwestern corner of the giant Kinta Gas Field, which extends from here ~70 mi northeast, almost to the Arkansas state line. The field is briefly described at Mile 35.9, Day Two of this guidebook.

Return to main county road through Adamson.

22.6 0.2 Turn left (east).

23.0 0.4 Intersection with county road to right (south) to Hartshorne. Continue straight. Cross unnamed arm of Lake Eufaula.



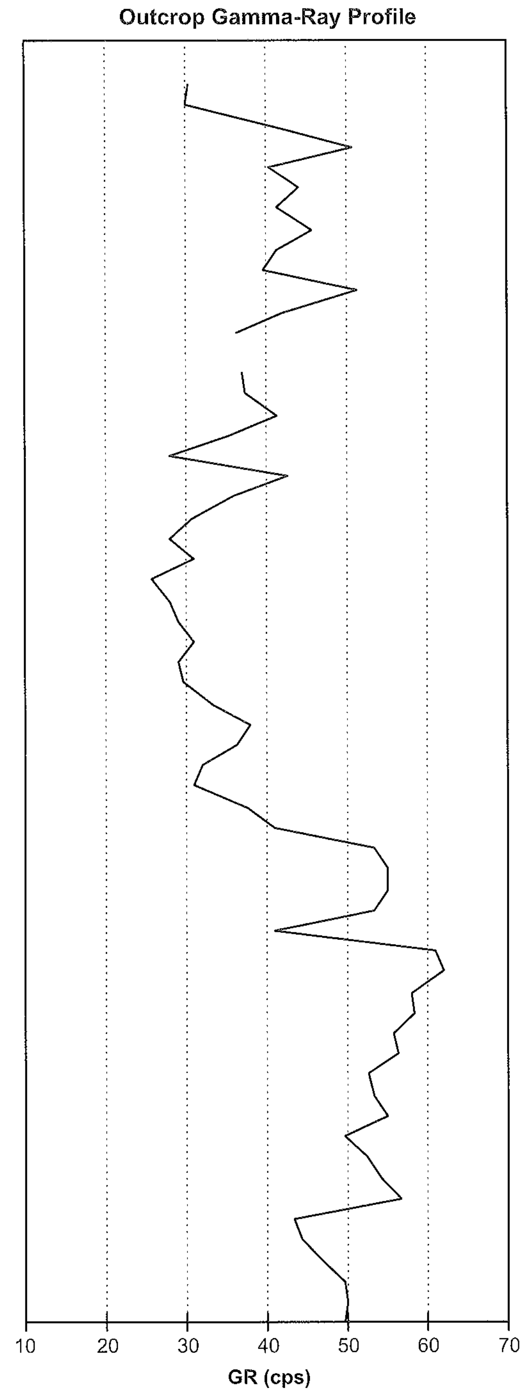


Figure 32. Graphic columnar section of Cameron Sandstone exposed at Stop 4, Adamson measured section, and outcrop gamma-ray profile. Although major lithologic differences are indicated on the gamma-ray profile, subtle changes are difficult to discern in outcrop. For example, the slight fining-upward (increasing shale content) in unit 6 based on its gamma-ray profile is not obvious in outcrop. The profile was not extended to the isolated sandstones at the top of the measured section because they are discontinuous and the intervening strata are covered.

For the next 3.1 mi the county road follows a valley underlain by the McCurtain Shale Member of the McAlester Formation. The ridge to the right (south) is underlain by moderately (40o) north-dipping Hartshorne sandstone; the ridge to the left (north) is underlain by moderately (35°) north-dipping Warner Sandstone.

Hemish (1995) did not map lower and upper Warner sandstones in the Adamson quadrangle, but based on topographic expression, the upper Warner sandstone appears to be better developed than the lower. The topographic expression of the Warner Sandstone varies along strike. From Mile 23.0 to Mile 25.0 it forms a prominent ridge immediately north of the road; from Mile 25.0 to 26.1 (and extending east across the Gowen quadrangle) the "ridge" is barely discernible. The topographic expression probably increases with the amount of sandstone present.

Hendricks (1937a, 1939) and Hemish (1992, 1995) show several strip and slope mines along the length of the Hartshorne coals between Adamson and Chilli (~6.5 mi east of Adamson). Most of the mines were in the Lower Hartshorne coal; some were in the Upper. Some of the mines extended underground as much as 1,000 ft from the surface outcrop of the coal. Two slope mines exploited the McAlester coal between Adamson and the Pittsburg-Latimer County line (Hendricks, 1937a).

24.2 1.2 Road passes over Pierce No. 1 Mine (underground) in Lower Hartshorne coal.

24.9 0.7 Leave Pittsburg County, enter Latimer County. Note old railroad grade immediately on right (south) side of road.

25.4 0.5 Leave Adamson 7.5'quadrangle, enter Gowen 7.5' quadrangle. Hemish (1992) mapped the geology of the Gowen quadrangle.

26.0 0.6 Turn right (south) on Clonsilla Hill Road. Begin ascent of Hartshorne ridge.

26.2 0.2 Top of ridge underlain by Hartshorne sandstone.

Hemish and Suneson (1997) measured more than 370 ft of Hartshorne Formation below the Lower Hartshorne coal here and on the southern slope of the ridge. The section consists mostly of shale and siltstone with minor, although locally as thick as 20 ft, sandstone beds. They interpreted most of the strata as delta-plain, shallow-marine, and prodelta deposits.

26.6 0.4 Base of ridge. Road straightens and follows section line.

Road crosses trace of steeply north-dipping Carbon Fault. The subsurface geometry of the fault here (as shown by Hemish (1992)) is similar to that at Mile 18.9. The fault juxtaposes shales in the Atoka Formation.

Discovery of Wilburton Gas Field

Three "discovery" wells in the Wilburton Field (Fig. 38) were drilled just south of here (Suneson and others, 1990, p. 7). The "first" discovery well is the Limestone Oil and Gas No. 1 Nettie McCurray in the SW¼SW¼SW¼ sec. 15, T. 5 N., R. 18 E. It was spudded on May 12, 1927, and finished drilling on December 9, 1929 at a total depth of 4,038 ft. The driller's log shows mostly slate [*sic*], shale, and sandy lime to TD, with some oil shows and gas starting at 1,075 ft. Production of 2 MMcf gas per day was from a gray sand at 2,518–2,548 ft (Hendricks, 1939). Logs of nearby wells show the base of the Atoka Formation to be ~9,000 ft deep; therefore, this well produced gas from a shallow sandstone in the Atoka Formation. Gas from the Nettie McCurray supplied nearby residents.

The "second" discovery well is recognized by the Oklahoma Nomenclature Committee of the Mid-Continent Oil and Gas Association as the discovery well of the Wilburton Field. The Ambassador Oil Corporation No. 1 W. M. Williams Unit was drilled in the SW¼SW¼NE¼NW¼ sec. 23, T. 5 N., R. 18 E., ~1.25 mi east of the McCurray well. It was spudded on September 21, 1960, and drilling finished on November 11, 1960 at a total depth of 9,704 ft. It was completed on December 15, 1960 in the Spiro sandstone at 8,811–8,831 ft with an open-flow potential of 8.3 MMcf gas per day. The well started production in November 1963 and has produced 14.2 Bcf gas; it currently produces 98 Mcf gas per day (IHS Energy, 2006).

The "unofficial" discovery well of the "Wilburton Deep" field is the Arco No. 2 Yourman in the S½S½NE¼ sec. 15, T. 5 N., R. 18 E. about half a mile south of here and a mile northeast of the McCurray well. It was spudded on February 8, 1987 and reached a total depth of 15,391 ft on June 25, 1987. Arbuckle carbonates were perforated between 14,259 and 14,500 ft. The well had a calculated open-flow potential of 73 MMcf gas per day and an initial-flow potential of 9.3 MMcf gas and 128 bbl water per day.

The Yourman well is the seventh most prolific gas well in Oklahoma, having produced 53.1 Bcf gas since its discovery (IHS Energy, 2006). The best Arbuckle well in the field, and the fifth best gas well in the State, is about a mile west of the Yourman well; the Arco No. 2 Kilpatrick, completed on June 23, 1988, has produced 61.6 Bcf gas and is still producing ~3MMcf gas per day. To date the 18 Arbuckle wells in the Wilburton Field have produced about 361 Bcf gas and are still producing ~10 MMcf gas per day. By comparison, the Spiro wells just south of the highway commonly have cumulative production volumes of between 5 and 25 Bcf of gas per well.

Interestingly, all three "discovery" wells are within ~1 mi of each other and are near the crest of the Wilburton Anticline (Fig. 38). Despite their proximity, they are not simply deeper pools associated with the same structure but are, in fact, separate pools separated by significant structural discontinuities.

Wilburton, Oklahoma

The history of Wilburton is closely tied to the railroad that passes through the center of town and the coal mines to the east and west. The town was named for Will Burton, a contractor or surveyor, who helped build the Choctaw, Oklahoma, and Gulf railroad and plat the townsite in 1890 (Wooldridge, 1976). The first coal shaft was constructed by Peter Adamson, Sr. in 1889 ~1 mi west of Wilburton; that same year, the railroad company also constructed a shaft just west of town. In 1895 James Degnan and James McConnell, future major coal operators, began regular mining operations.

Three major coal mining companies operated in the Wilburton area starting about 1900. The Eastern Coal Mining Company, locally known as the "Degnan Mines," operated west of Wilburton. The Great Western Coal and Coke Company (GWCC), or "Busby Mines," operated 1 mi to the east of town and the Hailey-Ola Company had mines 3 mi to the east. Two sites associated with Wilburton's coal industry are included on the National Register of Historic Places. These are the GWCC Company building at 701 E. Main Street and the surface structures associated with the GWCC Mine No. 3, which underlies much of the town. Notable dates in Wilburton's history are 1906, when 442,000 tons of coal was shipped from Wilburton, surpassing Coalgate, and January 13, 1926, when 91 miners were killed in an explosion at the Degnan-McConnell Mine No. 21.

Wilburton-Area Coal-Mine Hazards

The Hartshorne coals have been extensively underground-mined near Wilburton and strip-mined west of town. Although some coal was mined for use by the Butterfield Overland Stage Line (see Mile 41.8, Day One), large-scale mining in the area began "in 1887 with the construction of the Choctaw Coal and Railway Company line from Wister to McAlester" (Gunning, 1975, p. 39). Hendricks (1939, pl. 27) shows the extent of the underground mines in 1931 and lists the major coal companies: Missouri Kansas and Texas Coal, Eastern Coal and Mining, Degnan and McConnell, Great Western Mining, Hailey–Ola Coal, among others. The Oklahoma Conservation Commission (OCC) estimates that ~1,500 acres is undermined in the Wilburton area. In the mid-1930s, most of the underground mines closed, and in the early 1940s strip mines opened along the outcrops of the Hartshorne coals. Most of the strip-mining operations had ceased by 1960.

The OCC divides the Wilburton area into a number of "problem areas" because of the hazards left as a result of the old mining operations. Perhaps the most serious (and continuing) hazard is subsidence over the Great Western Mining Company Mine No. 3 (Fig. 40), particularly in the area of Wilburton south of the railroad tracks. Periodically, houses, roads, and utilities are damaged due to surface subsidence into the mine.

Strip mines in the McAlester coal are present north of town.

27.3 0.7 Turn left (east) on county road.

28.3 1.0 Re-enter Wilburton Gas Field (Boyd, 2002) (see Mile 8.7). This is part of the original Wilburton Gas Field of Burchfield (1985).

30.3 2.0 County road (also section-line road) intersection. Continue straight.

About 2 mi north is the small village of Chilli. Chilli is located where Boiling Springs Creek forms a gap in the long ridge of Hartshorne sandstone crossed at Mile 26.2. Hendricks (1939, pl. 27) shows a "Boiling Spring" ~0.2 mi southwest of Chilli along the creek and near the base of the ridge. The springs issue very near the trace of the Carbon Fault. Hendricks (1939, p. 277) notes that "Boiling Spring, a gas seep in sec. 6, T. 5 N., R. 18 E., is situated on the Carbon fault plane, which serves as an avenue of escape for gas present in beds beneath the surface at the locality."

31.3 1.0 County road (also section-line road) intersection. Bowers, Oklahoma.

31.4 0.1 Intersection with U.S. Highway 270. Continue straight. The road log for Mile 31.4 to 45.3 and from 47.7 to 76.2 is modified from Suneson and others (2005).

32.8 1.4 County road to Wilburton Airport to left (north). This location is at the middle of the section line between secs. 10 and 15, T. 5 N., R. 18 E., and is near the center of the Wilburton Gas Field.

33.8 1.0 Leave Gowen 7.5' quadrangle; enter Wilburton 7.5' quadrangle. Hemish and others (1990a) mapped the geology of the Wilburton quadrangle.

Note the mounds on either side of the highway (Fig. 39). Suneson and others (2005, p. 117-118) describe the various explanations of the origin of mima mounds. These, most likely, are the result of tunneling by pocket gophers, moles, and earthworms, and sheet erosion in the intermound areas (Allgood and Gray, 1974).

36.3 2.5 Eastern Oklahoma State College (formerly Oklahoma School of Mines and Metallurgy, founded in 1908) on left (north). EOSC houses the Oklahoma Miner Training Institute.

38.8 0.5 Intersection with State Highway 2. Continue straight.

The trace of the Choctaw Fault crosses S.H. 2 ~0.7 mi to the south.

39.1 0.3 AOK Railroad (formerly Chicago, Rock Island, and Pacific) on right (south). See Mile 14.3 for a brief history of this important railroad.

39.3 0.2 Intersection with S.H. 2 to left (north). Continue straight on U.S. 270.

39.8 0.5 Enter Wilburton, Oklahoma. Continue west on U.S. 270 through the center of town. The boundary of Wilburton Gas Field is ~1 mi east of town (Boyd, 2002).

40.3 0.5 Road forks. Stay left on U.S. 270. An old store used to be at the fork.

41.8 1.5 Lutie Coal Miner's Museum on left (north) (Fig. 41). This is an excellent museum and well worth a visit.

About 1 mi east of the Lutie Museum and just south of U.S. 270 is the Lutie Cemetery. The cemetery is very close to the site of Riddle's Station, a stop on the Butterfield Overland Stage Line which operated from 1858 to 1861.

Enter Panola Gas Field (Boyd, 2002).

Panola Gas Field

The Panola Gas Field was discovered by the Mobil No. 1 Pete Parks well (SE¼SW¼SW¼ sec. 33, T. 6 N., R. 20 E.), which was spudded on September 1, 1963. Drilling was finished on January 14, 1964, and the well was completed on February 18, 1964, in the Spiro sandstone at 13,089–13,114 ft for 831 Mcf gas per day. The well has a cumulative production of 77 MMcf gas and is now abandoned.

The Panola Field includes 87 wells, of which 65 remain active (IHS Energy, 2006). Cumulative production from the field is 135 Bcf gas. The principal reservoirs are sandstones in the middle part of the Atoka Formation, including, from top to bottom, the Red Oak, Panola, Diamond, Bullard, Cecil, Shay, and Spiro. The only middle Atoka sandstone that does not appear to produce gas in the Panola Field is the Brazil sandstone. In addition, Oklahoma Corporation Commission 1002A forms show "lower" and "upper" Atoka sandstones as producers. Most of the production is from the Spiro, which produces from 52 wells (including commingled wells).

Most of the reservoir units in the Panola Gas Field consist of thrust-faulted and folded Atoka turbidite sandstones, including channel and lobe deposits (Andrews, 2008). Structurally high sandstones with >6-8 percent porosity are the most productive in the field.

42.4 0.6 Highway crosses a low ridge underlain by Warner Sandstone dipping 19° north.

42.9 0.5 Cross Fourche Maline, French for "treacherous fork."

43.1 0.2 Leave Wilburton 7.5' quadrangle; enter Panola 7.5' quadrangle. Hemish and others (1990b) mapped the geology of the Panola quadrangle.

44.5 1.4 Low ridge to left (north) is underlain by Cameron Sandstone dipping 25° north. High ridge to right (south) is underlain by Warner Sandstone also dipping 25° north. Between here and Wister (Mile 76.2, Day One) the highway crosses the McAlester Formation; flat areas are shales within the McAlester and ridges are underlain by McAlester sandstones. The steep south-facing slopes of the Sans Bois Mountains to the left (north) are underlain by the Savanna Formation.

45.3 0.9 County road to right (south) in small town of Panola. Turn right (south) and immediately cross railroad tracks.

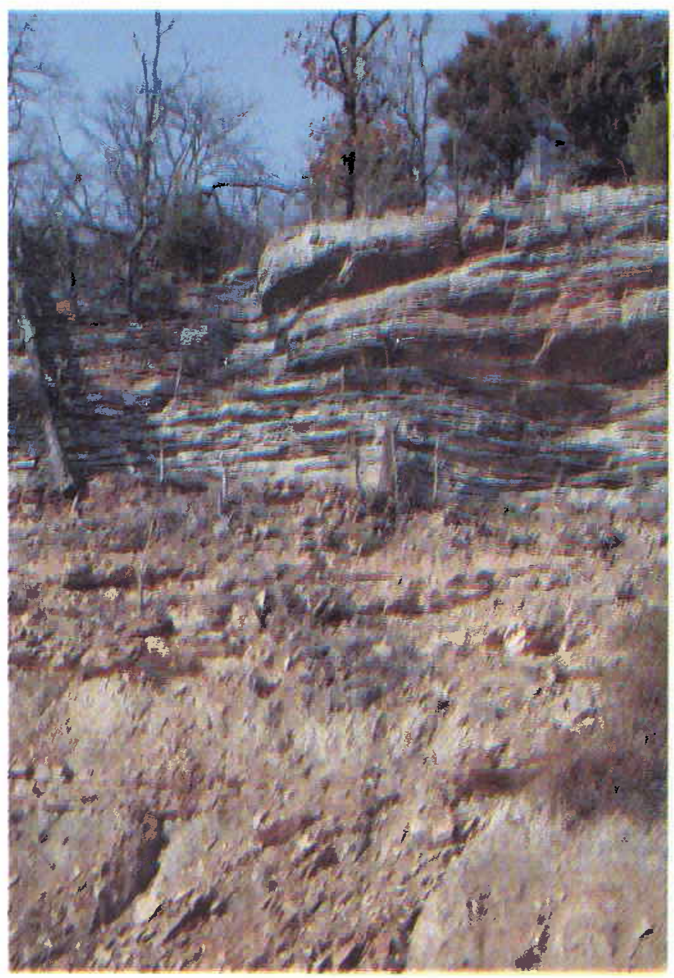


Figure 33. Outcrop photograph of Cameron Sandstone at Stop 4, Adamson measured section. Photograph includes all but basal ~10 ft and upper ~20 ft of measured section. Well-stratified sandstone in lower left of photograph is unit 3; sandstone unit 6 includes most of exposed section.

Butterfield Overland Stage Line and the Riddle Station

(From Suneson and Hemish, 1994)

As the population of the western United States increased during the 1840s and 1850s, particularly after the discovery of gold in California, the need for better east-west communications grew. In April 1857, the postmaster-general advertised for bids to operate an overland stage line between the Mississippi River and San Francisco. In September, John C. Butterfield (of Utica, New York) and associates were awarded the contract. The route they chose to follow started in Tipton, Missouri (the railroad terminus at that time), and extended west to Fort Smith, Arkansas; Preston, Texas; El Paso, Texas; Fort Yuma, California; and on to San Francisco – a trip of about 2,800 miles. The terms of the contract required that mail and passengers be carried safely to and from San Francisco twice a week and that the total time for the one-way trip was not to exceed 25 days. For this, Butterfield and his associates would be paid $600,000 per year. An additional stipulation of the contract was that stations were to be built along the route; they would serve a "restaurants" for the passengers on the stageline, and also as stables, blacksmith shops, and local post offices. In Indian Territory (now Oklahoma), these stations were run by citizens of the Choctaw and Chickasaw Nations.

The stage ran 24 hours a day so passengers had to sleep on the move, but "the seat backs would let down for beds at night" (Wooldridge, 1976, p. 9). The one-way fare was $200, not including meals, and passengers were allowed 40 pounds of luggage at no extra cost. A letter from Missouri to California cost 10¢.

The Butterfield Mail operated in southeastern Oklahoma between 1858 and 1861. The 192-mile trip through Indian Territory started in Fort Smith, Arkansas, and ended at Colbert's Ferry (near present-day Colbert) on the Red River. The stage passed through 12 stations in Oklahoma: Walker's (Skullyville) [see Day Two, Mile 20.7] and Trahern's in Le Flore County; Holloway's (the Narrows), Riddle's, and Pusley's in Latimer County; Blackburn's in Pittsburg County; Waddell's, Geary's, and Boggy Depot in Atoka County; and Nail's Crossing, Fisher's (Carriage Point), and Colbert's Ferry in Bryant County. The Choctaw Nation recognized the importance of permanent highways through their lands, and the Choctaw General Council passed laws requiring all free men (excluding school teachers, farmers, students, and doctors) to work six days per year on public roads. However, the size of the territory (18,220 square miles) and low population (24,000 persons) precluded effective highway maintenance (Wright, 1933, p. 805).

The operation of the Butterfield stages through Indian Territory was of such importance that the Choctaw and Chickasaw Nations each granted eight toll-gate privileges along the road from Fort Smith to the Red River. The tolls (as granted by the Choctaw Council) were as follows:

For each four wheeled wagon, or other vehicle, drawn by four or more horses, mules, or oxen with driver, the sum of Fifty cents; For each four wheeled wagon, or other vehicle, drawn by one or two horses, mules or oxen, the sum of Twenty-five cents; For each man and horse, the sum of Ten cents; and for each animal in every drove of cattle, horses, mules, hogs, or sheep, One cent. (Wright, 1933, p. 806)

The tolls were collected by citizens of the Choctaw and Chickasaw Nations who guaranteed to build bridges over the larger streams and to maintain roads over the more difficult parts of the countryside.

Because the Butterfield Mail route traverses a part of our field-trip area, a description of its course it given here:

About one mile east of present-day Red Oak, highway 270 and the tracks of the Rock Island Railroad cross the abandoned mail road where it curved west after traversing the old McCurtain place. From this point the road continued on a course almost due west, south of the present main line of traffic, to [Capt. John] Riddle's keeping along the edge of the southern foothills, that border the narrow valley now traversed by the railroad and highway. Both Little and Big Fourche Maline creeks were crossed … An iron bridge now spans the stream [Big Fourche Maline] near the old crossing which may have been about seventy-five feet north of the bridge.

The west course of the Overland Mail, south of Red Oak, was no accident. It was determined by the geology of the country. From a point three miles south of Red Oak to a point south of Wilburton, there is a line of east-west hills, rising to a height of over eight-hundred and fifty feet, that would have been real "horse-killers" to cross. The Overland Mail in choosing this route took advantage of the fine engineering work of nature and crossed these hills at a point where Fourche Maline Creek had laboriously cut through the hills. (Wooldridge, 1976,p. 7)

[Riddle, whose mother was Choctaw,] … was a prominent leader … in the Indian Territory. … [Riddle Station] was … a little over two miles east of Wilburton … near the old [Lutie] cemetery just to the south of the present highway, on the side of the hill a few hundred yards west of the Fourche Maline. (Wright, 1933, p. 807-808)

The station was a two room log house with a breezeway and stone chimneys. … Some of the land was bottom, some prairie, and some hillside. … Wood, water, and shade were abundant here in the station area and seams of good coal outcropped in the hillside to the south of the station. This coal was mined and used for fuel and forge. There was considerable blacksmithing to do in the Butterfield business as well as for the Choctaw farmers and ranchers, and the coal was a boon to the blacksmith forges. It is known that much coal was mined and shipped by wagon to other blacksmith shops east and west of the Riddle station along the Butterfield Road. The company itself operated blacksmith shops at intervals along the route. (Gunning, undated, p. 25)

The stable at the Riddle Station was south of the house on a grassy plat and Riddle's two sons took care of the horses, as well as harnessing them and bringing them out to hitch to the stage as the coach approached the station. … The Riddle station was completely demolished at the death of George Riddle [John Riddle's son] by people digging for gold, because of a story that he had buried gold on his premises. (Wooldridge, 1976, p. 7-8)

After the Civil War, the Butterfield Overland Mail changed its name to Wells-Fargo Express Company and new routes were established. The company became known as the American Railway Express Company when railroads replaced stagecoaches. Later it was split into the American Express Company (credit cards, traveler's checks) and the Railway Express Company (Fox, 1961, p. 41).

The Upper and Lower Hartshorne coals have been extensively underground-mined west of Panola. Three small adits in the McAlester coal are present immediately north and west of Panola just north of the highway. The Upper McAlester coal is also present.

45.7 0.4 Cross very low ridge underlain by Warner Sandstone dipping about 25° north (Hemish and others, 1990b). This probably is the lower Warner sandstone.

46.1 0.4 Road forks; bear left (south).

46.4 0.3 Roadcut through Hartshorne Formation.

"This is the only outcrop of the Hartshorne Formation in the southern part of the Arkoma Basin in which both the Lower and Upper Hartshorne coals and the Atoka – Hartshorne and Hartshorne – McAlester contacts are exposed" (Suneson, 1998, p. 44).

46.5 0.1 Park on side of road. Walk along road upsection through the Hartshorne. Stop 5 focuses on the nature of the Hartshorne – McAlester (McCurtain Shale) contact.

Stop 5. Base of McCurtain Shale Panola Measured Section

Location: Natural exposure and stream cut west of county road ~0.5 mi south of Panola, Oklahoma. CSW¼SW¼NE¼ sec. 8, T. 5 N., R. 20 E., Panola 7.5' quadrangle. UTM: 15S 297520 E 3866270 N.

Discussion and Interpretation:

This stop was visited as part of the Hartshorne Formation field trip in 1998 (Suneson, 1998). It is unique among Hartshorne outcrops in the Arkoma Basin because the entire formation is exposed, including its lower and upper contacts and the Upper and Lower Hartshorne coals. This outcrop is included in this guidebook because the flooding surface that initiated Booch deposition is exposed.

This outcrop is located ~1 mi north of the trace of the Choctaw Fault along the southern margin of the Arkoma Basin. The strata dip ~35° north towards the western projection of the axis of the Cavanal Syncline.

Suneson (1998, p. 45) described the shale at the base of the McAlester Formation as follows:

> Shale, silty, dark yellowish brown (10YR4/2). Basal 2-3 ft grayish brown (5YR3/2) to dark gray (N3) with thin streaks and blebs of coal. Most of unit splintery to spheroidal weathering, uniform lithology. Rare 1-in.-thick ironstone beds. Comminuted plant material rare, but a single 1-in.-long fragment observed.

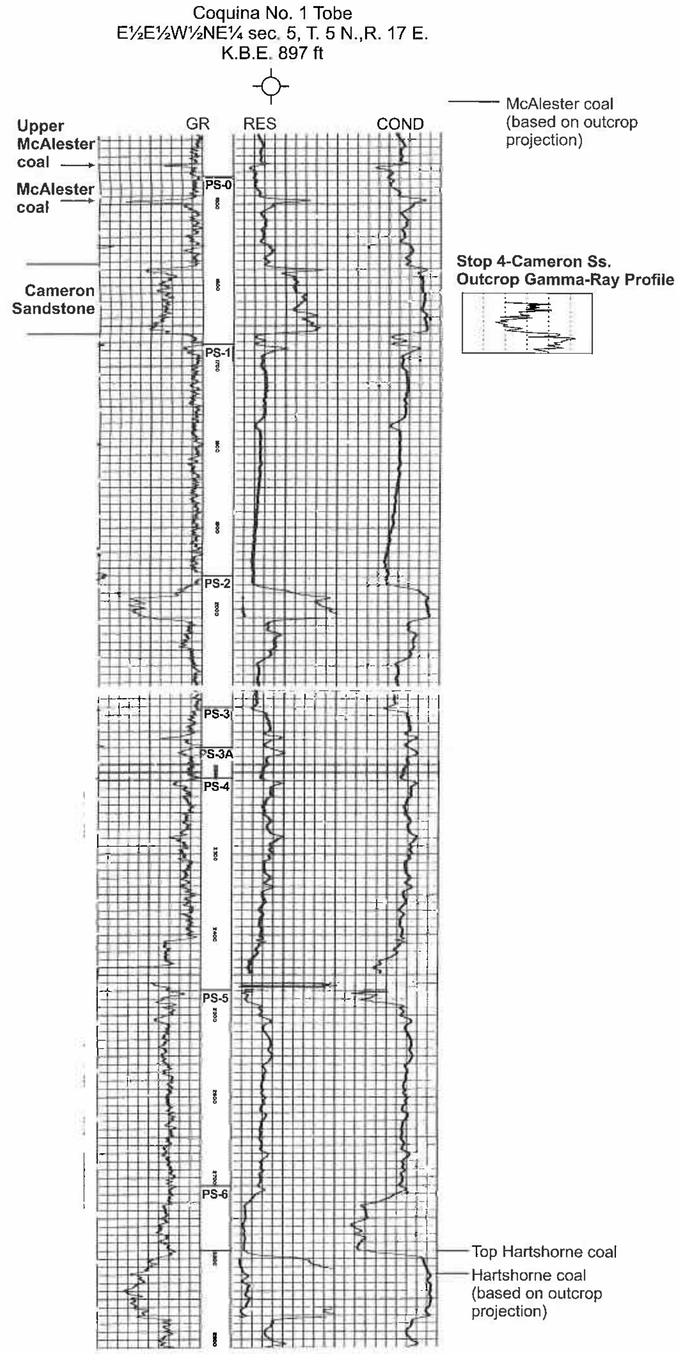


Figure 34. Part of wireline log of Coquina No. 1 Tobe comparing outcrop and log-derived stratigraphic thicknesses to regional markers (Hartshorne Formation and McAlester coal).

Most likely, the transition strata (bay-fill(?) deposits) between the Upper Hartshorne coal and the marine shale of the McAlester Formation is the 2-3-ft-thick coaly shale at the base of the unit. The basal McAlester Formation flooding surface is therefore 2 to 3 ft above the coal. Color appears to be the key

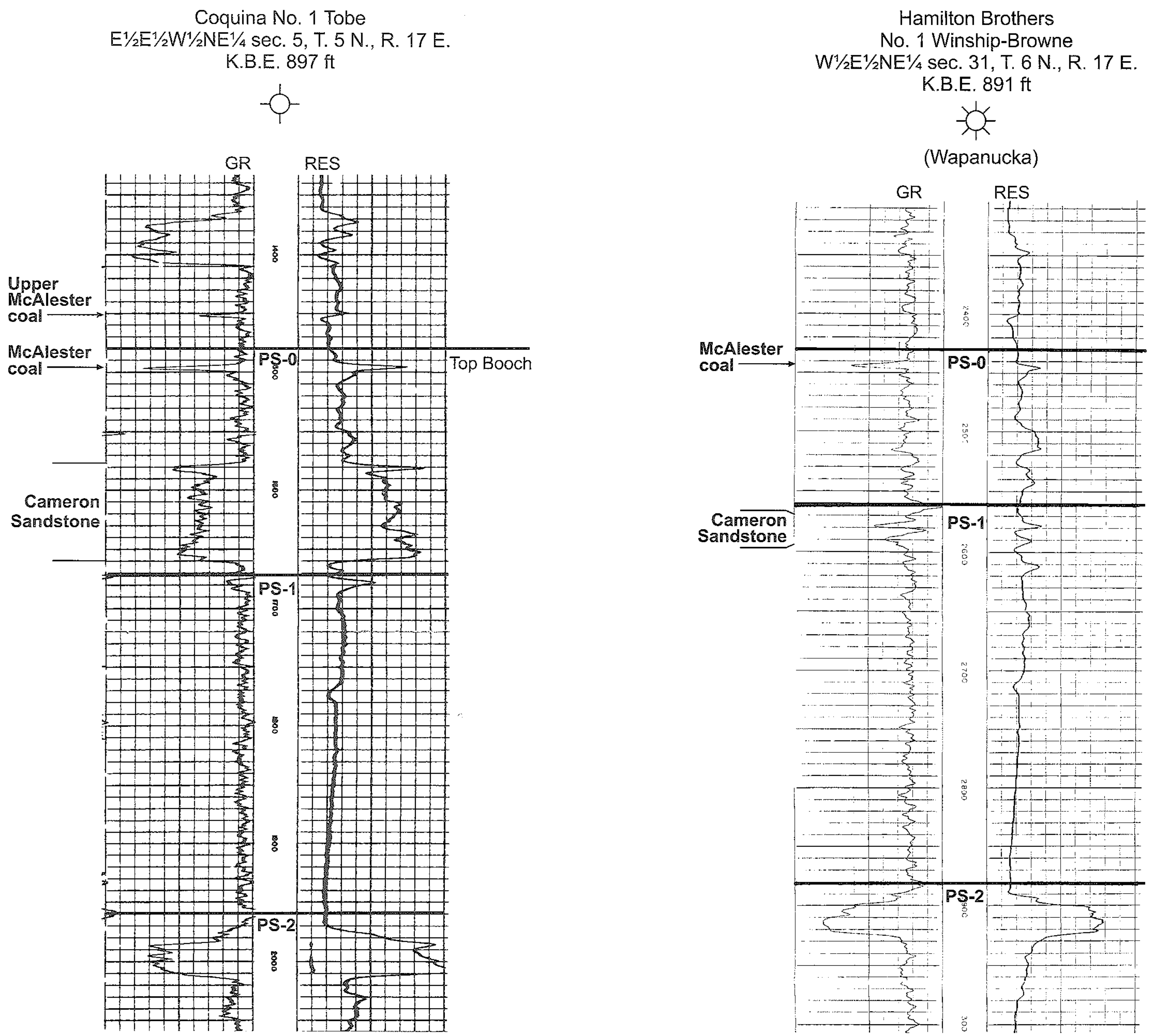


Figure 35. Parts of wireline logs of Coquina No. 1 Tobe (Fig. 34) and Hamilton Brothers No. 1 Winship-Browne showing the stratigraphic variability of the upper Booch interval. The Tobe has more than 80 ft of sandstone whereas the No. 1 Winship-Browne has ~5 ft. The high gamma-ray reading at the top of the PS-1 in the Tobe well probably is not a flooding surface, as it is in the Winship-Browne, but rather the base of a PS-0 incised valley. Note that the Upper McAlester coal is absent in the Winship-Browne well.

with the Hartshorne shale being grayish brown and the McAlester shale being dark gray.

Figure 42 is the well log from the Tenneco No. 1-29 Pierce (N½S½NW¼ sec. 29, T. 6 N., R. 20 E.) located ~3 mi north of this outcrop. The Hartshorne Formation is well-expressed as are the Upper and Lower Hartshorne coals (3,800 ft and 3,849 ft, respectively). Only a thin (~10 ft) Hartshorne shale appears to be present between the coal and the low-resistivity marine shales above it. The flooding surface at the base of the McAlester Formation, which is also the base of PS-6, is marked by the gamma-ray high at 3,790 ft.

Figure 36. Herringbone cross-stratification in unit 6, Adamson measured section. This type of sedimentary structure is diagnostic of tidal reworking. Dime for scale.

Return to U.S. 270.

47.7 1.2 Intersection of county road with U.S. 270. Turn right (east).

48.2 0.5 Cross Little Fourche Maline.

Conkling and Conkling (1947 p. 253) note that, "There was an intermediate station between the Narrows and Riddle's on later established mail routes between the years 1864–1878 [after the Butterfield Overland Stage Line]. This was known as Austin's, four miles east of Riddle's, and it is believed to have been located on the mail road near the crossing on Little Fourche Maline creek, or about a mile east of Panola." (Suneson and Hemish, 1994, p. 55).

49.0 0.8 County road to right (south).

The low ridge immediately to the right (south) of the highway is underlain by the Cameron Sandstone. The topographic expression of the Cameron Sandstone varies along its strike in this area; this likely is due to differences in the amount of sandstone present in the unit.

50.9 1.9 Leave Panola Gas Field.

The low ridge immediately to the right (south) of the highway is underlain by the Tamaha Sandstone. Oakes and Knechtel (1948) and Knechtel (1949) formally included the Tamaha Sandstone as a member within the McAlester Formation, and most surface mappers accept this nomenclature (Hemish and Suneson, 1997, p. 16-17). Because the Tamaha Sandstone (and overlying Keota Sandstone) produce little gas in the Arkoma Basin, petroleum geologists commonly do not include them in the Booch stratigraphic interval.

51.4 0.5 Craven Corner; Ayerdale Road to right (south).

The 1994 field trip examined the Hartshorne Formation ~1.5 mi south of here (stop 8). The same outcrops also were visited on the 1998 Hartshorne Formation field trip (stops 10A and 10B). From north to south, the county road crosses a low ridge underlain by the Tamaha Sandstone, then a higher ridge underlain by the Cameron Sandstone, and then a double ridge underlain by the upper and lower Warner sandstones (as mapped by Hemish and others, 1990b). (Based on well-to-outcrop correlations from elsewhere in the field-trip area, the mapped upper Warner sandstone may, in fact, be the Lequire Sandstone and the mapped lower Warner sandstone may be the Warner Sandstone.) Finally, the road crosses a low ridge underlain by an unnamed sandstone in the McCurtain Shale Member of the McAlester Formation.

The three flat-topped mountains in front and slightly to the left are named Second Mountain (on left/west), Red Oak Mountain (in middle), and Red Oak Peak (on right/east). All are capped by sandstones in the Savanna Formation and the axis of the Cavanal Syncline trends about east-west across their tops.

52.7 1.3 Leave Panola 7.5' quadrangle; enter Red Oak 7.5' quadrangle. Hemish and others (1990c) mapped the geology of the Red Oak quadrangle.

53.7 1.0 Farrell-Cooper's Red Oak South coal mine is immediately south of the highway (Fig. 43). The McAlester coal was mined, and the area is now completely reclaimed.

55.4 1.7 Intersection with S.H. 82 to the right (south) just east of town of Red Oak. Continue straight on U.S. 270.

Figure 37. Flaser bedding in unit 6, Adamson measured section. The presence of flaser bedding is evidence for alternating high- and low-energy conditions that are typical of tidal environments.

The Butterfield Stage Line crossed U.S. 270 near here and then passed through the gap between Red Oak Mountain and Red Oak Peak. In 1858 William Holloway established a station (Holloway Station, also known as The Narrows) just south of Brazil Creek and built a toll road through the gap.

Many geological field trips have taken S.H. 82 to examine the Hartshorne Formation and the geology of the Ouachita Mountains frontal belt. Some of the more recently published field guides are Suneson and Hemish (1994), Suneson (1998), and Suneson and others (2005).

Red Oak, Oklahoma

Established in 1868, Red Oak is much older than many of the towns along the Chicago, Rock Island, and Pacific railroad that were established during the heyday of coal-mining operations. It was named for a large oak tree near the center of town that was "used as a whipping post for punishment handed down by the district court of the Choctaw Nation" (Fugate and Fugate, 1991, p. 80).

Red Oak – Norris Gas Field

The Red Oak – Norris Gas Field, located immediately north of the town, and the Red Oak sandstone, a prolific producer in this field and other Arkoma Basin gas fields, are named for the town of Red Oak. Suneson and Hemish (1994, p. 51) describe the well as follows:

> The Red Oak – Norris deep-field discovery was made by the Midwest Oil No. 1 Orr in sec. 8, T. 6 N., R. 22 E. The surface location of the well was on the crest of the Brazil Anticline, and drilling began in May 1959. At 7,190 ft (drilled depth) the top of the Red Oak sandstone was penetrated and gas was discovered; the sandstone in the well was 145 ft thick and flowed 11.7 MMcf gas per day on a 0.5-in. choke with 1850 psi tubing pressure on a subsequent production test (McClain and Planalp, 1961). The well continued to drill and the top of the basal-Atoka Spiro sandstone was penetrated at 11,510 ft (drilled depth). The well drilled 73 ft of

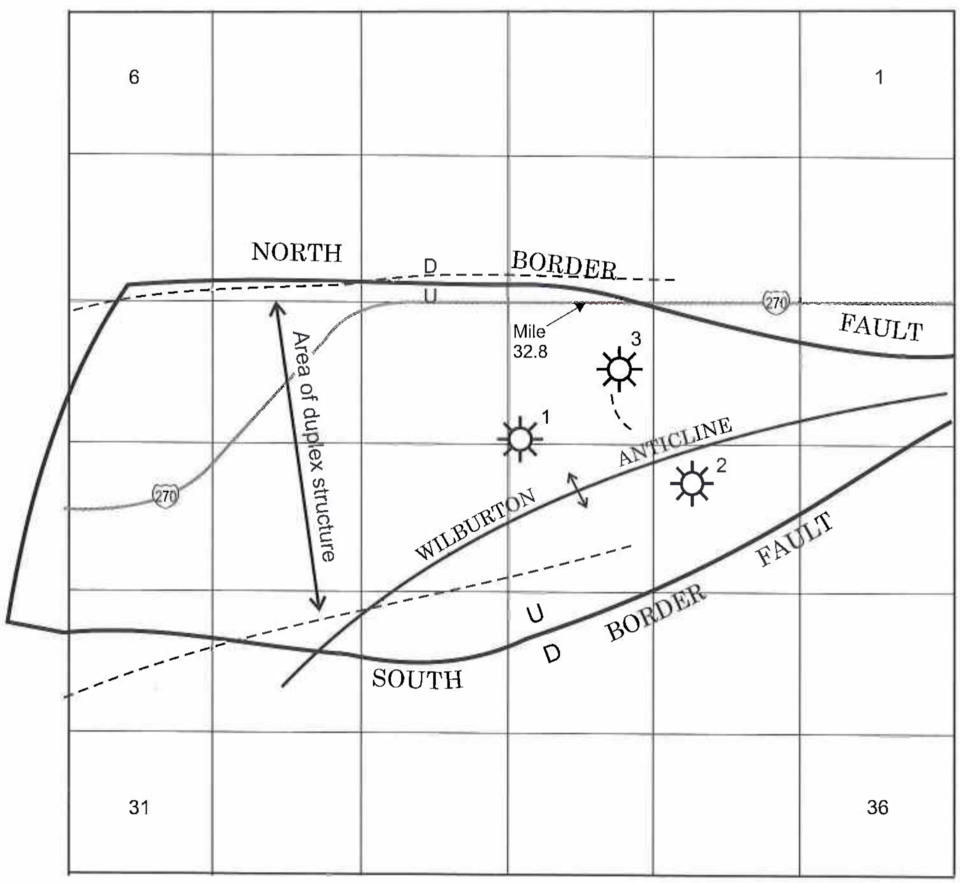


Figure 38. Map of T. 5 N., R. 18 E., showing Wilburton gas field "discovery" wells and surface and subsurface structures (modified from Suneson and others, 2005, fig. 100). The Limestone Oil and Gas No. 1 Nettie McCurray (well no. 1) was drilled on the Wilburton Anticline (from Hemish, 1992; Hemish and others, 1990a), which is exposed at the surface. The Ambassador No. 1 Williams (well no. 2) discovered gas in thrust-faulted Spiro sandstone (duplex structure of Cemen and others, 2001). The Arco No. 2 Yourman (well no. 3) discovered the "Wilburton Deep" field in a horst block of Arbuckle carbonate strata (north and south border faults from Mescher and others, 1993).

gross sandstone and a later production test gauged 5.5 MMcf gas per day on a 0.25-in. choke with 3,009 psi flowing tubing pressure (McClain and Planalp, 1961).

A brief history of the Red Oak – Norris Gas Field is given by Suneson and Hemish (1994, p. 49). "The history of the field is typical of many Arkoma Basin gas fields: initial discovery [in 1912] on surface structure; later exploratory drilling on the structure based on nearby discoveries of deeper reservoirs; still later drilling off-structure based on improved interpretation of seismic data, sedimentology, and diagenesis." Reservoir sandstones in the field are, from top to bottom, the Booch, Hartshorne, Fanshawe, Red Oak, Panola, and Spiro; the Red Oak sandstone is the primary producer. Recently, Hartshorne CBM production has been established in the field. The

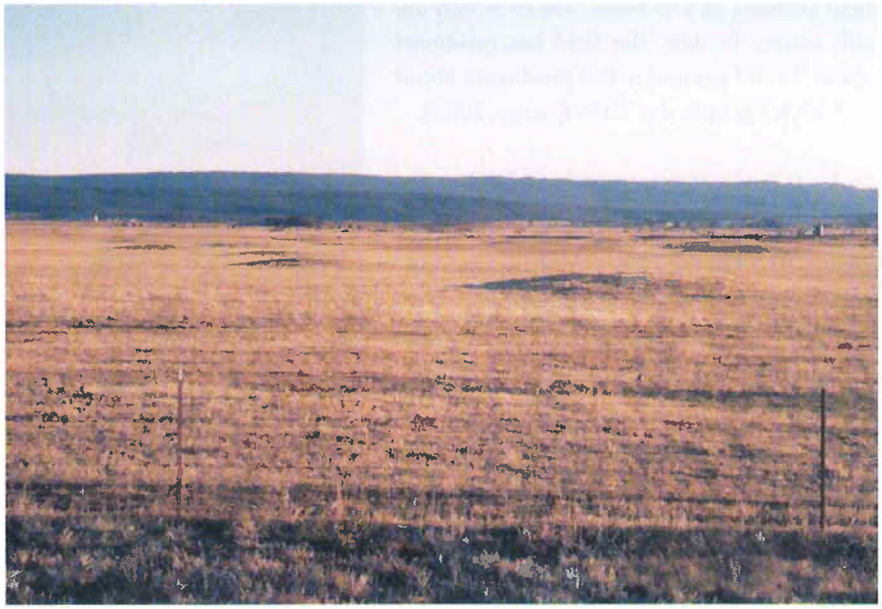


Figure 39. Mima mounds west of Wilburton (from Suneson and others, 2005, fig. 101).

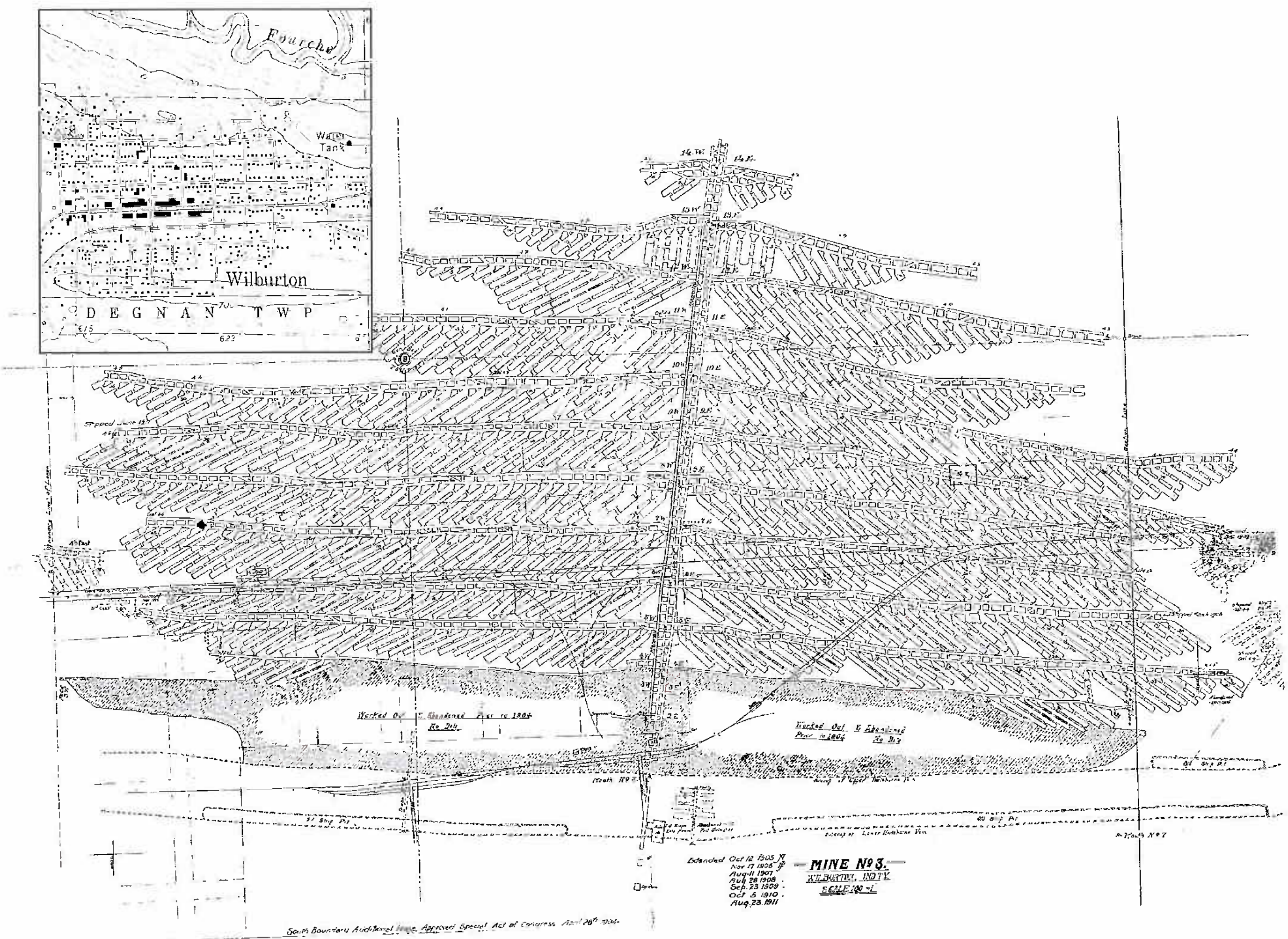


Figure 40. Map of Great Western Mine No. 3 underlying much of the town of Wilburton with inset showing modern topographic map of Wilburton (from Suneson and others, 2005, fig. 102). Prior to 1904 the Hartshorne coal was strip mined along its outcrop south of the underground workings.

field consists of 776 wells, 564 of which are still active. To date, the field has produced about 2.1 Tcf gas and is still producing about 152 MMcf gas per day (IHS Energy, 2006).

Figure 41. The Lutie Coal Miner's Museum is an excellent museum located on the east side of Wilburton (from Suneson and others, 2005, fig. 103).

56.1 0.7 Intersection with S.H. 82 to the left (north).

56.4 0.3 On the right (south) is the loading dock for McAlester coal, mined by Farrell-Cooper Coal Company northeast of Red Oak.

57.2 0.8 A small pre-1931 adit in the McAlester coal is present just south of the highway. Some land near this mine has subsided.

57.9 0.7 County road to right (south). The low ridge ~1.5 mi to the south is called Bull Hill and is underlain by the Hartshorne Formation. Both Hartshorne coals are present and were underground-mined by the Oak Ridge Coal Company and the Bache and Denman Coal Company before 1931 (Hendricks, 1939).

59.8 1.9 Leave Red Oak 7.5'quadrangle; enter Leflore 7.5' quadrangle. Hemish (1991) mapped the geology of the Leflore quadrangle.

60.4 0.6 Cross Turkey Creek.

61.4 1.0 County road to right (south). Location: C sec. 34, T. 6 N., R. 22 E.

Three small strip pits in the McAlester and Upper McAlester coals are present south of the highway just west of here. A number of adits and two underground mines (Texas Coal Company, Le Bosquet Coal and Mining Company) in the Hartshorne coals are present ~1 mi south of here. The mines were active in 1931, when Hendricks (1939) did the field work for his report, and were still active in 1943 (OCC files). Three McAlester sandstones (Cameron, upper Warner, and lower Warner) also are well exposed to the south.

63.9 2.5 Leave Latimer County; enter Le Flore County. County road to right (south). Turn right.

64.2 0.3 Road cut through Cameron Sandstone. Stop 6.

Stop 6. Cameron Sandstone Cedar Creek Road, Fanshawe Measured Section

Location: Roadcut along county road (Cedar Creek Road) (also section-line road and boundary between Le Flore and Latimer Counties). Cedar Creek Road is 1 mi west of Fanshawe, Oklahoma. First ridge south of U.S. Highway 270 ~0.25 mi south of highway. Top of measured section (sandstone) located in southwest corner NW¼SW¼ sec. 31, T. 6 N., R. 23 E. and southeast corner NE¼SE¼ sec. 36, T. 6 N., R.22 E., Le Flore 7.5' quadrangle. UTM: 15S 324005 E 3868530 N.

Discussion and Interpretation:

The Cameron Sandstone exposed in this roadcut (Fig. 44) underlies a discontinuous ridge as high as ~100 ft. In places along the projected course of the ridge there is no topographic expression of the Cameron Sandstone; this is likely due to varying amounts of sandstone in the unit. Suneson and Hemish (1994, stop 7) described the sandstone as follows:

> Sandstone, grayish orange (10YR7/4) to light brown (5YR6/4) to very pale orange (10YR8/2), very fine grained, micaceous, includes black comminuted plant fragments on some stratification planes, thin- to medium-bedded, generally flat-parallel bedded; ripple marks on some bedding planes; contains low-angle cross-bedding in part; load casts on some soles, shale partings common; slump structures rare; contains some fine-grained conglomerate near base; basal contact sharp.

The Cameron Sandstone here dips 26° north into the axis of the Cavanal Syncline, the trough of which is ~2 mi to the north (Hemish, 1991). The outcrop also is ~2 mi north of the trace of the Choctaw Fault, which is concealed beneath alluvium associated with Fourche Maline. Three very low ridges underlain by Booch sandstones are present along this road to the south. From north to south, Hemish (1991) mapped two Warner Sandstones (probably upper and lower and equivalent to Boyd's (2005) PS-3A and PS-3) and an "unnamed" sandstone in the McCurtain Shale (probably equivalent to Boyd's (2005) PS-4 or PS-5). The southernmost and highest ridge along this road is underlain by the Hartshorne Formation, which is immediately north of the Fourche Maline valley. Based on mapping by Hemish (1991), the McAlester coal is ~175 ft above the base of the Cameron Sandstone and the Upper McAlester coal is ~110 ft higher.

The Cameron Sandstone is well-displayed in the Mobil No. 2 James (S½N½SW¼ sec. 23, T. 6 N., R. 22 E.) located ~3.0 mi north of the outcrop. The McAlester coals are distinctive and 56 ft apart (Fig. 45). The base of the Cameron Sandstone is 235 ft below the McAlester coal.

The Cameron Sandstone at this outcrop was deposited in a moderately high-energy environment; the abrupt basal contact, shale rip-up clasts, and pinch-and-swell structures characterize many of the beds. Small load casts and soft-sediment-deformation features suggest rapid deposition of some beds. However, the abundance of partings, most of which represent a concentration of organic debris or fine-grained sediment, is evidence for periodic lower-energy conditions. Unit 5 locally exhibits very regular spacing of sandstone beds which may indicate tidal influence. In general, however, there is little evidence of tidal reworking in this outcrop. The abrupt base strongly suggests erosion into the underlying marine shale, but most of the sedimentary structures and lithologies indicate that the Cameron at this locality was deposited as a distributary-mouth bar.

The lower part of the Cameron Sandstone on the No. 1 James well log (Fig. 45, 1,828 ft – 1,855 ft) is similar in character to the outcrop. Both have abrupt bases and fine upward, indicating a possible origin in a tidally(?) reworked distributary channel. The upper part of the sandstone on the log (1,740 ft to 1,828 ft) is not exposed at Stop 6 and may be absent. The seriate character suggests it is a delta-plain deposit, possibly consisting of alternating crevasse-splay sandstones and shales. The log character suggests the Cameron Sandstone in the No. 1 James is mostly a back-filled incised valley in which the basal 30 ft of cleaner sandstone represents the initial incision and channel-fill, with the overlying interbedded sandstone and shale (Fig. 45) representing delta-plain sediments filling the topographic low.

Description of units (Fig. 44):

McALESTER FORMATION:

Cameron Sandstone Member:

Note: 0-25 ft measured on east side of road; 25-35 ft on west side, 35-42 ft on east side.

6. Sandstone and covered intervals. Lower sandstone: fine grained, moderately sorted. Highly irregularly wavy-parted, lensoid; much pinch and swell. Middle sandstone: very fine grained, poorly sorted. Wavy partings; irregular base. Poorly exposed. Upper sandstone: Ripple-marked, abundant trough-crossbeds, wavy-bedded.

5. Sandstone and minor shale. Fine grained to medium-fine grained, sorted, quartzose. Beds generally ~1.5 – 4 in. thick; regularly spaced with thin partings, probably shale. Comminuted organic debris and mica form partings. Plane-parallel stratified, ripple-marked; cross-stratification rare. Soft-sediment-deformed bed with detached sandstone "balls" at base; rare beds with small load casts.

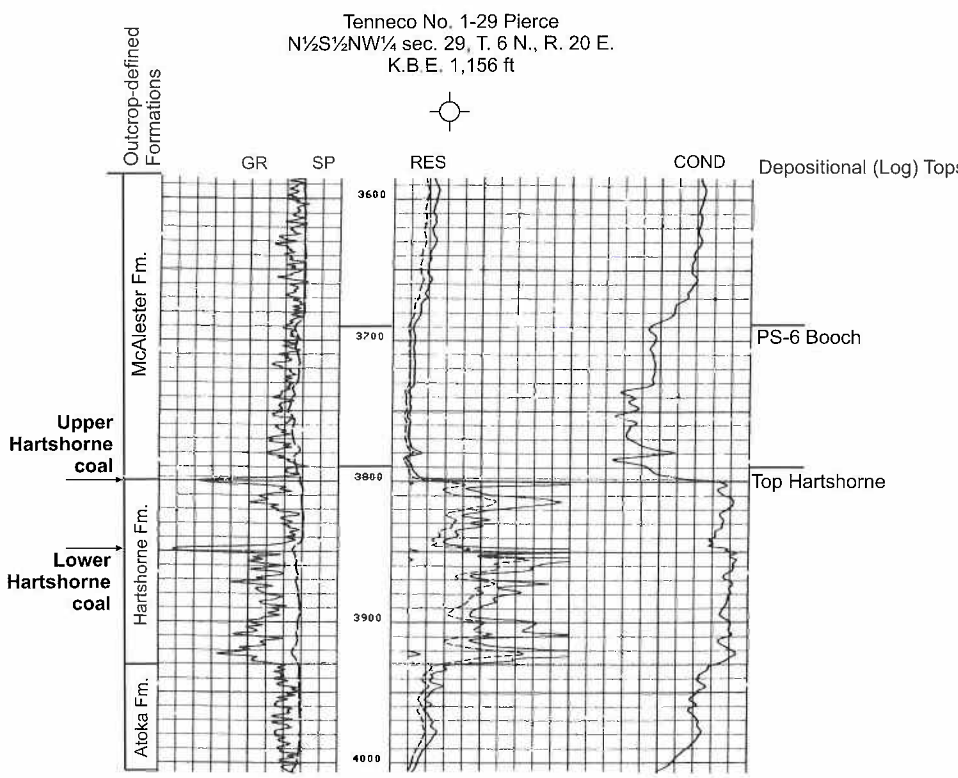


Figure 42. Part of wireline log of Tenneco No. 1-29 Pierce showing contact between Hartshorne and McAlester Formations. The Lower and Upper Hartshorne coals are characterized by distinctive gamma-ray lows; the Lower and Upper Hartshorne sandstones are immediately below each of these coals. The surface-defined base of the McAlester Formation is at the top of the Upper Hartshorne coal (3,799 ft). The subsurface-defined base of the Booch interval (McAlester Formation) is the flooding surface at the base of PS-6, which is characterized by high gamma-ray readings (3,790 ft). The difference between the surface- and subsurface-defined base of the McAlester Formation can be tens of feet.

Figure 43. Drag line used by Farrell-Cooper Coal Company (from Suneson and others, 2005, fig. 104). Farrell-Cooper strip-mined the McAlester coal in its Red Oak South mine. The area is now completely reclaimed.

4. Covered.

3. Sandstone. Very fine grained, poorly sorted. Comminuted carbonaceous organic debris on faint bedding planes and disseminated within rock matrix. Abundant mica on bedding planes. Well parted and well stratified, mostly plane-parallel-stratified (Fig. 46). Sandstone lensoid on moderately large scale; many beds pinch and swell, but only rarely truncated as cut-and-fill structures as much as 8 in. thick (Fig. 47). Lenses typically with flat bases, convex-up tops. Minor wavy-bedding. Abundant shale rip-up clasts just above base. Small load casts near middle.

2. Covered.

1. Shale. Slightly silty. Fissile.

Return to U.S. 270.

64.5	0.3	Turn right (east) on U.S. 270.
65.6	1.1	Enter small town of Fanshawe. A small strip pit in the McAlester coal, operated ca. 1920 (OCC files), is present on the southeast side of Fanshawe.

Fanshawe Sandstone, Atoka Formation

The Fanshawe sandstone is one of several productive Atoka sandstones in the Arkoma Basin. Some geologists place the Fanshawe in the upper part of the Atoka Formation (e.g., Suneson and Hemish, 1994, p. 51), but no formal division of the Atoka into upper, middle, and lower parts has been made in Oklahoma.

The Fanshawe sandstone was first named in the Midwest No. 1 Lewis well, which spudded on December 23, 1961 and was completed on February 20, 1962. The well is in the SE¼NW¼SE¼ sec. 4, T. 6 N., R. 22 E., ~7 mi northwest of the town of Fanshawe. Based on Oklahoma Corporation Commission form 1002A reports, most Fanshawe sandstone production is in T. 6 N., R. 21 E., and T. 6 N., R. 22 E. (88 wells). There is little Fanshawe sandstone production west of R. 21 E. (14 wells in five townships) and east of R. 24 E. (three wells in two townships). The westernmost Fanshawe producer is in T. 6 N., R. 17 E., and the easternmost is in T. 9 N., R. 26 E.

Fanshawe, Oklahoma

The post office at Fanshawe was established on March 13, 1891, but it was not until 1902 that the town was surveyed and staked. In the early 1900s Fanshawe was an active lumbering, coal-mining, sawmilling, farming, and stock-raising center, as well as being a stop on the railroad. In 1919 a fire destroyed all but one store and the town never recovered.

66.1	0.5	Cross Coal Creek.
67.5	1.4	Leave Leflore 7.5' quadrangle; enter Summerfield 7.5' quadrangle. Hemish and Mazengarb (1992) mapped the geology of the Summerfield quadrangle.

A discontinuous Keota(?) coal is present at the base of the ridge just to the left (north) of the highway, and the McAlester and Upper McAlester coals are present, but poorly exposed, just to the right (south) of the highway.

68.3	0.8	The cone-shaped mountain directly ahead is Sugar Loaf Mountain (elevation 2,543 ft). Because of its conical appearance the Oklahoma Geological Survey frequently receives inquiries about when it last erupted. In fact, Sugar Loaf Mountain is capped by a sandstone in the Boggy Formation and, like many high points in the Arkoma Basin, marks the axis of a syncline (in this case, the Sugar Loaf Syncline).
69.9	1.6	Intersection of U.S. 270 and U.S. 271 in the community of Caston. Continue straight (east) on U.S. 270/271.

Suneson and Hemish (1994, stop 6) examined the lower and upper Warner sandstones ~1 mi to the south along U.S. 271. A small adit in the Hartshorne coal is present just south of the 1994

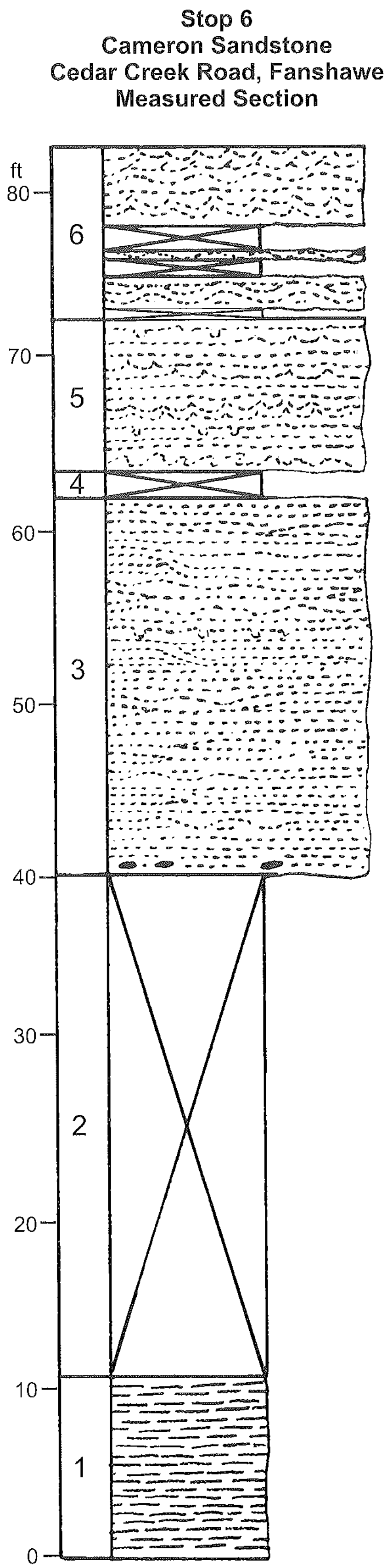


Figure 44. Graphic columnar section of the Cameron Sandstone at Stop 6, Cedar Creek Road, Fanshawe measured section.

stop, and another is present ~2.5 mi to the east near Braidwood.

Three small adits in the Cavanal coal are present ~0.5 mi north of the highway. The coal in the westernmost adit (~CE½ sec. 26, T. 6 N., R. 23 E.) is 1 ft 8 in. thick (Hendricks, 1939).

70.8 0.9 Cross Caston Creek. The Keota Sandstone, Tamaha Sandstone, McAlester coal, and Cameron Sandstone are exposed in the creek bed south of the bridge. Beds dip 22–28° north in this area on the south flank of the Cavanal Syncline.

71.7 0.9 Enter the small Caston East Gas Field (Boyd, 2002).

Caston East Gas Field

The Caston East Gas Field is a one-well field discovered by the Eberly and Meade No. 1-29 Humphreyville (SW¼NE¼ sec. 29, T. 6 N., R. 24 E.). The well was spudded on April 24, 1980, reached total depth at 3,260 ft on May 20, and was completed in lower Booch sandstone at 2,122–2,146 ft on November 19, 1980. Several other nearby wells drilled and/or tested Hartshorne sandstone, Atoka sandstones, Spiro sandstone, and Wapanucka Limestone; all tested or showed dry. However, the Jacobs, Stewart, Hart, and Coleman No. 1 Judy-Jackson well, also drilled in section 29, production-tested the McAlester coal at 480 to 484 ft for 39 Mcf gas per day. The well was declared uneconomic.

Coalbed methane (CBM) is being produced from the Hartshorne coal in the Caston East Field. As of May 2005, seven wells had been drilled and production averages 30 to 50 Mcf gas per day per well.

72.7 1.0 County road to left (north) in small community of Victor. Continue straight on U.S. 270/271. The 1994 field trip took this county road to visit the Farrell-Cooper Mining Company's Wister Mine in the Secor and Secor Rider coals (Boggy Formation). This mine is now reclaimed.

About a tenth of a mile north of the highway, the county road crosses a small pre-1931 strip mine in the Cavanal coal. According to the owner, this area was first mined before statehood (OCC files).

Leave the Caston East Gas Field.

74.8 2.1 Leave Summerfield 7.5' quadrangle; enter Wister 7.5' quadrangle. Hemish and Suneson (1993) mapped the geology of the Wister quadrangle.

75.6 0.8 Cross Mountain Creek.

Two small adits in the Cavanal coal are on the west bank of Mountain Creek. The adits were constructed by the Wister Coal Company before 1931 (Hendricks, 1939).

A stone yard is on the left (north) side of the highway. Flagstone quarrying and marketing is a major industry in northern Le Flore, Haskell, and Latimer Counties (Fig. 48). Most of the quarries are in the Savanna and Boggy Formations; a few are in the Atoka, Hartshorne, and McAlester Formations. Most of the flagstone quarries are developed in delta-plain sandstones; the thickness of the flagstones probably is related to position within individual distributary-mouth bars, where thin sandstones represent a low-energy, lower-bar facies and thick sandstones a high-energy, upper-bar facies.

76.2 0.6 U.S. 270/271 splits. U.S. 271 continues northeast to Poteau. Turn right (south) on U.S. 270.

76.6 0.4 Downtown Wister, Oklahoma. U.S. 270 jogs right. Follow U.S. 270.

76.8 0.2 Cross railroad tracks. U.S. 270 turns left (southeast). Follow U.S. 270. Sign to "Old Frisco Trail" on right.

77.1 0.3 Cross Caston Creek and drive southeast on its floodplain. The ridges to the right (southwest) are underlain by the Cameron, upper Warner, and lower Warner sandstones.

78.1 1.0 Dip-slope outcrop of the upper Warner sandstone on right (south) side of road. Continue around broad curve in road and enter Wister State Park.

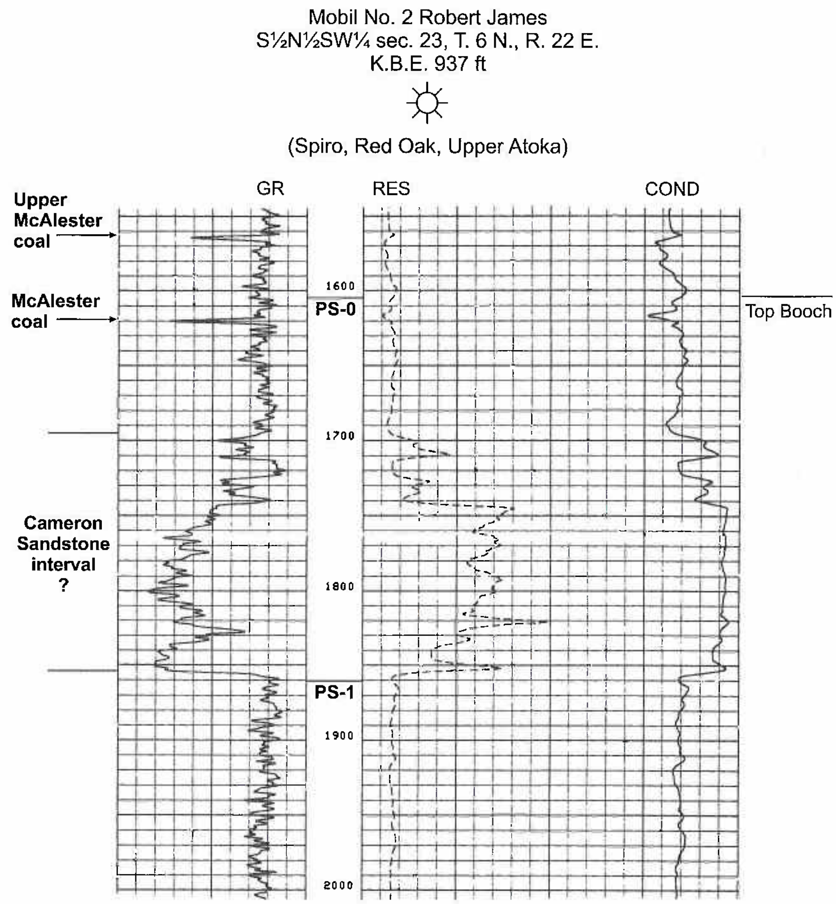


Figure 45. Part of wireline log of the Mobil No. 2 Robert James. The sharp base of the Cameron Sandstone in this well may be similar to that exposed at Stop 6 (Fig. 44) but cannot be proved because the strata below unit 3 (probably shale) are covered.

Figure 46. Well-parted, mostly plane-parallel stratified sandstone typical of unit 3, Cedar Creek Road, Fanshawe measured section. Hammer for scale.

78.8 0.7 Turn right (west) into area with cabins immediately before proceeding on to dam.

78.9 0.1 Immediately turn right (south) again and follow narrow drive towards highest cabin to prominent outcrop of lower Warner sandstone and Stop 7.

Stop 7. Warner Sandstone Wister Lake State Park Measured Section

Location: Behind cabins at north end of dam forming Wister Lake. Northwest corner SW¼ sec. 31, T. 6 N., R. 25 E., Wister 7.5' quadrangle. UTM: 15S 343290 E 3868525 N.

Wister, Oklahoma

The town of Wister, Oklahoma was founded on June 30, 1890 at the junction of the St. Louis – San Francisco ("Frisco") and Choctaw Coal and Railway Company (later Chicago, Rock Island, and Pacific) railroads. The Frisco, unlike many of the railroads in this part of Oklahoma, was not built to service the coal mines in the area, although it did service the mines on Cavanal Mountain. Rather, it was built as part of the nation's concept of "manifest destiny" and involved railroad monopolies and Indian land rights. [For a summary of the Frisco in Indian Territory, see Suneson and Hemish (1994, p. 76-77).] Between 1905 and 1920, the town thrived as a lumber, mining, and stock center. In addition, a cotton gin and the railroad were important sources of income for local residents.

Perhaps the most memorable events in the town's history relate to disasters. In the spring of 1909, a fire started in a room of the Brown Boarding House between the bank and the Frisco railroad. At the time, all the buildings in town were made of wood, and there was no water to fight fires. The flames spread quickly, and the entire northern part of Wister was destroyed. Later that same day, a clerk at the Shipley Drugstore, located on the south side of the Rock Island railroad tracks, accidentally ignited a can of wood alcohol. There was an explosion and eight nearby buildings were destroyed within a matter of hours.

On April 18, 1927, heavy rains caused Mountain Creek to overflow its banks and flood Wister. The Reverend Buck Thomas and his wife were trapped in their home; when rescued, they were clinging to their mattress as it floated to the ceiling of their bedroom. The flood was blamed on new highway construction that turned the water from Mountain Creek into the center of town. The State highway department settled $80,000 in claims for damages. Another flood hit Wister in 1961. On May 18, nearly 6 in. of rain fell in the Mountain Creek and Caston Creek drainages. Rapidly, the part of Wister north of the Rock Island railroad was inundated by about 8 feet of water. This storm occurred less than two weeks after a tornado had devastated the town of Howe (see Mile 86.5).

Discussion and Interpretation:

This outcrop of the Warner Sandstone (lower Warner sandstone of Hemish and Suneson, 1993) is the westernmost of three along the same ridge (this stop, Stops 8 and 9) (Figs. 49, 50). Hemish and Suneson (1993) mapped the sandstone underlying the ridge immediately to the north as the upper Warner sandstone; the base of the upper Warner ~225 ft above the base of the lower Warner. Boyd (2005, pl. 6, well no. 11) mapped the sandstone ~200 ft above the Warner (Boyd's (2005) PS-3 and -3A) within his PS-2, which correlates with the Lequire Sandstone. Therefore, this outcrop should be mapped as Warner (undivided) rather than lower Warner. This unit is also described at Stop 8 ~2 mi to the east and at Stop 9 ~4.2 mi to the east. Differences in lithofacies between these closely spaced outcrops is important for interpreting the depositional environment of the unit. Similarly, the differences in the character of the well logs described below also are important.

Figure 47. Cut-and-fill structure in unit 3, Cedar Creek Road, Fanshawe measured section. Hammer for scale.

This 15-ft-thick outcrop of the Warner Sandstone dips 27° north and is ~2 mi north of the crest of the east-west-trending Heavener Anticline and ~10 mi south of the Cavanal Syncline (trough passes through top of Cavanal Mountain, visible on skyline). Hemish (1993) measured an outcrop of the sandstone ~200 yds to the east where U.S. Highway 270 goes through the ridge. There, the base of the sandstone is exposed and the Warner abruptly overlies the McCurtain Shale. Hemish's (1993) description of the sandstone is generally similar to that given here, but less is exposed:

> Sandstone, grayish-orange (10YR7/4) to pale-reddish-brown (10YR5/4), weathers dark-reddish-brown (10YR3/4), very fine grained, noncalcareous; medium-bedded at top and bottom of unit, otherwise thin-bedded; wavy, parallel-bedded; contains low-angle cross-stratification; interference ripple-marked; includes rare plant impressions as well as trace fossils on the soles of some beds; both surface and underside of beds well-exposed; base sharp.

Figure 48. Piles and stacks of Lequire Sandstone at quarry in CW½ sec. 1, T. 8 N., R. 20 E., Haskell County.

Hemish (1993, p. 14) interpreted the Warner as a "high-energy, deltaic-marine inner fringe sandstone."

The El Paso 1-30 Kerr CBM well (SE¼SE¼NW¼NE¼ sec. 30, T. 6 N., R. 25 E.) is located ~1.5 mi north-northeast of this outcrop. The Warner Sandstone is well-expressed on the gamma-ray and resistivity logs (Fig. 51) and is composed of two units: a blocky lower unit from ~1,606 ft to ~1,582 ft and a coarsening-upward unit from ~1,580 ft to ~1,558 ft. These are equivalent to the PS-3A and -3 sandstones of Boyd (2005). The 15-ft-thick exposure at this stop most likely is the PS-3A sandstone on the log.

This outcrop of the Warner Sandstone is interpreted as a middle- to upper-distributary-mouth-bar deposit. The lower part of the bar is absent; it probably was eroded, as evidenced by the apparent sharp base of unit 1 and the sharp base in Hemish's (1993) measured section. The predominance of sandstone and moderate-energy structures such as ripple marks and cross-stratification are evidence for deposition in relatively shallow water. A tidal influence is evidenced by repetitive 0.5- to 2-in-thick beds in unit 3 and the flaser beds and drapes in unit 1. Hemish's (1993) identification of plant impressions suggests proximity to a source of vegetation, making it likely that this bar formed near the mouth of a distributary channel, rather than in a distal marine environment.

Description of units (Fig. 50):

McALESTER FORMATION:

Warner Sandstone Member:

3. Sandstone. Lower part: very fine grained. Individual beds 0.5 to 2 in. thick. Plane-parallel laminated (Fig. 52). Tops typically flat,

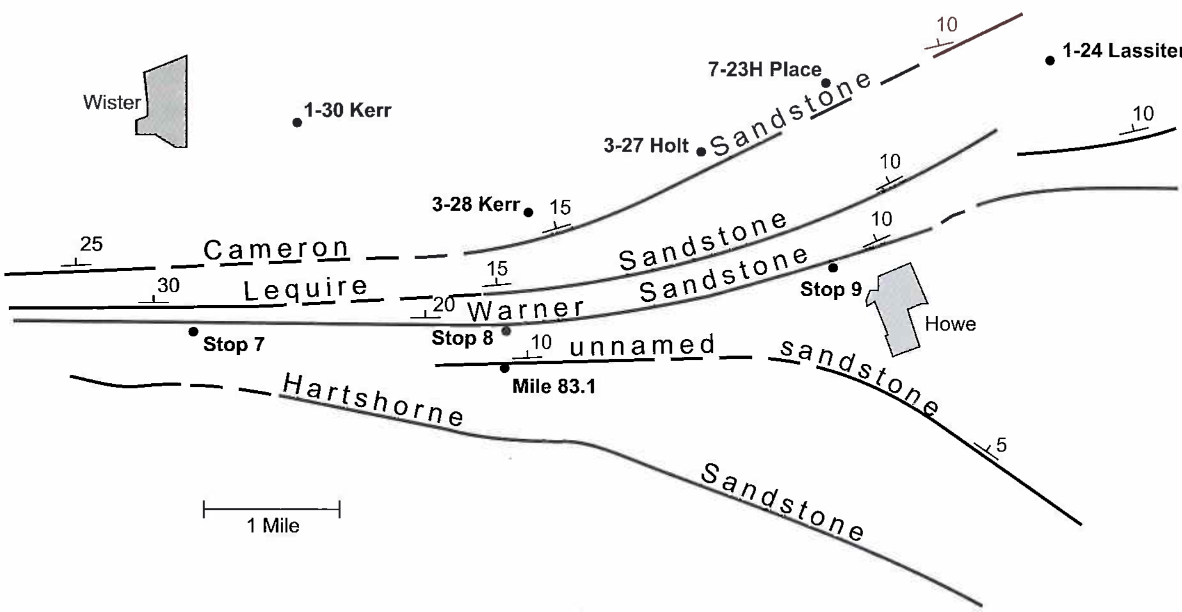


Figure 49. Sketch map showing the locations of Stops 7, 8, and 9 on a discontinuous ridge of Warner Sandstone. Hemish and Suneson (1993) mapped this ridge as the lower Warner sandstone and the ridge immediately to the north as upper Warner sandstone. Correlation with subsurface data suggests that this ridge is the Warner Sandstone (PS-3/3A of Boyd, 2005) and the ridge to the north is the Lequire Sandstone (PS-2). Also shown are the surface locations of five comparison wells. Note the increase in dip to the west and the divergence of the Warner ridge from a ridge underlain by an "unnamed" sandstone in the McCurtain Shale near Howe.

rarely ripple-marked. Individual beds continuous, no thickening or thinning. Partings flat and continuous. Base rippled and wavy bedded. Upper part: medium-fine-grained and coarser than below. Mostly plane-parallel laminated; some tabular cross-stratification. Some beds gradually thin. Throughout unit there is a regular repetition of bed thicknesses separated by partings in places.

2. Covered.

1. Sandstone. Lower part: Fine-grained, quartzose. Cross-stratified. Tops ripple-marked; bases irregular, fill in ripples. Individual beds continuous, no pinch and swell or channeling. Partings continuous and draped over ripple-marks. Sparse trails (trace fossils) on base of some beds. Upper part: Very fine grained. Flaser-bedded, ripple-marked. Faint partings draped over ripples. Base appears flat, sharp, but underlying strata not exposed.

Return to U.S. 270.

79.0 0.1 Turn right (south) toward Wister Dam. Cross dam.

Wister Lake and Dam

(The following information is from the U.S. Army Corps of Engineers website: www.swt.usace.army.mil/projects/pertdata/wister/ wister.htm, retrieved April 18, 2005)

Wister Lake was authorized by the Flood Control Act of 1938 for the purposes of flood control and conservation. The project was designed and built by the U.S. Army Corps of Engineers, Tulsa District. Construction of the dam began in April 1946, and the dam was placed in full-flood control operation in December 1949. The dam impounds waters of Fourche Maline Creek and the Poteau River; the area of the drainage basin above the dam is 993 sq mi. The 4,000-acre lake stores 27,100 acre-ft of water and has a shoreline of 115 mi.

79.3 0.3 Quarry Isle and Wister State Park Headquarters on right (west). Continue south across the dam.

The geology of Wister State Park is described by Hemish (1993). Quarry Isle is formed by a hogback of moderately dipping sandstone in the Hartshorne Formation. Suneson (1998) measured a section of the Hartshorne Formation at the end of Quarry Isle (stop 14). Dips here are ~25°, increasing to the south toward the axis of the Heavener Anticline.

79.8 0.5 Control tower and lift gates on the right (west); discharge chute on the left (east), with outcrops of steeply dipping, dark gray shales of the upper part of the Atoka Formation visible in the channel walls downstream.

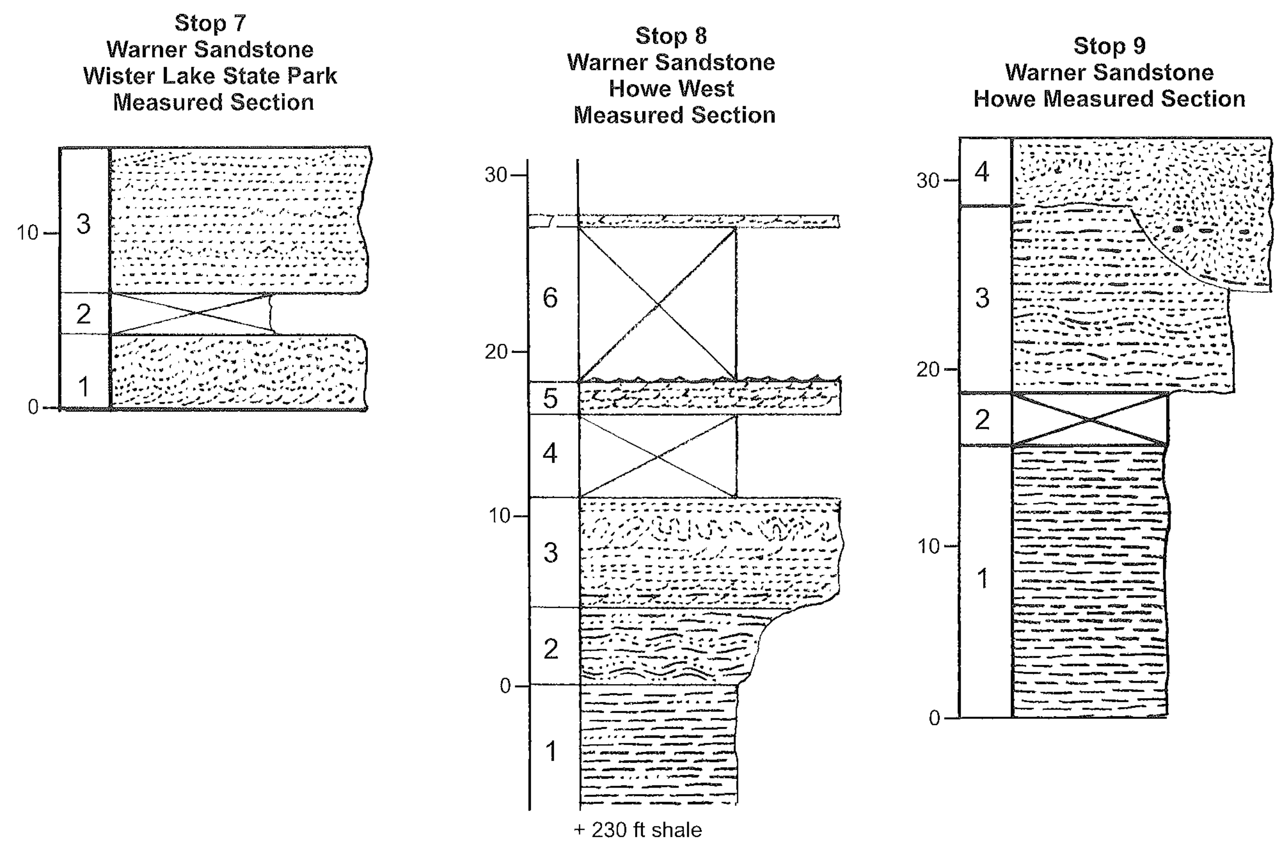


Figure 50. Graphic columnar sections of the Warner Sandstone at the Wister Lake State Park (Stop 7), Howe West (Stop 8), and Howe (Stop 9) measured sections. These outcrops occur along the same ridge and are clearly stratigraphic equivalents. The measured sections illustrate the lithologic variability of the unit. Limited areal extents and rapid lateral facies changes are typical of sediments deposited in a deltaic environment.

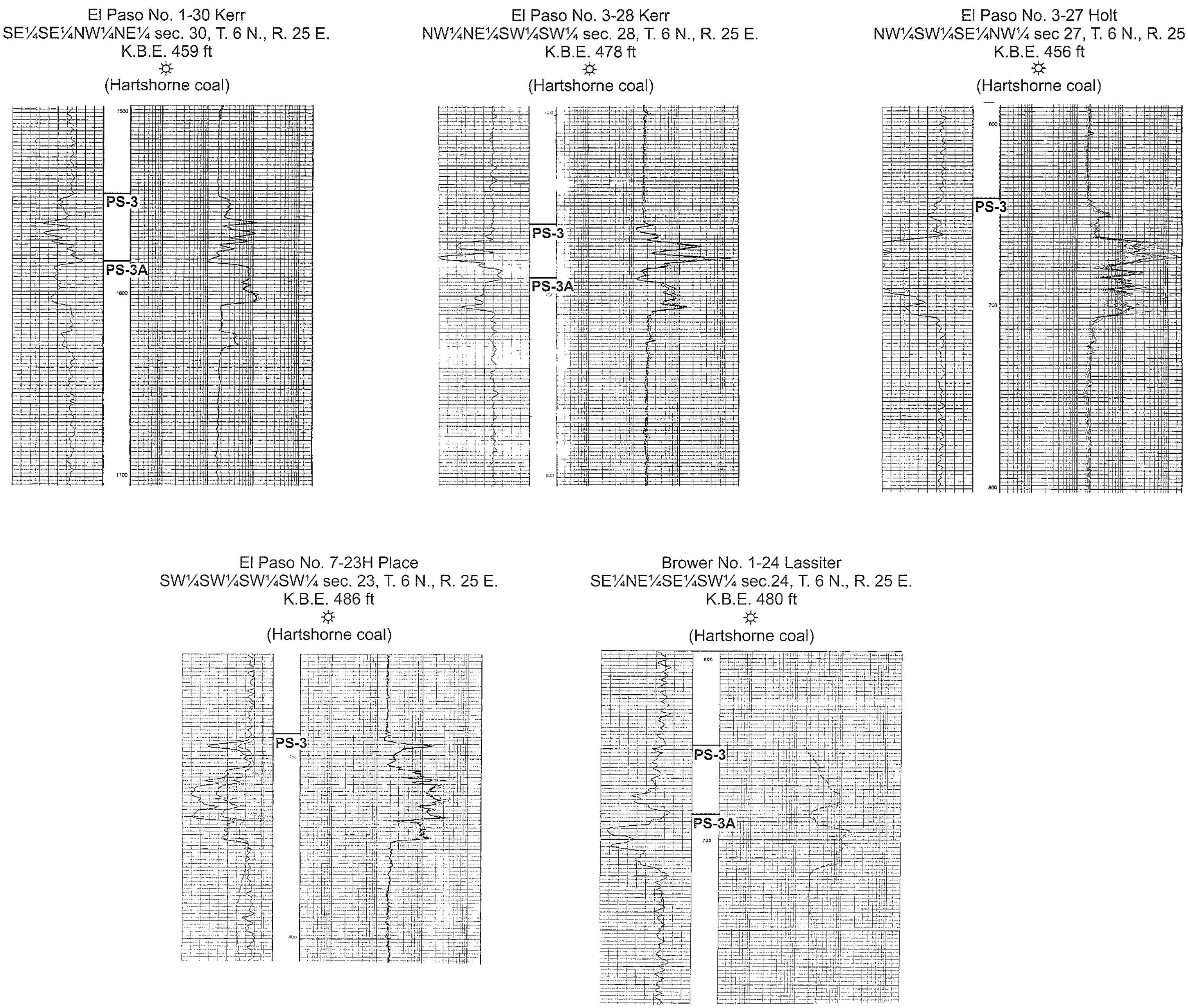


Figure 51. Parts of wireline logs from five wells located immediately downdip of the graphic columnar sections of the Warner Sandstone (PS-3/3A) at Stops 7, 8, and 9 (Fig. 50). Thick marine shales of PS-2 overlie the sandstones and underlying marine shale of PS-3A. Although the general log character of the Warner Sandstone in these wells is similar, there are significant differences. This matches the variability seen in outcrop at Stops 7, 8, and 9, and is typical of deltaic deposits.

Figure 52. Plane-parallel-stratified sandstone, unit 3, Warner Sandstone at Stop 7, Wister Lake State Park measured section.

79.9 0.1 Entrance to rest stop and scenic overlook at south end of dam.

80.1 0.2 West side of spillway. Continue east on U.S. 270.

Chaplin (1994) measured almost 900 ft of the upper part of the Atoka Formation in the spillway. This is the best continuously exposed section of the Atoka Formation in the Arkoma Basin in Oklahoma. The sequence dips about 25° north and is located on the north flank of the Heavener Anticline.

80.4 0.3 Gravel road enters at sharp angle from left (west). This ridge is underlain by moderately (~25°) north-dipping sandstone high in the Atoka Formation, informally called the sandstone of Potts Mountain by Hemish and Suneson (1993).

80.5 0.1 Turn left off of U.S. 270.

81.1 0.6 Low ridge to left (west) and right (east) of road is the highest mappable sandstone in the Atoka Formation in this area and is informally called the sandstone of Horseshoe Ridge by Hemish and Suneson (1993). Here, it dips ~ 25° north away from the crest of the Heavener Anticline.

82.1 1.0 High ridge to left (north) is underlain by the Hartshorne Formation.

The topographic expression of the Hartshorne here is both higher and wider than along its strike for many miles. It seems likely that this is due to the presence of abundant sandstone, probably deposited in a channel system, in the Hartshorne.

82.5 0.4 Road bends to left (north). Broad valley underlain by the McCurtain Shale Member of the McAlester Formation.

82.7 0.2 Main road bends to right (east). Continue straight ahead, turn left on dirt road just before railroad tracks.

83.0 0.3 Road bends right and crosses railroad tracks. Drive through gate; please close it behind you if you find it open. (Note: If the gate is locked, Stop 8 may be accessed from the north. An alternate road log to Stop 8 follows Stop 9.)

The railroad is a spur of the Choctaw, Oklahoma, and Gulf Railway built from Wister to Howe and farther east in 1898. Its junction with the Kansas City Southern line just east of Howe enabled Oklahoma coal to be shipped north to Kansas and Missouri and east to Texas and Port Arthur (Gunning, 1975).

83.1 0.1 Very low ridge underlain by gently (15°) north-dipping unnamed sandstone in the McCurtain Shale (Hemish and Suneson, 1993). This sandstone is ~400 ft above the top of the Hartshorne Formation.

Hemish (1992) first mapped an "unnamed" sandstone in the McCurtain Shale in the Gowen quadrangle and Hemish and Suneson (1997) reported its presence elsewhere in the southern part of the Arkoma Basin. Boyd (2005, p. 9) suggested that these "unnamed" sandstones cap his parasequences PS-5 and PS-4. Surface geologic maps of the McAlester Formation and Boyd's (2005) subsurface study document the occurrence of local sandstones beneath the Warner (PS-3 and 3A) throughout the Arkoma Basin.

Figure 53 is a log from the El Paso 3-28 Kerr (NW¼NE¼SW¼SW¼ sec. 28, T. 6 N., R. 25 E.) showing this sandstone (1089 ft - 1094 ft). The thickness of the sandstone varies; it is absent in the El Paso 1-30 Kerr (Stop 7), 2 ft thick in the El Paso 3-27 Holt (Stop 9), and 14 ft thick in the El Paso 7-23H Place (Stop 9). In addition, the log character of the "unnamed" sandstone varies. This sandstone probably is the lower Booch (PS-5) sandstone of Boyd (2005). To date, however, the Booch sandstones below the Warner—those that locally cap Boyd's (2005) PS-5 and PS-4—remain little studied anywhere in the Arkoma Basin.

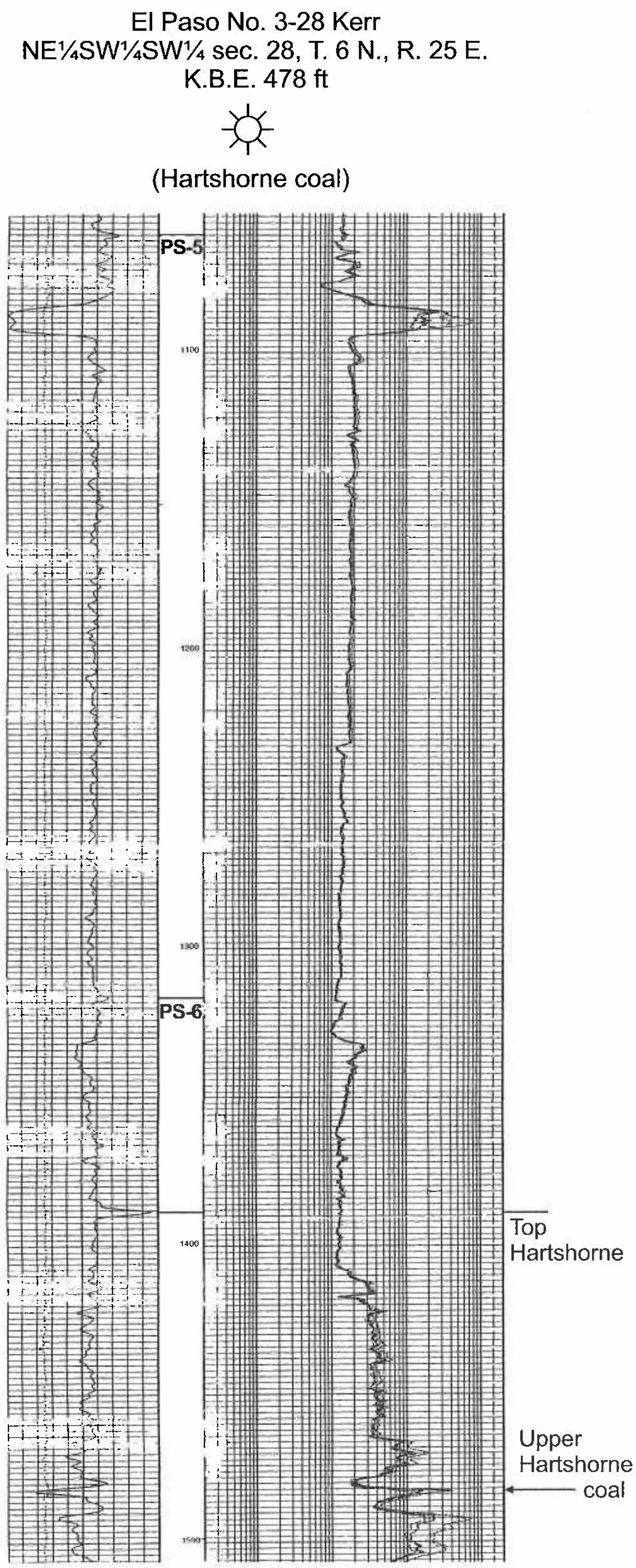


Figure 53. Part of wireline log of the El Paso No. 3-28 Kerr showing a conspicuous sandstone near the top of PS-5 and below the Warner Sandstone which is at ~700 ft in this well (compare Fig. 51). The thickness and log character of this PS-5 sandstone varies greatly throughout the area.

83.3 0.2 Intermittent exposures of McCurtain Shale in bar ditch on right (east) side of road.

83.4 0.1 Sharp bend in road to right. Large exposure of McCurtain Shale.

83.5 0.1 Top of ridge and exposure of Warner Sandstone (Stop 8).

Stop 8. Warner Sandstone Howe West Measured Section

Location: Roadcut and bar-ditch outcrops along private ranch road (generally open) ~2.5 mi west of Howe, Oklahoma, and 2.5 mi east-southeast of Wister, Oklahoma. Going upsection, outcrops are in NE¼NE¼SE¼ sec. 32, northwest corner SW¼ sec. 33, southwest corner NW¼ sec. 33, and southeast corner NE¼ sec. 32, T. 6 N., R. 25 E., Wister 7.5' quadrangle. UTM: 15S 346505 E 3868490 N.

Discussion and Interpretation:

The Howe West outcrop of the Warner Sandstone (Figs. 50, 54) is on the same ridge as the Wister Lake Campground outcrop (Stop 7) ~2 mi to the west and the Howe outcrop (Stop 9) ~2.2 mi to the east. Interpretation of the depositional environment of the Warner Sandstone in this area must include observations from all three outcrops. This outcrop is probably the easiest to interpret.

The Warner Sandstone dips ~20° north and is on the north flank of the Heavener Anticline (crest ~3 mi south) and south flank of the Cavanal Syncline (trough passes through top of Cavanal Mountain, visible on skyline ~10 mi to north). This outcrop is important because ~240 ft of the McCurtain Shale (Fig. 54) is relatively well exposed below the sandstone.

The El Paso 3-28 Kerr CBM well (NW¼NE¼SW¼SW¼ sec. 28, T. 6 N., R. 25 E.) is located ~1 mi north-northeast of the outcrop. The Warner Sandstone (Boyd's (2005) PS-3 and -3A) is conspicuous on the log (Fig. 51) and is similar to the El Paso 1-30 Kerr CBM well (Fig. 51) discussed above.

The dark gray fissile shale underlying the Warner Sandstone is a typical marine shale. The absence of siltstone or thin sandstone beds and soft-sediment deformation features is evidence that it is not a prodelta deposit. The gradational nature of the contacts between units 1, 2, and 3 and the coarsening-upward nature of the Warner Sandstone here (Figs. 54 and 55) suggest the sandstone is a distributary-mouth bar. Unit 2 records the transition from a marine shale to a bar; the lower part of unit 3 is a middle-bar deposit and the upper part is an upper-bar deposit. The increase in sandstone content, bed thickness, cross-stratification, and rip-up clasts suggest increasing energy probably caused by shoaling in unit 3. Un-

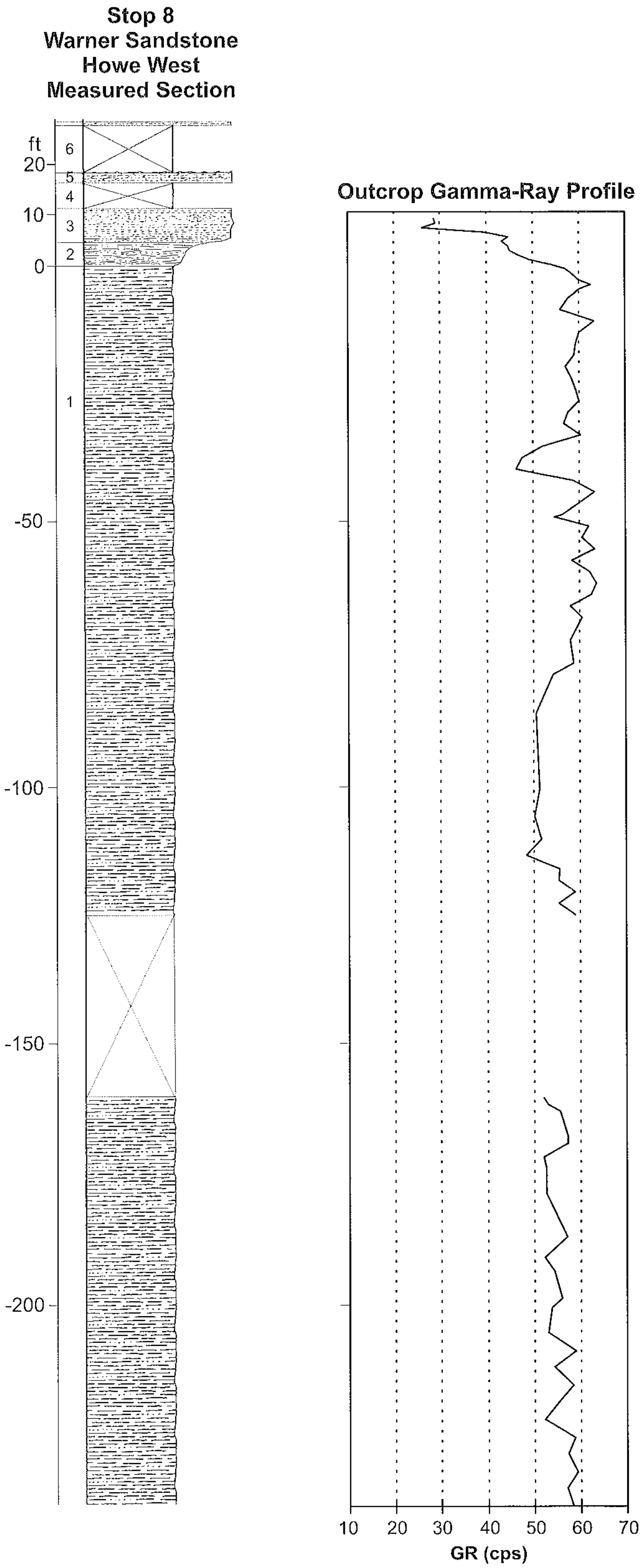


Figure 54. Graphic columnar section of Warner Sandstone at Stop 8, Howe West measured section, and outcrop gamma-ray profile.

like many of the other outcrops of Booch sandstone described in this guidebook, there is little evidence for tidal reworking at this location; however, minor draping in unit 2 is evidence for changing energy conditions. The origin of units 5 and 7 is difficult to interpret because they are poorly exposed and because the intervening units (4 and 6) (presumably shale) are covered.

The Booch interval in the well log from the 3-28 Kerr (Fig. 51) is unlike the outcrop section at this stop. The lower part of the Warner Sandstone on the log is 16 ft thick, has an abrupt base, and fines upward; in contrast, the sandstone outcrop is 13.5 ft thick (units 3, 4, and 5) but contains a 5-ft-thick (probable) shale break (unit 4) and coarsens upward. Unit 6 (covered, probably shale) may correlate with the 684 ft – 692 ft interval on the log; if so, the sandstones above 684 ft do not crop out. The ~6-ft-thick coarsening-upward character so evident in outcrop probably would appear similar to the 684 ft – 679 ft interval on the log. This suggests that the transition from marine shale to bar can occur over a relatively thin interval (5 – 6 ft) and care must be taken when interpreting depositional environments from logs. The gamma-ray profile of the outcrop (Fig. 54) confirms that upward-coarsening sequences can be thin, making the basal contact of the sandstone on the log appear abrupt. Also, the rapidly changing character of Warner outcrops (Stops 7, 8, and 9) is similar to that seen in logs from nearby wells. Variable lithofacies are evidence that the Warner bars here are near a sediment source, making it likely they are distributary-mouth bars.

Description of units (Figs. 50, 54):

McALESTER FORMATION:

Warner Sandstone Member:

7. Sandstone. Fine-grained, quartzose. Faintly trough-cross-stratified. Poorly exposed at bend in road.

6. Covered.

5. Sandstone. Top ripple-marked. Thickness approximate. Poorly exposed immediately south of road.

4. Covered

3. Sandstone, very minor siltstone. Sandstone very fine grained. Conformable with unit 2. Beds 0.5 to 1 in. thick, cross-stratified to gently wavy-bedded, tops ripple-marked. Individual beds very continuous, some pinch and swell. In middle, some plane-parallel stratification, minor very low-angle crossbeds. Includes zone of soft-sediment deformation. Shale rip-up clasts observed on float blocks. Rare iron-oxide-stained plant-limb compressions as long as 2 ft. At top, plane-parallel laminated. (Note: After this section was measured, the top of the ridge (most of unit 3) was bulldozed; as a result, the stratigraphic thickness and in situ strata can no longer be observed.)

Figure 55. Upper part of unit 2, unit 3, and lower part of unit 4 showing coarsening-upward character of Warner Sandstone at Howe West measured section. This character and the sedimentary structures exposed in the outcrop are characteristic of marine or distributary-mouth bars. Hammer for scale.

2. Siltstone and shale, minor sandstone. Conformable with unit 1. Well stratified, gently wavy-bedded, lenticular-bedded very fine-grained sandstone and interlaminated siltstone, shale, and thin sandstone laminae (Fig. 56). Includes resistant 2-in.-thick, complexly cross-stratified, highly parted sandstone in middle. Partings consist of thin, draped, micaceous and organic-rich shale.

1. Shale and very minor sandstone. Shale slightly silty, fissile, weathers flaky and to pencil structure. Rust color on some bedding planes and fractures. Shale locally appears highly deformed, but is iron-oxide cement on planar and curved fractures. Shale grades upward to shale with very thin lenticular-bedded sandstone and very planar sandstone laminae. Partly covered, but probably shale.

Return to main road

84.3 0.8 Intersection of dirt road with main road from right (south). Continue east (straight) on main road.

85.8 1.5 Road intersection. Turn left (north).

The area of the intersection is a slight topographic high. Hemish and Suneson (1993) mapped this as the unnamed sandstone in the McCurtain Shale (see discussion at Mile 83.1) which here dips gently to the northeast and strikes northwest into the east-northeast-trending ridge of lower Warner sandstone (Stops 8 and 9). This pattern and the transfer of shortening from the Hartford Anticline and Poteau Syncline to the east to the Heavener Anticline and Pine Mountain Syncline to the west requires a detachment zone within the McAlester Formation near Howe (Fig. 57). This detachment must climb upsection to the southeast to within the Savanna Formation.

86.0 0.2 Road turns right (east). Main Street.

86.5 0.5 Howe, Oklahoma. Turn left (north) on Texas Avenue.

Howe, Oklahoma

The town of Howe, originally known as Klondike, has always been a coal-mining center. Its post office was established on May 5, 1889. At the turn of the century, about 2,000 people lived in Howe, then the largest town in Le Flore County. The population had grown so quickly that "... one found only rocky, dusty streets with no drainage; winding roads with stumps, ruts, and rocks leading from it into the country. There were no bridges, few fences, with the principal building consisting of miner's [sic] shacks, and of course, lots of children, with no schools or churches...." (Peck, 1963, p. 305).

Figure 56. Interlaminated siltstone, shale, and very thin sandstone (unit 2, Warner Sandstone, Howe West measured section). This facies is typical of low-energy distal-bar facies. Hammer for scale.

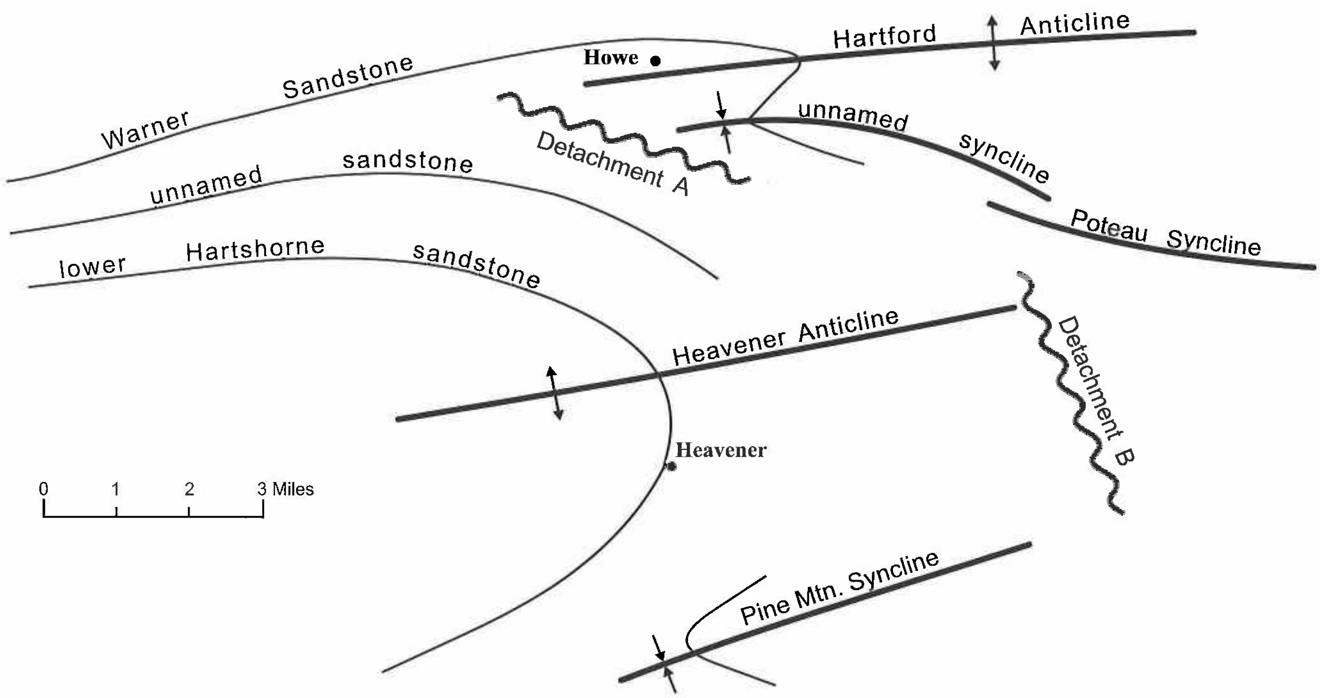


Figure 57. Schematic geologic map showing proposed structural explanation of divergent ridges underlain by the Warner Sandstone and the "unnamed" sandstone in the McCurtain Shale. Transfer of shortening from the Hartford Anticline – Poteau Syncline to the Heavener Anticline – Pine Mountain Syncline must be accompanied by a detachment that rises to the southeast from within the McCurtain Shale (Detachment A) to within the upper part of the Savanna Formation (Detachment B). Schematic geologic map is based on Marcher and Bergman (1983), Hemish and Suneson (1993), and Hemish and Suneson (1994).

The major industries were the coke ovens, a brick plant, and the nearby coal mines. Coal has been produced commercially from the Lower Hartshorne coal in the Howe area since about 1890. Most of the miners worked for Degnan and McConnell, which was the largest mining interest in the Indian Territory at that time. Production records have been kept by counties only since 1907, when Oklahoma became a state, so total coal production is unknown (Hendricks, 1939, p. 279).

Most of the coal was mined underground. Between 1900 and 1905, a battery of 40 coke ovens operated by Potter Coal and Coke Company manufactured coke. The coke produced was of good quality, but the coking was abandoned because of the distance to an adequate market (Hendricks, 1939, p. 281).

On May 5, 1961, a tornado destroyed a 36-block area in the residential part of Howe. At the time, 360 people were living in Howe; 13 people were killed and 56 were injured by the tornado. Only two weeks earlier, the nearby town of Wister was severely damaged by a major flood (see Mile 76.6).

86.6 0.1 Cross railroad tracks (originally Choctaw, Oklahoma, and Gulf; later Chicago, Rock Island, and Pacific) and immediately turn left (west) on North Railroad Street.

86.7 0.1 Turn right (north) at second right. Chestnut Street.

87.0 0.3 Top of ridge. Park in turnout on left.

Stop 9. Warner Sandstone Howe Measured Section

Location: About 0.5 mi northwest of center of Howe, Oklahoma; on ridge ~1500 ft west of water tank on north side of Howe. SE¼NW¼NWw¼ sec. 35, T. 6 N., R. 25 E., Wister 7.5' quadrangle. UTM: 15S 349925 E 3869010 N.

Discussion and Interpretation:

This outcrop of the Warner Sandstone (Fig. 50) dips ~8° north, is on the north flank of the Hartford Anticline (crest ends near center of Howe), and on the south flank of the Cavanal Syncline (trough passes through top of Cavanal Mountain, visible on skyline ~10 mi to north). The outcrop is the easternmost of three Warner outcrops occurring along the same ridge. Stop 7 is a description of the Warner Sandstone at the Wister Lake Campground ~4.2 mi west of here and Stop 8 is a description of the Warner Sandstone at the West Howe exposure ~2.2 mi west of here. Like the other outcrops, Hemish and Suneson (1993) mapped this outcrop as the lower Warner sandstone and mapped the ridge immediately to the north as the upper Warner sandstone. Boyd's (2005) study shows that this outcrop correlates with his PS-3 and 3A parasequences. The ridge to the north correlates with his PS-2 parasequence and likely is the Lequire Sandstone.

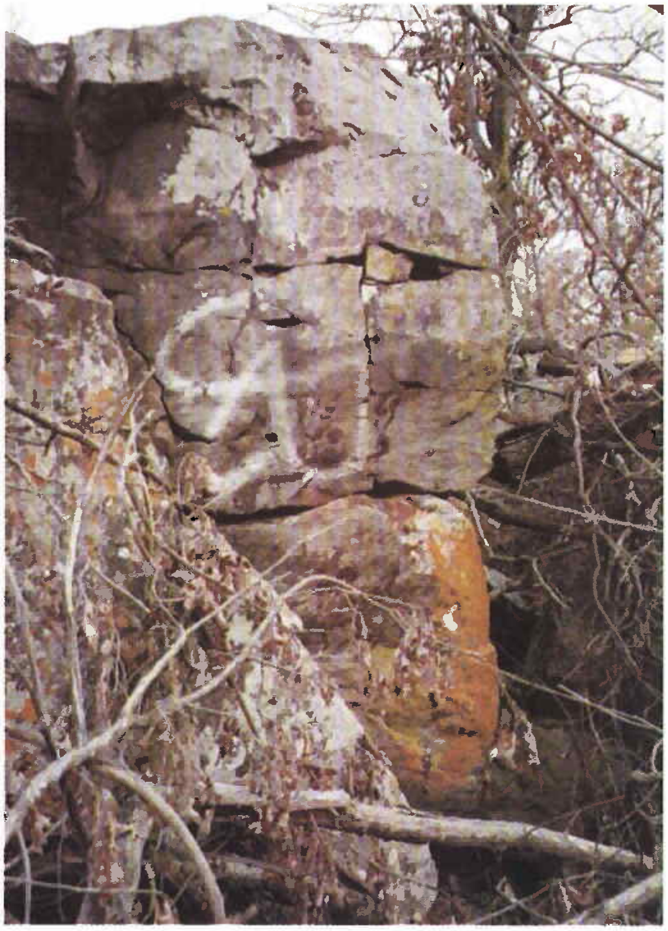


Figure 58. Graffiti-covered massive distributary-channel sandstone (unit 4) in Warner Sandstone at Stop 9, Howe measured section. The presence of channel sandstones such as this are evidence that the bar deposits in the Booch are formed at distributary mouths.

Three CBM wells close to this outcrop of Warner Sandstone have gamma-ray and resistivity logs that can be compared to the outcrop. The El Paso 3-27 Holt (NW¼SW¼SE¼NW¼ sec. 27, T. 6 N., R. 25 E.) CBM well (Fig. 51) is located ~1 mi west-northwest of this outcrop. The El Paso 7-23H Place (SW¼SW¼SW¼SW¼ sec. 23, T. 6 N., R. 25 E.) CBM well (Fig. 51) is located ~1 mi to the north and the Brower 1-24 Lassiter (SE¼NE¼SE¼SW¼ sec. 24, T. 6 N., R. 25 E.) CBM well (Fig. 51) is located ~2 mi to the northeast. All show the Warner Sandstone to be 45 to 55 ft thick.

This outcrop of the Warner Sandstone and underlying McCurtain Shale is, in some respects, similar to the outcrop at Stop 8 (Fig. 54) . The gray fissile shale underlying the sandstone is marine; the absence of siltstone layers and soft-sediment deformation features is evidence that it is a distal marine deposit. Although the contact between units 1 and 3 is covered, it is probably gradational. Unit 3 was deposited under relatively low-energy conditions, probably in a lower- to middle-bar environment. The 4-in.-thick repetitive sequences in the lower part suggest a tidal influence (not evident at Stop 8); the thicker sequences are perhaps indicative of spring-neap tidal cycles rather than diurnal cycles. Unit 4 erosionally overlies unit 3; the relatively coarse grain size, rip-up clasts, unstratified nature, and variable thickness (9 ft west of road compared to 4 ft east of road) of the unit suggest it is a distributary-channel deposit. One interpretation of this outcrop is that any upper-bar deposits similar to unit 3 at Stop 8 or units 1 and 3 at Stop 7, if deposited, were eroded by the distributary channel.

Like the well logs discussed at Stops 7 and 8, the logs from the Warner interval from nearby wells differ significantly from the strata exposed here. The Warner Sandstone in the 3-27 Holt (Fig. 51) and 7-23H Place (Fig. 51) has an abrupt base, and there is little on the logs to suggest a 15-ft-thick coarsening-upward sequence. The 1-24 Lassiter, in contrast, does show a 6-ft-thick coarsening-upward sequence at the base. All the wells show sharp-based sandstone beds, suggesting the presence of channels.

In summary, the Warner Sandstone exposed at Stops 7, 8, and 9 are similar, but also exhibit many differences, mimicking what is seen on well logs. Outcrops and logs show a variety of distributary-mouth-bar environments (bar-transition, lower bar, middle bar, and upper bar) and sharp-based distributary-channel deposits. The bar deposits generally coarsen upward, but in some cases middle- to upper-bar strata abruptly overlie marine shale. Thus, sharp-based sandstones are not necessarily channel-fill deposits.

Description of units (Fig. 50):

McALESTER FORMATION:

Warner Sandstone Member:

4. Sandstone. Medium-grained, porous, sorted. Unconformable (erosional) with unit 3. Unstratified and blocky to parted (Fig. 58). Approximately 120 ft west: contains abundant shale rip-up clasts as large as 1 in., possibly soft-sediment deformed at top.

3. Sandstone and silty shale. Sandstone fine to very fine grained; thicker beds moderately sorted, thinner beds silty. Mostly plane-parallel stratified, rarely very slightly cross-stratified. Well-parted along bedding planes (Fig. 59). Thin light gray claystone may immediately underlie unit 4, but is poorly exposed. Lower part: slightly wavy-bedded, sandstone beds lensoid. Some parts show fairly uniform (~4 in. thick) and repetitive bedding. Well-preserved 2-in.-long *Calamites* stem observed in float.

2. Covered.

1. Shale. Very slightly silty. Fissile. Rust-colored on some bedding planes and fractures.

If the road to Stop 8 is blocked by a locked gate at Mile 83.0, follow alternate route along county roads following mileages (reset to 0.0) shown in parantheses. Otherwise, continue route as shown below.

Alternate Route to Stop 8

(0.0) (0.0) Continue northwest along county road.

(0.3) (0.3) Road bends left, follows section line. All of the wells in this area are Hartshorne CBM wells.

(1.5) (1.2) Very low ridge underlain by Lequire Sandstone of Hemish and Suneson (1993).

(1.7) (0.2) Road bends left. Ridge in front (west) and to right (north) underlain by Cameron Sandstone.

(2.2) (0.5) Turn left (south). Road follows section line.

(2.5) (0.3) Very low ridge underlain by upper Warner sandstone of Hemish and Suneson (1993).

(2.6) (0.1) Road turns right, begins ascending ridge underlain by Warner Sandstone.

(2.7) (0.1) Road turns sharply left.

(2.8) (0.1) Top of ridge underlain by Warner Sandstone (Stop 8). This is the same location as Mile 83.5.

Return to Stop 9. End of alternate route to Stop 8.

90.0 0.3 Return to North Railroad Street in Howe. Turn left (east) immediately on north side of railroad tracks.

90.4 0.4 Turn left (north) on east side of Howe on North Access 59 before going beneath bridge under U.S. 59. The junction of the old Choctaw, Oklahoma, and Gulf railroad with the Kansas City Southern is just east of the bridge.

90.6 0.2 Large borrow pit in McCurtain Shale on left (west) side of road.

Suneson and Hemish (1994, stop 16) described the McCurtain Shale and base of the lower Warner sandstone in this borrow pit. However, the outcrop is considerably different now because it continues to be quarried.

90.7 0.1 Turn left (north) on U.S. 59.

Figure 59. Well-stratified sandstone and silty shale typical of unit 3, Warner Sandstone at Stop 9, Howe measured section. This is very similar to units 2 and 3 at the Howe West measured section and represents deposition in a lower-bar environment.

91.0 0.3 Road cut through upper Warner sandstone.

91.2 0.2 Cross Morris Creek.

91.6 0.4 Intersection with country road (also section-line road).

Very subtle ridge just north of intersection is underlain by thin Lequire Sandstone dipping about 11° north.

Enter Howe Gas Field and Poteau Southeast CBM Field (Boyd, 2002). The Poteau Southeast Gas Field extends from just west of here ~16 mi to the State line.

Howe Gas Field

The Howe Gas Field was discovered by the Okland No. 1-23 Blake (CNW¼SE¼ sec. 23, T. 6 N., R. 25 E.) which was completed in the Hartshorne coal on August 10, 1992, at a depth of 1,558 to 1,674 ft. The well spudded on June 25, 1992 and drilling finished four days later at 1,849 ft total depth. The well had an initial potential of 30 Mcf per day. Eighteen wells are in the field and all are active. The field has produced 936 MMcf gas and continues to produce ~700 Mcf gas per day (IHS Energy, 2006).

Poteau Southeast CBM Field

The Poteau Southeast CBM Field was discovered by the Bear Productions No. 1 Turner well in the W½NE¼SW¼ sec. 22, T. 6 N., R. 26 E. The well was spudded on August 2, 1997, finished drilling on August 3, 1997, and was open-hole completed on September 10, 1997, from 838 to 1,025 ft. The initial potential from the Hartshorne coal was 44 Mcf gas per day with no water. The well has produced 59 MMcf gas and continues to produce ~20Mcf gas per day (IHS Energy, 2006).

The field consists of 32 wells, 31 of which are active. The cumulative production is 1.7 Bcf gas and current production is ~600Mcf gas per day (IHS Energy, 2006).

The mapped field extends from ~2 mi northwest of here almost to the state line. It includes most of the township immediately east (T. 6 N., R. 26 E.) (Boyd, 2002) but has expanded considerably to the west since 2002. The southern part of the field lies on the crest of the Hartford Anticline, but most of the field is on the north flank of the anticline. All wells were completed in Hartshorne coals. The completion depth in the field ranges from 412 to 1,921 ft with initial potentials ranging from 2 to 240 Mcf gas and 0 to 175 bbls water per day.

91.8 0.2 Second low ridge underlain by Cameron Sandstone.

92.7 0.9 Intersection with State Highway 83 to right (east). Continue straight (north) on U.S. 59. Leave Howe Gas Field.

93.1 0.4 Cross Poteau River.

93.8 0.7 Leaver Wister 7.5' quadrangle; enter Poteau West 7.5' quadrangle. Knechtel (1949) mapped the geology of the northern part of Le Flore County. Leave Poteau Southeast CBM Field.

93.9 0.1 Cross Long Lake, an abandoned channel segment of the Poteau River.

94.4 0.5 Top of ridge crest underlain by sandstone no. 2 (of Hemish and Suneson, 1993) in the Savanna Formation. Cavanal Mountain (elevation 2,385 ft) is ahead and slightly to the left.

94.8 0.4 County road to left (west) and right (east). Continue straight on U.S. 59.

96.2 1.4 Bridge over U.S. 271 on south side of Poteau. Field trip resumes on north side of Poteau. Mileage is reset.

Poteau, Oklahoma

Poteau (French for "post") is named for the nearby Poteau River and was established as a railroad town with the arrival of the St. Louis – San Francisco ("Frisco") railroad in 1886 and the Kansas City, Pittsburg, and Gulf railroad (bought by Kansas City Southern in 1900) in 1895. In 1900, the Federal Courthouse was moved from Cameron to Poteau and the county seat was established here. Poteau also served the coal mining industry.

During the 1950's and early 1960's, J.F. Turnipseed offered the coal mines near Poteau as fallout shelters. They were "advertised" as being 1,000 ft deep, could shelter 35,000 people, and included individual, family, and group rooms at very reasonable prices and ready for occupancy (Peck, 1963).

Poteau was the first school district in Oklahoma to integrate following the U.S. Supreme Court decision on desegregation (Peck, 1963).

Cavanal Mountain

Cavanal Mountain is advertised by Le Flore County boosters as the "World's Highest Hill." Exactly how the mountain earned its reputation is unknown, but Fugate and Fugate (1991, p. 76) suggest the following:

> Before World War II, members of an English class in a Le Flore County high school exchanged letters with students in a similar class in England. The British class discovered from a Boy Scout manual that Cavanal Hill, near Poteau, was "The World's Highest Hill." Subsequent investigation revealed that the British Geological Society defined a hill as less than 2,000 feet above the surrounding terrain, and a mountain as 2,000 or more. Cavanal Hill measured 1,999 feet above the local area.

(Note: The AGI "Glossary of Geology" defines a hill as having less than 1000 ft of relief.)

The highest point on Cavanal Mountain is 2,385 ft above sea level (1968 topographic map of the Poteau West 7.5' quadrangle). If a "hill" has 1,999 ft of relief, but no more, the "base" of Cavanal Mountain should be 386 ft above sea level. As one drives west from Poteau toward the top of Cavanal Mountain, the "base" of the mountain would seem to be the base of the slope capped by the Bluejacket Sandstone Member of the Boggy Formation. The Bluejacket separates the rugged topography of Cavanal Mountain from the surrounding countryside on at least three sides of the mountain. The base of the slope capped by the Bluejacket is between 600 and 700 ft in elevation. The elevation of the Poteau River just east of Poteau is about 410 ft above sea level. The closest 386-ft elevation to Cavanal Mountain cannot be determined exactly from existing topographic maps, but probably is close to where the Poteau River empties into the Arkansas River on the west side of Fort Smith, Arkansas. In hindsight, this may be a logical "base" of Cavanal Mountain.

DAY TWO

0.0 0.0 State Highway 112 bridge over U.S. 59 and 271 on north side of Poteau. Go east on S.H. 112.

The geology of Le Flore County is based mostly on Knechtel (1949).

Several old, small strip mines in a local coal immediately below the Cavanal coal cross S.H. 112 near the intersection with U.S. 59/271. Knechtel (1949) shows several slope mines along the outcrop belt; these mines must have been present in 1943 when Knechtel did his field work. The strip mines are shown on the 1968 topographic map of the Poteau West 7.5′ quadrangle. OCC files show that the strip mines were active from 1946 to 1948.

0.4 0.4 Leave Poteau West 7.5′ quadrangle; enter Poteau East 7.5′ quadrangle.

0.8 0.4 Enter Cameron Gas Field and Cameron A CBM Field (Boyd, 2002).

Cameron Gas Field

The Cameron Gas Field extends from ~3 mi west of here to the Arkansas state line (Boyd, 2002); it is ~15 mi long and ~5 mi wide at its widest point. The Cameron A CBM Field overlaps the west end of the Cameron Field, and the Cameron B CBM Field overlaps the east end of the field (Boyd, 2002).

The Cameron Gas Field was discovered in 1911 by the Le Flore County Gas and Electric Company No. 9 Tucker (NE¼NW¼ sec. 3, T. 7 N., R. 26 E.) (Knechtel, 1949). The producing formation (1,526 ft deep) was either the Hartshorne sandstone or a sandstone in the lower part of the McAlester Formation; the open-flow capacity was 500 Mcf gas per day. Additional activity in the field did not occur until 1923 (Knechtel, 1949).

The principal reservoirs in the Cameron Field are Atoka sandstones, including the Atoka Middle (indefinite), Red Oak, Gose (indefinite), and Morris. The "indefinite" sandstones vary in stratigraphic position throughout the field. The field contains 112 wells, 72 of which are active. The cumulative production from the field is 67.4 Bcf gas and the field continues to produce 3.8 MMcf gas per day (IHS Energy, 2006).

Cameron A and B CBM Fields

The Cameron A and B CBM Fields cover relatively small areas on either end of the Cameron Gas Field (Boyd, 2002). Based on data compiled by Brian Cardott (Oklahoma Geological Survey), all the wells in the fields are completed in the Hartshorne or Lower Hartshorne coal. The first CBM well in the area was the Jolen Operating Company No. 1 Lynch in the NW¼NW¼SE¼NW¼ sec. 28, T. 8 N., R. 26 E. The well spudded on July 16, 1991, reached total depth at 1,014 ft, and was completed in the Lower Hartshorne coal at 942–947 ft on December 20, 1991.

1.5 0.7 Highway cuts through ridge underlain by the Keota Sandstone Member of the McAlester Formation. This is the highest sandstone in the McAlester Formation and is not considered to be a Booch sandstone by Boyd (2005).

1.6 0.1 Cross Poteau River.

2.4 0.8 Highway cuts through ridge underlain by the Tamaha Sandstone Member of the McAlester Formation. This sandstone is also in the upper part of the McAlester Formation and is not a Booch sandstone.

2.6 0.2 County road to left (north) and right (south). Continue straight on S.H.112.

A northwest-southeast-oriented belt of strip mines in the McAlester coal was at one time present here. Another coal ~80 ft stratigraphically above the McAlester (Knechtel, 1949, p. 49) is present at the base of the Tamaha Ridge, noted at Mile 2.4. In 1943 both coals were marked by a series of prospect pits (Knechtel, 1949, pl. I), and by 1968 parts of the lower coal (McAlester) had been strip mined. Records on file at the OCC show the strip mining to have occurred in 1947.

3.0 0.4 Leave Cameron A CBM Field (Boyd, 2002).

Cameron Mountain is straight ahead. It is capped by the Tamaha Sandstone and has two coal beds (the lower is the McAlester coal) that crop out around the mountain (Knechtel, 1949).

3.7 0.7 Intersection with county (and section-line) road. Turn left (north).

3.8 0.1 Leave Poteau East 7.5' quadrangle; enter Spiro 7.5' quadrangle.

4.2 0.4 Cross east-west section-line road. Very low ridge is underlain by Cameron Sandstone dipping ~5° south.

4.4 0.2 Re-enter Cameron A CBM Field (Boyd, 2002).

4.7 0.3 The hill to the left (west) is underlain by a local sandstone (unnamed) (Knechtel, 1949, pl. I) between the Lequire Sandstone (Stop 10) and the

Cameron Sandstone at Mile 4.2, Day Two. Its topographic expression and limited extent suggests it is a channel-fill sandstone. In this area it appears that the Cameron Sandstone is in PS-0 of Boyd (2005), the local sandstone is in PS-1, and the Lequire is in PS-2.

5.1 0.4 Stop at top of ridge and park. The field trip will examine the sandstone that underlies the ridge (Lequire Sandstone) and the shale that underlies it in the borrow pit immediately to the northeast.

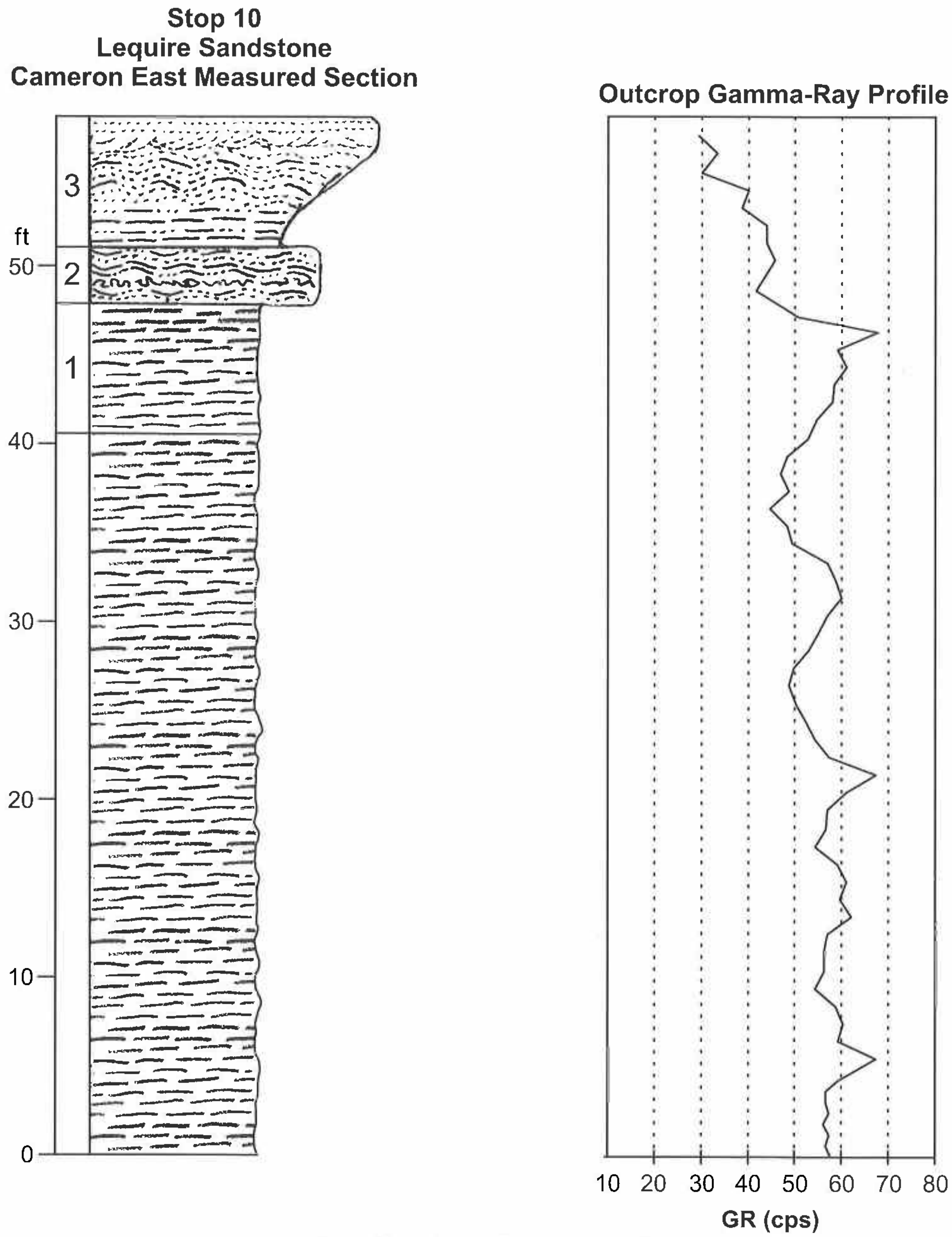


Figure 60. Graphic columnar section of Lequire Sandstone at Stop 10, Cameron East measured section, with outcrop gamma-ray profile. The upper part of the profile shows a coarsening-upward sequence with a moderately sharp base.

Stop 10. Lequire Sandstone Cameron East Measured Section

Location: Roadcut along north-south county (section-line) road, on east side of road, ~2.5 mi west-northwest of Cameron, Oklahoma. About 400 ft south of the northwest corner of sec. 28, T. 8 N., R. 26 E., Spiro 7.5' quadrangle. UTM: 15S 365470 E 3889970 N.

Discussion and Interpretation:

The Lequire Sandstone is well exposed at this stop (Figs. 60 and 61). Here, it dips 7° south and is located on the south flank of the east-west trending, thrust-cored Backbone Anticline. The trace of the thrust fault (Backbone Fault) is ~2.5 mi to the north. The trough of the east-west trending Cavanal Syncline is ~4.5 mi to the south. The Warner Sandstone (Stop 11) underlies the prominent ridge immediately to the north. The Hartshorne coal was extensively strip-mined ~.75 mi to the north in the floodplain of the James Fork. The Lequire Sandstone is also well exposed on the northern flank of the Backbone Anticline at Stop 12 (this guidebook).

Knechtel (1949, p. 22-23) describes the Lequire Sandstone as follows:

The Lequire sandstone member crops out in several localities southeast of the Milton Anticline, and in sec. 6, T. 8 N., R. 23 E., forming in most places low, relatively inconspicuous ridges. Farther north, in Tps. 9 and 10 N., R 24 E., it is either absent or is so close to either the Warner sandstone member or the Cameron sandstone member that it has not been recognized as a separate unit. It is logged in numerous wells in the Cameron and Potaeu-Gilmore Gas Fields. The member is largely made up of thin, slabby beds of fine-grained sandstone, commonly showing prominent ripple-marks, with smaller amounts of siltstone and shale.

Figure 61. Lequire Sandstone at Stop 10, Cameron East measured section, showing two coarsening-upward sequences. Co-author (NS) (6 ft tall) standing on marine shale (unit 1).

Knechtel (1949) does not interpret the depositional environment of the Lequire Sandstone or any of the other sandstones in the McAlester Formation.

Two nearby wells logged the Lequire Sandstone. The J.B. Drilling 2-33 French (SW¼NE¼SW¼SE¼ sec. 33, T. 8 N., R. 26 E.) is located ~2 mi south-southeast of this outcrop. The Lequire is expressed as an ~50-ft-thick, generally coarsening-upward and then fining-upward sequence (Fig. 62). The Evans 31-2 Christenberry (CE½W½SW¼ NE ¼ sec. 31, T. 8 N., R. 26 E.) is located ~1.5 mi southwest of this outcrop. Like the French well, the Lequire generally coarsens upward in this well (Fig. 63).

The well-exposed shale (unit 1) (Fig. 60) below the Lequire Sandstone is a marine shale. The absence of siltstone layers and soft-sediment-deformation structures is evidence that it was deposited in a low-energy environment with little deltaic input. The contact between the shale and overlying sandstone (unit 2) is relatively sharp; this is confirmed on the outcrop gamma-ray profile (Fig. 60). Thin shale beds similar to those in unit 1 suggest that units 1 and 2 are related and reflect increasing energy, most likely due to shallowing. Despite the presence of draping, there is no evidence for tidal reworking of sediments. Unit 2 is a distal marine bar (possibly distributary-mouth-bar) deposit. The thin deformed bed near the middle probably is a storm or slump deposit. Unit 3 also coarsens upward due to shoaling and continues the trend observed in units 1 and 2. Unit 3 probably was deposited in a lower- to middle-bar environment. The absence of a capping sandstone in this outcrop suggests that upper-bar strata were never deposited at this location.

The well logs (Figs. 62 and 63) record the same upward-coarsening sequence displayed in outcrop, but also show the development of a distributary-mouth bar at the top. The seriate character of the logs are evidence for changing energy conditions. The sandstone gama-ray "spikes" may represent periodic influxes of sand associated with higher sediment discharge rates resulting from floods. The cleanest sandstone at the top of the Lequire in the 31-2 Christenberry may be a distributary channel or a well-winnowed upper-bar deposit.

In summary, the outcrop of Lequire Sandstone at Stop 10 and nearby well logs suggest the unit probably is a distributary-mouth bar. Minor deviations from the generally coarsening-upward nature of such deposits may be caused by the periodic influx of sand which, in turn, may be due to distributary-channel switching.

Description of Units (Fig. 60):

McALESTER FORMATION:

Lequire Sandstone Member:

3. Sandstone, siltstone, and shale. Probably conformable on unit 2, but not well exposed. Lower part laminated silty shale and lenticular-bedded siltstone grading upward to well-stratified, generally plane-parallel stratified to slightly wavy-bedded shale, siltstone, and very fine grained sandstone. Middle part dominantly well stratified sandstone, very fine grained, parallel- to wavy-bedded with low angle trough-crossbeds. Some thin sandstone beds draped across truncated crossbeds. Upper part of sandstone fine grained. Trough-cross-stratified on small scale, top ripple-marked. Locally plane-parallel stratified.

2. Sandstone, minor siltstone and shale. Sandstone very fine grained. Conformable with unit 1; contact sharp, no evidence for erosion. Mostly well-stratified, gently wavy-bedded to parallel-stratified. Very thin siltstone beds draped across irregular tops of sandstone beds. Also thin shale beds similar to unit 1. Includes 3-in.-thick highly soft-sediment-deformed bed containing "rolled" sandstone masses surrounded by dewatering structures.

1. Shale, slightly silty. Fissile, minor pencil structure. Weathered to rust-colored on some bedding planes. Monotonous.

Continue north to east-west section-line road.

5.2 0.1 Turn left (west) on county road (also section-line road).

5.7 0.5 Descend through gap in ridge underlain by gently south-dipping (10°) Warner Sandstone. This sandstone is well-exposed at Stop 11.

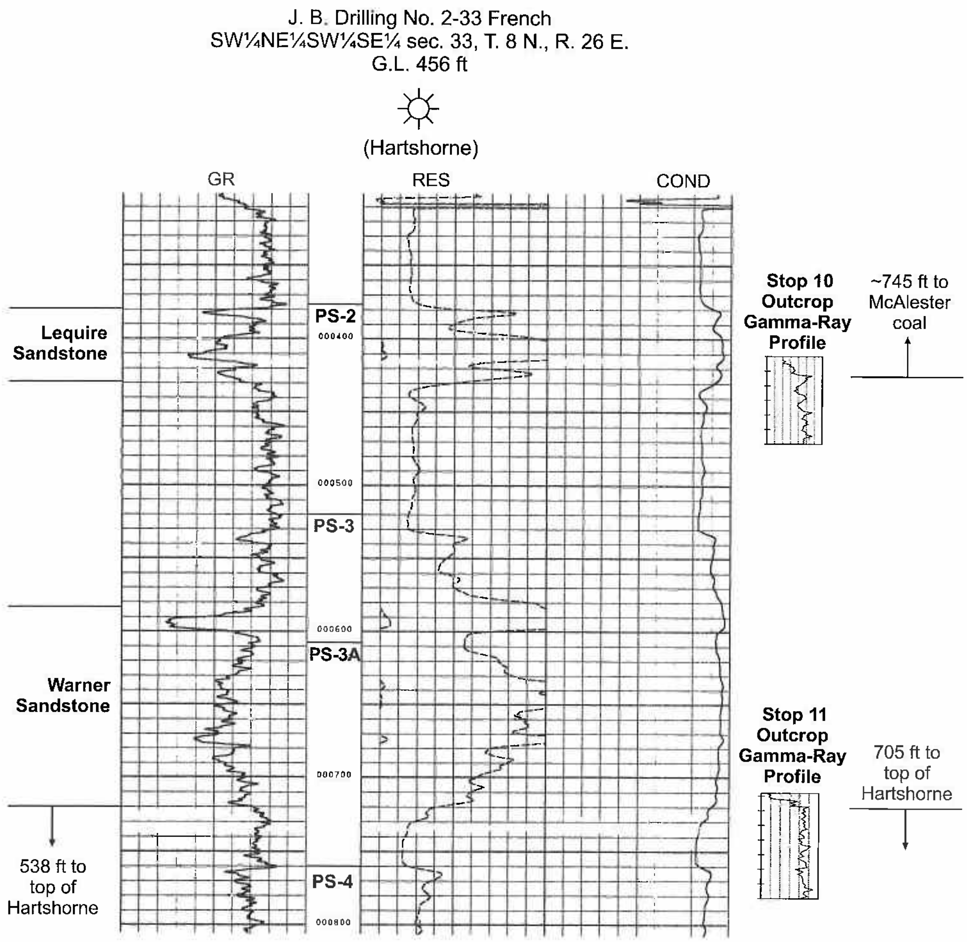


Figure 62. Part of wireline log of J.B. Drilling No. 2-33 French showing log character of Lequire and Warner Sandstones, parasequence boundaries, and outcrop gamma-ray profiles for Lequire Sandstone at Cameron East measured section and Warner Sandstone at Cameron West measured section. Although the gamma-ray profiles are similar to the logs, the thicknesses vary.

The Hartshorne coals have been extensively strip-mined in the floodplain of the James Fork ~0.5 mi north of here. Knechtel (1949) showed a large number of slope mines, some almost a mile long, in both coals.

6.2 0.5 Intersection with county road (also section-line road) to left (south). Turn left.

6.3 0.1 Park immediately south of top of ridge. The field trip will examine the sandstone that underlies the ridge (Warner Sandstone) and the shale that underlies it in the bar ditch to the north.

Stop 11. Warner Sandstone Cameron West Measured Section

Location: Roadcut along county (section-line) road, on east side of road, ~3.5 mi west-northwest of Cameron, Oklahoma. About 400 ft south of the northwest corner of sec. 29, T. 8 N., R. 26 E., Spiro 7.5' quadrangle. UTM: 15S 354870 E 3890030 N.

Discussion and Interpretation:

The Warner Sandstone and upper part of the underlying McCurtain Shale are well-exposed in the roadcut and bar ditch along this county road (Fig. 64). The structural position of the sandstone is similar to that of the Lequire Sandstone at Stop 10, being on the south flank of the Backbone Anticline and north flank of the Cavanal Syncline. The prominent ridge to the south is underlain by the Lequire Sandstone. The Lequire outcrop at Stop 10 is ~1 mi to the east. The low ridge to the north is an unnamed sandstone (possibly parasequence PS-5 of Boyd (2005)) in the McCurtain Shale Member of the McAlester Formation. The Warner Sandstone is also well exposed on the north flank of the Backbone Anticline at Stops 13, 14, and 15. (Stop 13 is ~3.5 mi north of here.)

Knechtel (1949) mapped this outcrop as the Warner Sandstone and described the Warner as follows:

> The Warner sandstone member crops out in several belts in northern Le Flore County, where it characteristically forms prominent ridges, and is logged in most of the wells in the Poteau-Gilmore and Cameron Gas Fields. Its thickness, which is irregular, ranges from about 15 to about 150 feet. It consists largely of fine-grained sandstone including both massive, irregular beds and some slabby to platy layers intercalated with smaller amounts of siltstone and shale. In a roadside exposure in NW¼NW¼ sec. 24, T. 8 N., R. 26 E., a thin, valueless coal bed occurs at the top of the member (p. 21).

Like the Lequire Sandstone (Stop 10), Knechtel (1949) suggested no environment of deposition for the Warner. However, his observation of its variable thickness and presence of "massive, irregular beds" suggests at least some of the Warner Sandstone was deposited as channel-fills.

The logs from two nearby wells display the Warner Sandstone. The J.B. Drilling 2-33 French (SE¼NE¼SW¼SE¼ sec. 33, T. 8 N., R. 26 E.) is located ~2.5 mi southeast of this outcrop. The Warner interval consists of a thick (~120 ft) sequence of mostly siltstone with some sandstone and shale (Fig. 62) overlain by a sharp-based sandstone. In contrast, the Warner in the

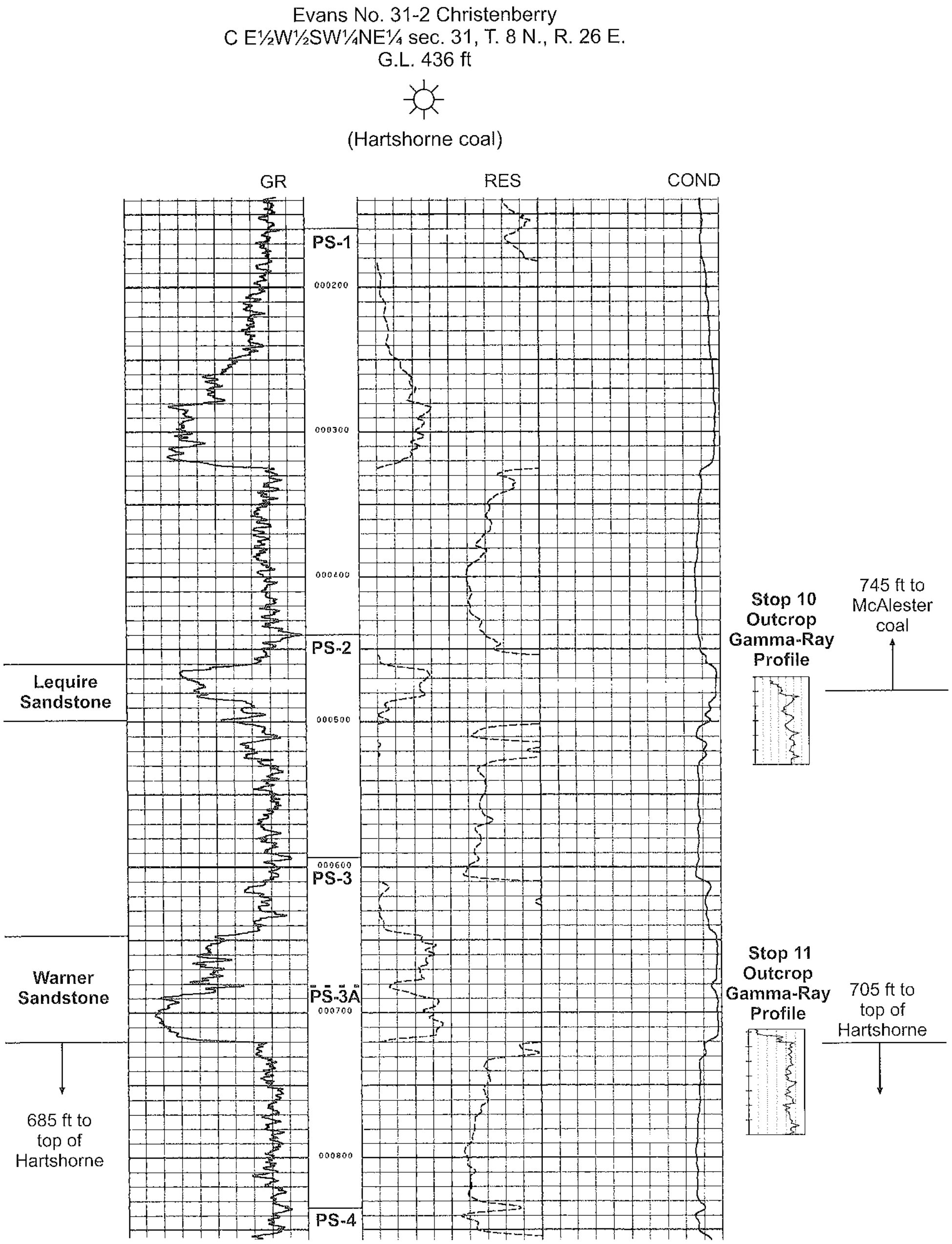


Figure 63. Part of wireline log of Evans No. 31-2 Christenberry showing log character of Lequire and Warner Sandstones, parasequence boundaries, and outcrop gamma-ray profiles. The character of the Warner Sandstone in the well log differs from that in outcrop and in the No. 2 French (Fig. 62). Rapid lateral facies changes are characteristic of deltaic deposition.

Evans 31-2 Christenberry (CE½W½SW¼ NE ¼ sec. 31, T. 8 N., R. 26 E.) is a thick (33 ft), almost massive sandstone (Fig. 63) capped by a 40-ft-thick seriate, slightly fining-upward sequence. The variable character of the Warner Sandstone in these two logs confirms Knechtel's (1949, p. 21) observation – that the unit has different thicknesses and lithologies. It also confirms an observation made at other stops in this field trip – that rapid lateral and vertical facies changes are common in deltaic deposits. Thus, the preservation of a complete parasequence consisting of, from bottom to top, marine shale, prodelta shale, distributary-mouth bars, distributary channel, delta-plain deposits (including crevasses-splay sandstone and shale, bay-fill shale, and coal), is rare.

Unit 1 (Fig. 64) is a marine shale. The generally well-stratified and fine-grained character of the strata in unit 2 is evidence that parts this unit were deposited in a relatively low-energy environment. Evidence that unit 2 was relatively rapidly deposited includes its abrupt base (outcrop, gamma-ray profile) and the presence of load casts. Thus, it is possible that some of the top of the unit 1 marine shale was eroded. The repetitive sequences in unit 2 are evidence for tidal reworking. Rip-up clasts in unit 3 suggest slightly higher energy conditions. A tidal channel or a tidally reworked distributary channel may be the depositional environment for units 2 and 3.

Units 5, 7, and 9 (Fig. 64) probably were deposited in a moderate-energy, delta-plain environment as evidenced by the abundant cross-stratified beds and ripple marks, but thick covered intervals preclude a more definitive interpretation.

This outcrop and surface gamma-ray profile (Fig. 64) are dissimilar to either of the well logs (Figs. 62 and 63). However, based on their proximity, all three probably are related to the same prograding delta. Most of the stratified intervals are mouth-bar deposits and the sharp-based sandstone intervals on the logs probably are distributary-channel deposits. The distributary channel in the 31-2 Christenberry may project up-dip and crop out in the southwest corner of sec. 21, T. 8 N., R. 26 E., where the ridge underlain by the Warner Sandstone is unusually wide and steep-sloped. Boyd (2005, pl. 3, well 4), however, shows a ~100-ft-thick Warner Sandstone (his PS-3/3A) in the Jolen 1 Archey (SE¼SE¼NW¼SE¼ sec. 30, T. 8 N., R. 26 E.) located immediately down dip ~0.8 mile south-southwest of the outcrop. He interprets this sandstone as incised-valley fill.

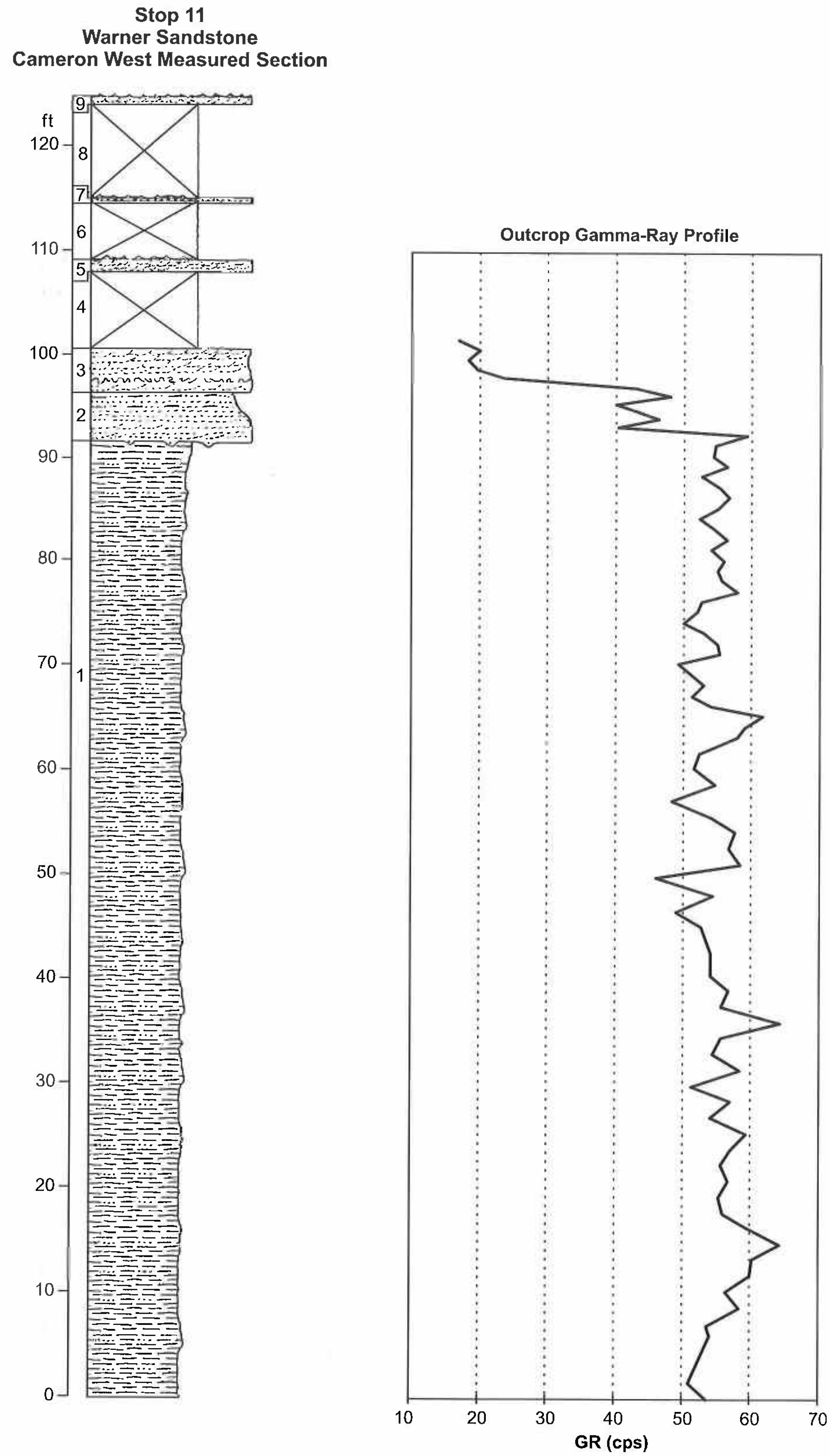


Figure 64. Graphic columnar section of Warner Sandstone at Stop 11, Cameron West measured section, with outcrop gamma-ray profile.

In summary, the Warner Sandstone in this area is complex and consists of a variety of different lithofacies deposited in different environments. Most of the unit consists of distributary-mouth-bar strata (e.g., No. 2-23 French well); however, these strata appear to be variably reworked by tides and locally capped by and/or eroded into by distributary channels (e.g., Cameron West measured section, No. 31-2 Christenberry well, ridge in sec. 21). In addition, some of the Warner Sandstone in this area may consist of incised-valley fill (e.g., No. 1 Jolen well). These valley-fill sandstones would have been deposited later than the deltaic sediments and only after continued progradation moved the shoreline tens of miles down depositional dip (south).

Description of Units (Fig. 64):

McALESTER FORMATION:

Warner Sandstone Member:

9. Sandstone. Very fine grained. Well stratified, low-angle trough-cross-stratified. Top ripple-marked. Poorly exposed in roadbed.

8. Covered.

7. Sandstone. Fine-grained, quartzose. Plane-parallel- and cross-stratified, top highly ripple-marked. Poorly exposed in roadbed.

6. Covered.

5. Sandstone. Fine-grained. Complexly cross-stratified, tops ripple-marked, bases irregular, fill underlying ripples.

4. Covered.

3. Sandstone. Fine-grained, quartzose; conspicuously coarser than unit 2. Conformable with unit 2. Base sharp, flat. Large-scale, low-angle cross-stratified; thin shale rip-up clasts on foresets. Locally soft-sediment-deformed.

2. Sandstone, minor siltstone and shale. Contact with unit 1 conformable, but abrupt. Sandstone very fine grained. Base marked by load casts; subjacent shale deformed. Sandstone variably parted; partings caused by extremely thin, dis-

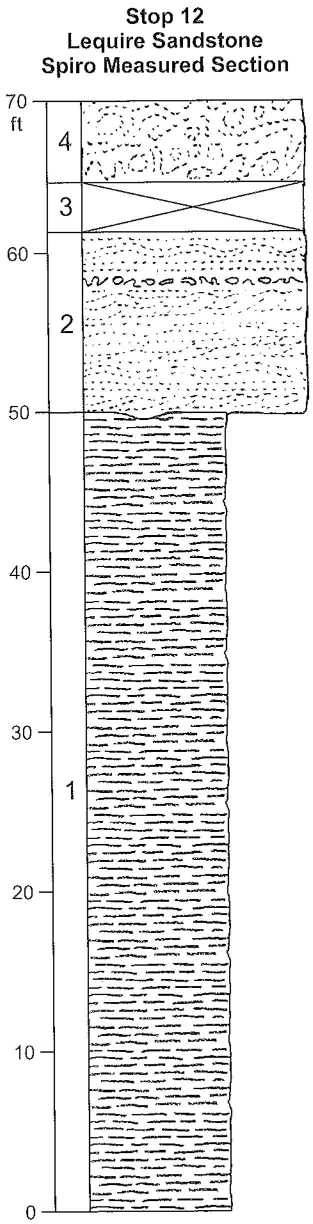


Figure 65. Graphic columnar section of the Lequire Sandstone at Stop 12, Spiro measured section. Here, the Lequire Sandstone has a sharp base and has eroded into the underlying marine shale.

continuous, organic-rich shale laminae. Varies from low-angle cross-stratified and plane-parallel-stratified near base to plane-parallel-stratified in middle. Middle part consists of 4-in.-thick repetitive sequences, each of which thickens slightly upward. Upper part consists of sandstone and siltstone.

1. Shale, slightly silty. Fissile. Weathered to rust-color on some fractures and bedding planes.

Continue south on county (section-line) road.

6.5 0.2 Cross low ridge underlain by Lequire Sandstone dipping 8° south. This is the same ridge as at Mile 9.6 and Stop 11.

6.7 0.2 Cross ridge underlain by a gently dipping (5°) unnamed sandstone in the McAlester Formation.

Knechtel (1949, pl. I) shows this sandstone extending for ~0.5 mi to the west and ~1 mi to the east. Topographically, the ridge has an abrupt, steep east end and a more gradual west end. This is suggestive of a channel sandstone that is thicker to the east (thalweg) and thinner to the west.

7.2 0.5 Intersection with county (section-line) road. Turn right (west).

Low ridge immediately to left (south) is gently south-dipping Cameron Sandstone.

7.9 0.7 Leave Cameron A CBM Field (Boyd, 2002).

8.2 0.3 Cross low ridge underlain by Cameron Sandstone. Leave Cameron Gas Field (Boyd, 2002).

8.7 0.5 Intersection with half-section-line road to right (north). Continue straight (west).

Knechtel (1949, pl. I) shows two prospects in the McAlester and Upper McAlester coals near the Poteau River ~0.25 mi southwest of here.

9.0 0.3 Leave Spiro 7.5' quadrangle; enter Panama 7.5' quadrangle.

9.8 0.8 Flat area is floodplain of Poteau River.

10.5 0.7 Bridge over Poteau River.

10.7 0.2 Turn left (south) on Wheelus Street just before railroad tracks.

10.9 0.2 Turn right (west) and cross Kansas City Southern railroad tracks. This part of the KCS line was built by the Kansas City, Pittsburg, and Gulf Railroad Company in 1895 – 1896 and sold to KCS in 1900. Enter Shady Point, Oklahoma.

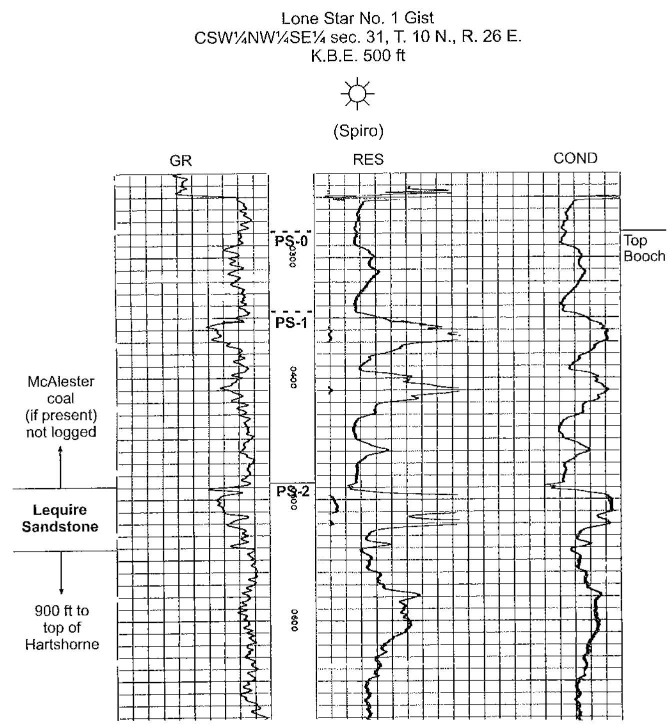


Figure 66. Part of wireline log of the Lone Star No. 1 Gist showing log character of the Lequire Sandstone and parasequence boundaries. Coarsening-upward sequences typify progradational parasequence cycles in the Booch. Small-scale coarsening-upward cycles that may be contained within the parasequences may reflect variations in sediment transport between different distributary channels within the delta (channel-switching). Tops of PS-1 and PS-0 are uncertain; if correct, the McAlester coal is absent at this location.

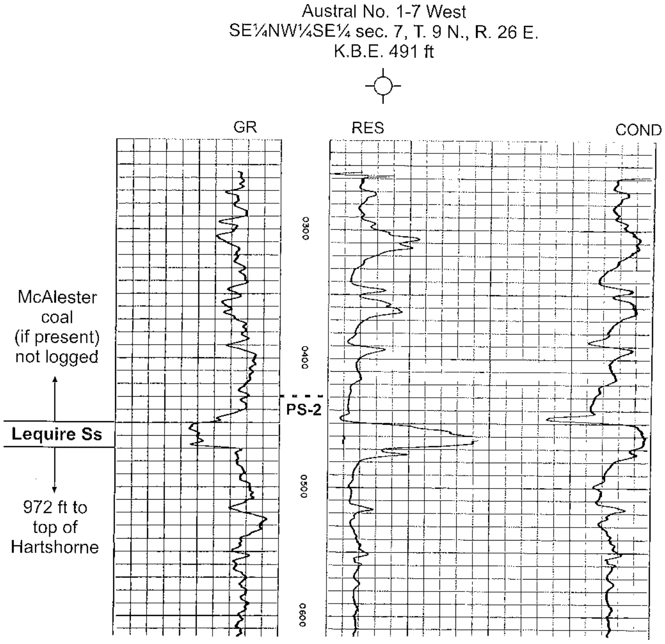


Figure 67. Part of wireline log of the Austral No. 1-7 West showing character of the Lequire Sandstone and parasequence boundaries. The Lequire here is different from that in the No. 1 Gist (Fig. 66), but the sharp base is similar to that seen in outcrop. The variable log character of the Booch sandstones is evidence for deposition in a delta environment.

Shady Point, Oklahoma

Shady Point can literally be called a "town on the move." Originally known as Harrison and located 1 mi west of its current location, the town was moved adjacent to the Kansas City Southern railroad in 1896. Later, it moved 0.25 mi west and still later moved to along U.S. 59/271 (Peck, 1963).

11.2 0.3 Cross Waterfield Street in center of Shady Point.

11.3 0.1 Turn right (north) at end of Wheelus Street onto L.C. Wells Road.

11.4 0.1 Turn left (west).

11.7 0.3 Intersection with U.S. Highway 59/271 on west side of Shady Point. Turn right (north) on highway.

Many of the higher flat areas near and immediately west of Shady Point are underlain by Pleistocene(?) sand and gravel composed of locally derived clasts. Despite the different composition, Knechtel (1949) correlates these deposits with the Gerty Sand (described at Mile 15.8, Day One, this guidebook).

12.7 1.0 Low ridge underlain by Lequire Sandstone.

12.9 0.2 Low ridge underlain by Warner Sandstone dipping 14° south and located on south flank of Backbone Anticline.

Cross Brazil Creek. The very flat area for the next ~0.6 mi is the floodplain of Brazil Creek.

13.4 0.5 The elongate pond on the left (west) side of the highway is a former strip pit in the Hartshorne coal. Knechtel (1949, pl. I) shows a slope mine into the coal. The hill immediately north of the pond is underlain by Hartshorne sandstone dipping 13° south.

14.3 0.9 Cross Buck Creek Road near center of Panama, Oklahoma.

Panama, Oklahoma

Panama, Oklahoma was originally called Red Town, a mining camp for the No. 1 Mine located near Buck Creek ~2 mi to the west (Peck, 1963). In 1896, the Kansas City Southern railroad was extended through the area. When the Midland Valley railroad intersected the KCS in 1904, the town of Panama was established at the railroad junction. The Midland Valley railroad was built from the Arkansas state line to Bokoshe in 1903-1904 (George and Wood, 1943) to service the coal mines. It later became the Texas and Pacific railroad.

The town of Panama was named for the Panama Canal which was being built at the time.

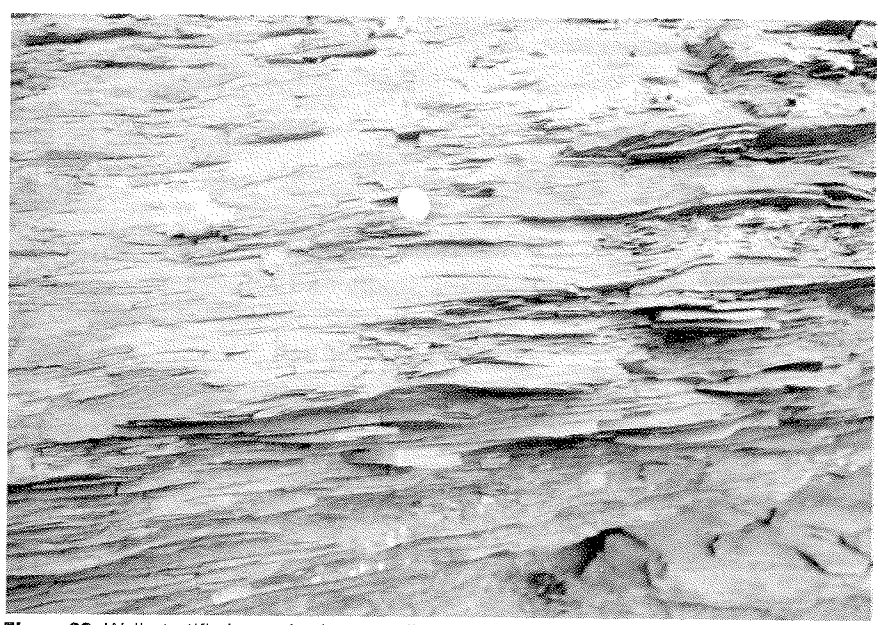


Figure 68. Well-stratified, mostly plane-parallel stratified sandstone in unit 2, Lequire Sandstone at Spiro measured section. Locally, bedding is slightly wavy and lensoid. Quarter for scale.

Shady Point Power Plant

(The following description of the Shady Point power plant is from Cardott and Levine (2004)):

Much of the coal mined in eastern Oklahoma is shipped by truck to the Applied Energy Services (AES) Shady Point coal-fired cogeneration facility near Panama, Oklahoma (Le Flore County, SE¼ sec. 3, T. 8 N., R. 25 E.). Commercial operation of the plant began on January 15, 1991. The plant supplies electricity to Oklahoma Gas and Electric Company and food-grade carbon dioxide to Tyson Foods. The plant has four coal-fired circulating fluidized-bed (CFB) steam boilers and two turbine generators with a net electrical output of ~320 megawatts per hour (enough electricity for ~230,000 homes). The CFB technology offers low sulfur dioxide and nitrogen oxide emissions while burning Oklahoma high-sulfur coal, and is a highly efficient combustion process at a low firing temperature. In the process of burning coal, there is a combustion gas reaction with limestone for sulfur dioxide capture. The plant uses ~3,000 tons of coal per day and 1,000 tons of limestone per day.

15.0 0.7 Cross crest of Backbone Anticline. Enter Spiro Southeast Gas Field (Boyd, 2002).

Spiro Southeast Gas Field and Spiro Southeast CBM Field

Located mostly in the southern half of T. 9 N., R.25 E., the Spiro Southeast Gas Field was discovered in 1964 by the Kaiser-Francis #1 Remer located in the SW¼NE¼ sec. 36, T. 9 N., R. 25 E. This Red Oak sandstone well has produced 1.1 Bcf gas and continues today at a rate of about 70 Mcf gas per day. The field contains 26 producing wells of which 14 are active. Cumulative production is 11.6 Bcf gas, mostly from Red Oak and Spiro reservoirs, and the field-wide production rate is 620 Mcf gas per day (IHS Energy, 2006).

Boyd (2002) identifies the Spiro Southeast CBM Field (Boyd, 2002) as mostly contained within the limits of the Spiro Southeast Gas Field. Although not always designated as such, almost all Hartshorne production in this area is from the coal and not the sandstone facies. The Spiro Southeast CBM Field began production in 1993 and today encompasses 58 active CBM wells completed in the Hartshorne. Cumulative production is 4.3 Bcf gas with a daily rate in December 2005, of 900 Mcf gas (IHS Energy, 2006). This equates to an average per-well daily rate of 15 Mcf.

15.3 0.3 Cross trace of steeply south-dipping Backbone Thrust. Here, the fault juxtaposes Atoka Formation against Atoka Formation.

15.6 0.3 Cross Coal Creek.

The Butterfield Overland Stage Line (see Mile 41.8, Day One, this guidebook) crossed Coal Creek near here. Heading east and after leaving Holloway Station (see Mile 55.4, Day One, this guidebook), the stage line passed the Edwards store just west of Norris (Gunning, undated) and continued southeast of Brazil Creek through Walls and Dog Creek to Trayhern Station near Latham. From there, the stage line went by Brazil Station, a local mail station active in the 1860s (Civil War), but not a Butterfield station. The line crossed Brazil Creek ~1 mi northeast of the station over a toll bridge, went by the Skullyville County jail (2 mi west of Panama), and crossed Coal Creek near here. The easternmost Butterfield station in the Indian Territory was located ~2 mi northeast of Spiro and called Walker Station. Walker Station was operated by Tandy Walker, Governor of the Choctaw Nation.

15.7 0.1 Cross old railroad grade built in 1901 by the Ft. Smith and Van Buren Railroad. See Mile 35.2, Day Two, this guidebook for further discussion.

20.9 0.1 Turn right (northeast) on county road toward Shady Point power plant.

16.3 0.5 Cross ridge underlain by Warner Sandstone dipping 10° northeast. Stop 14 is ~0.5 mi southeast.

17.1 0.8 Four-way road intersection. Follow road as it bends to left and becomes section-line road heading north. Enter Spiro Southeast CBM Field (see discussion at Mile 15.0).

Figure 69. Small-scale ripple marks on sandstone bedding plane, unit 2, Lequire Sandstone at Spiro measured section. Pen for scale.

Figure 70. Horizontal trace fossils on bedding plane in sandstone, unit 2, Lequire Sandstone at Spiro measured section. Pen for scale.

The surface geology (Knechtel, 1949) of this area is complex and is discussed at Stop 12.

18.1 1.0 Intersection with east-west county (section-line) road. Turn right (east).

18.6 0.5 Cross Kansas City – Southern railroad tracks.

19.8 1.2 Leave Panama 7.5' quadrangle; re-enter Spiro 7.5' quadrangle. The ridge to the left (north) is capped by Lequire Sandstone dipping gently to the north.

21.1 1.3 Intersection with north-south county (section-line) road. Turn left (north).

21.6 0.5 Road to right (east). Turn right and park. The Lequire Sandstone caps the ridge to the north.

Stop 12. Lequire Sandstone Spiro Measured Section

Location: Along county road ~1.5 mi southeast of Spiro, Oklahoma. All but very base of outcrop in southeast corner NE¼ sec. 25, T. 9 N., R. 25 E., Spiro 7.5' quadrangle. UTM: 15S 354225 E 3898885 N.

Discussion and Interpretation:

Knechtel (1949) mapped this outcrop as the Lequire Sandstone (Fig. 65). Here, it dips 7° north and is on the south flank of the Bokoshe Syncline and north flank of the thrust-cored Backbone Anticline (crest ~3 mi to south). Knechtel (1949) shows a low ridge underlain by the Cameron Sandstone immediately north of the Lequire, but does not map the McAlester coal north of the Cameron Sandstone between it and the Tamaha Sandstone. The geology south of this outcrop is similarly uncertain. The areal separation of the Warner and Lequire Sandstones is unusually large. (For example, the units are ~1.5 mi apart here but only ~0.3 mi apart at Stop 15). Knechtel (1949, pl. II)) mapped the Spiro Anticline and Coal Creek Syncline to the south, but the axes of these structures are only 4 mi long and they die out on the flanks of the larger Bokoshe Syncline. The Spiro and Coal Creek structures probably are "out-of-the-syncline" flexural-slip folds on the flank of the Bokoshe Syncline, but exactly how they die out and whether they are associated with any "out-of-the-syncline" faults is not known.

The Lequire Sandstone is well-displayed in two wells down-dip from this outcrop. The Lone Star No. 1 Gist (CSW¼NW¼SE¼ sec. 31, T. 10 N., R. 26 E.) (Fig. 66) is located ~4.5 mi north of this outcrop and the Austral No. 1-7 West (SE¼NW¼SE¼ sec. 7, T. 9 N., R. 26

Stop 13
Warner Sandstone
New Spiro Lake
Measured Section

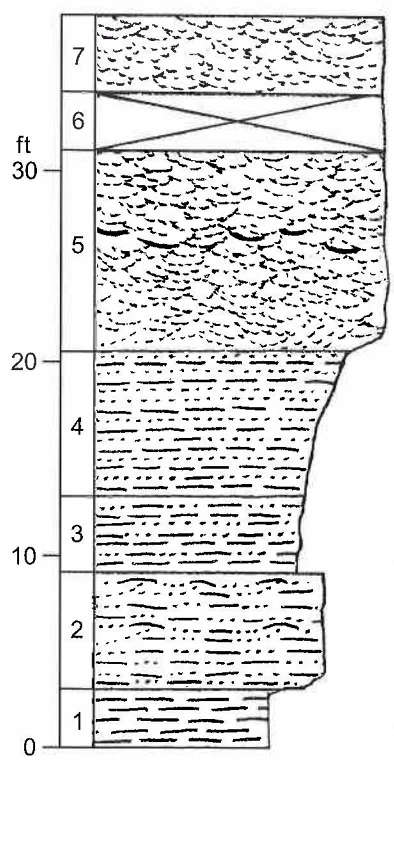


Figure 71. Graphic columnar section of Warner Sandstone at Stop 13, New Spiro Lake measured section. The section shows two upward-coarsening sequences which are similar to those in the Warner (PS-3/3A) in the No. 34-16 Cox (Fig. 73). See text for detailed description.

E.) (Fig. 67) is located ~3 mi north of this outcrop. The depth to the Lequire Sandstone in these wells ranges from 450 to 550 ft.

The shale (unit 1) (Fig. 65) underlying the Lequire Sandstone is a marine shale. It probably was not deposited in a prodelta environment based on the absence of siltstone layers and disturbed bedding. Most of the sedimentary structures in unit 2 are evidence of deposition in a moderate-energy environment, although the erosional contact at the base of the unit suggests a slightly higher energy. Despite its sharp base, the absence of common, large-scale cross-stratification suggests the unit is not a channel-fill deposit. The absence of a coarsening-upward profile suggests the sandstone is not a marine bar and there is no evidence for tidal reworking (e.g., draping, flaser beds). Features that suggest deposition in an unstable, relatively shallow-water environment are the rolled sandstone masses and small-scale and closely spaced ripple marks. Trace fossils on bedding planes and whole plant fossils (leaves) are evidence for a low-energy environment. The Lequire Sandstone here appears to be a relatively shallow-water deposit, possibly in a part of the lower delta plain little-affected by waves and/or tides. The sharp base reflects incision with all delta-front strata eroded. An alternative interpretation is that this outcrop is an upper-distributary-mouth-bar deposit (upper delta front) that was unaffected by tides or waves.

The upper part of the Lequire Sandstone (unit 4) (Fig. 65) is a high-energy deposit. It is coarser-grained than the underlying sandstone, contains abundant comminuted plant debris, and is highly soft-sediment deformed. Adjacent units are not exposed, therefore, a definitive interpretation is difficult. However, it is possible that unit 4 is a distributary channel-fill deposit.

The log character of the Lequire Sandstone in the Austral No. 1-7 West (Fig. 67) resembles that of the outcrop, but the origins likely are different. The sandstone in the well is ~20 ft thick, sharp-based, and relatively sharp-topped. The log signature from 450 ft to 469 ft is similar to that of a channel-fill deposit, but the slight coarsening-upward texture immediately below it may reflect a lower distributary-mouth-bar, suggesting a bar eroded into by a distributary channel. In contrast, the Lequire in the Lone Star No. 1 Gist (Fig. 66) is a coarsening-upward siltstone-shale sequence, most likely the lower and middle parts of a marine bar. This log of the Lequire Sandstone appears similar to those of the Lequire on the south side of the Backbone Anticline (Figs. 62 and 63).

The outcrop and logs of the Lequire Sandstone in this area are difficult to place in a paleo-depositional setting. At least some of the Lequire consists of marine-bar (probably distributary-mouth-bar) deposits. Other parts of the unit may be lower delta-plain or upper delta-front deposits, possibly closely associated with distributary channels, that are little-reworked by waves and/or tides and that immediately overlie deep-water marine shale. A more definitive depositional environment is difficult to establish.

Description of Units (Fig. 65):

McALESTER FORMATION:

Lequire Sandstone Member:

4. Sandstone, silty. Fine-grained, conspicuously coarser than unit 2. Highly soft-sediment deformed; rolled sandstone "balls" as much as 3 ft in diameter. Abundant iron-oxidized comminuted plant debris on many bedding planes; trace comminuted carbonized plant debris in matrix.

3. Covered

2. Sandstone. Very fine-grained, abundant mica on bedding planes. Generally conformable with unit 1; locally eroded at least 6 in. into unit 1. Typically plane-parallel-stratified to low-angle cross-stratified, rarely swaley- to wavy-bedded (Fig. 68). Individual beds show only very minor pinch-and-swell. Rarely cross-stratified. Towards top, contains a 0.5-ft-thick zone of soft-sediment-deformed rolled sandstone "boulders" and "cobbles." One bed in uppermost part shows two perpendicular sets of small-scale ripple-marks (Fig. 69). Other bed shows small vertical burrows and closely spaced ripple-marks. Observed in float: 1-ft x 3-in. compressed plant limbs, well-preserved horizontal trace fossils (Fig. 70).

Figure 72. Outcrop of Warner Sandstone at spillway of New Spiro Lake. Measured section was made on right side of outcrop.

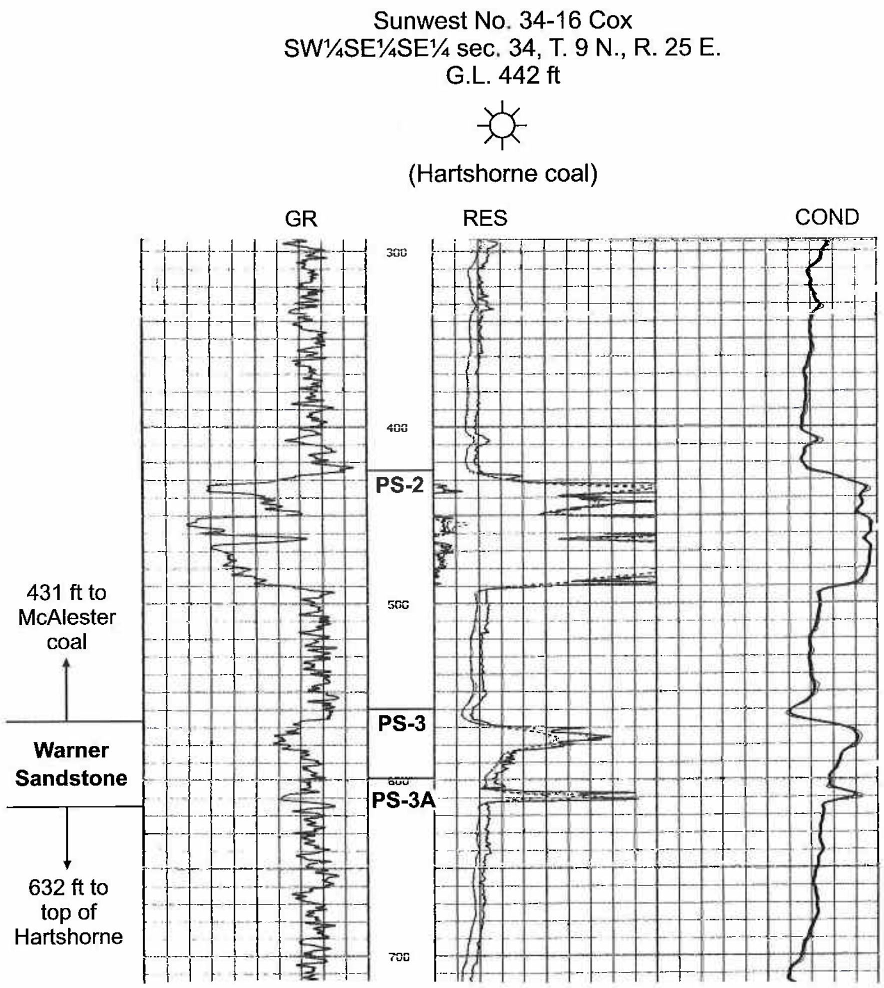


Figure 73. Part of wireline log of the Sunwest No. 34-16 Cox showing character of Warner Sandstone and parasequence boundaries. Coarsening-upward sequences are well developed for parasequences 3 and 3A (Warner Sandstone). The sandstone at the top of PS-2 (Lequire Sandstone) also displays a coarsening-upward textural profile. Coarsening-upward profiles are typical of distributary-mouth bar deposits which are common at the top of progradational sequences.

1. Shale, slightly silty. Fissile to platy, exhibits pencil structure. Weathers to rust-color on some fractures and bedding planes. No fossils. Monotonous.

Retrace route to south.

22.1 0.5 Intersection with east-west county (section-line) road. Continue straight (south). Leave Spiro Southeast CBM Field.

23.1 1.0 Road turns right (west).

23.6 0.5 Road turns left (south). Follow road along southeast side of New Spiro Lake.

24.3 0.7 Dam at southern end of New Spiro Lake. Park in parking area on east side of dam and walk down short trail through woods to bottom of dam. The Warner Sandstone is well exposed below the dam.

Stop 13. Warner Sandstone New Spiro Lake Measured Section

Location: Just below county road over spillway on east side of dam forming New Spiro Lake, ~3 mi south of Spiro, Oklahoma. SW¼NE¼SE¼ sec. 1, T. 8 N., R. 25 E., Spiro 7.5' quadrangle. UTM: 15S 353080 E 3895430 N.

Discussion and Interpretation:

This outcrop (Figs. 71 and 72) at the south end of New Spiro Lake (water-supply lake for the Town of Spiro) is the easternmost of three outcrops described (Stops 13, 14, and 15), all of which are located along a long ridge underlain by the Warner Sandstone (Knechtel, 1949). Here, the Warner dips 18° north and for ~8.5 mi to the west, the Warner also dips gently north. At this stop and Stop 14, the Warner is on the south flank of the east-west trending Coal Creek Syncline, a flexural-slip fold on the south flank of the Bokoshe Syncline (see discussion at Stop 12). The Warner at Stop 15 is on the south flank of the major northeast-trending Bokoshe Syncline. Just east of Bokoshe, the Warner Sandstone ridge curves to the north and then northeast, marking the axis of the Bokoshe Syncline. A summary of Knechtel's (1949) description of the Warner Sandstone is given at Stop 11.

Figure 74. Ripple marks on top of sandstone bed (unit 7), Warner Sandstone, New Spiro Lake measured section (Stop 13). Hammer for scale.

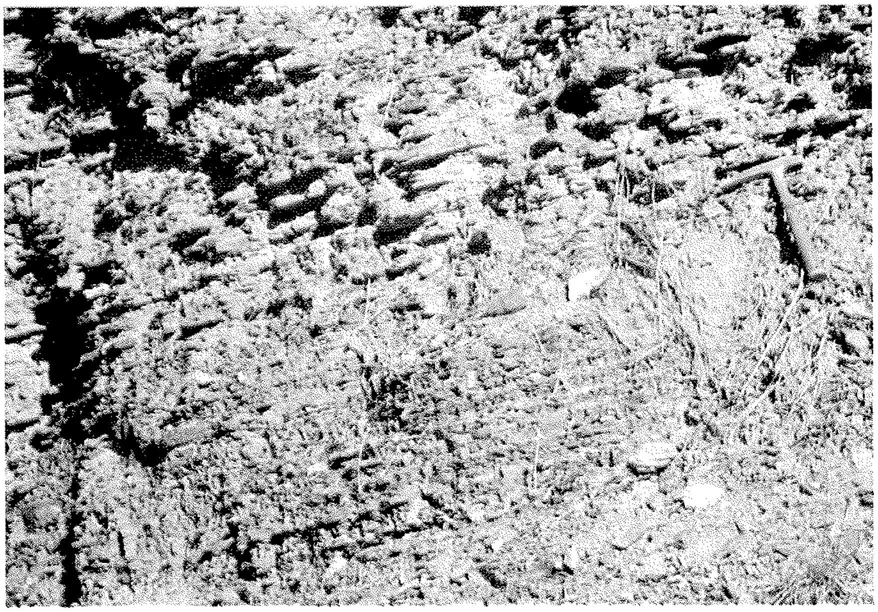


Figure 75. Contact (at head of hammer) between units 3 and 4, Warner Sandstone, New Spiro Lake measured section (Stop 13). Both units show cyclic deposition alternating between slightly finer- and coarser-grained sediments. This is evidence for tidal reworking.

The Spiro Southeast CBM Field is located ~1 mi northwest of this outcrop. All the wells in the field penetrated the Warner Sandstone, but few have logged it. The Sunwest Oklahoma No. 34-16 Cox (SW¼SE¼SE¼ sec. 34, T. 9 N., R. 25 E.) logged the Warner between ~565 ft and 613 ft (Fig. 73). Wireline logs in the area show the variable character of the Warner Sandstone.

The Warner Sandstone at New Spiro Lake (Fig. 71) consists of two coarsening-upward sequences typical of delta-front deposits. Unit 1 is a marine shale and is conformably overlain by low-energy (distributary-mouth) bar-transition strata. Several features in the bar-transition strata are evidence for tidal reworking, including lenticular bedding and siltstone drapes over the thin sandstone lenses. Units 3 and 4 are bar-transition to lower-bar strata. The abrupt change from a coarser unit 2 to a finer unit 3 may represent a decrease in sediment supply to the distributary-mouth bar due to channel-switching upstream or a parasequence boundary. Similar thicknesses of the Warner Sandstone at Stops 13 (here), 14, and 15 and in adjacent well logs shows this interval correlates to parasequences 3A and 3 of Boyd (2005). This suggests that the unit 2 – unit 3 contact is a parasequence boundary. Support for this interpretation is even more persuasive at Stop 14.

Units 3 and 4 show clear evidence for tidal reworking – both units consist of evenly spaced cycles of alternating fine- and coarse-grained beds. Lenticular bedding, flaser bedding, and shale and sandstone drapes over ripple marks also support a tidal origin for these units. A sandstone bed at the top of unit 3 thickens from 1 in. to 10 in. over a distance of ~50 ft; this sandstone is not incised into the underlying strata and therefore does not represent a channel fill. It probably filled a swale on the surface of the bar created by diurnal tides. Units 5 and 7 are upper-bar strata deposited in a relatively high-energy environment. Tidal activity is evidenced by the highly trough-cross-stratified and ripple-marked sandstone. Flaser bedding and rare bidirectional crossbedding are evidence that tidal reworking of the bar sediments occurred.

The Sunwest No. 34-16 Cox is located ~2 mi northwest of this outcrop. The log shows two "sandy" intervals – a thin (5 ft thick) lower one and a thicker (15 ft thick) upper one (Fig. 73). The coarsening-upward profile on the log, particularly in the upper interval, closely resembles the outcrop and is characteristic of a delta-front environment.

In summary, the outcrop of Warner Sandstone at New Spiro Lake is a tidally reworked distributary-mouth bar. All parts of the bar, including the bar transition, lower-bar facies, and upper-bar facies show abundant evidence for tides. The profile of the Warner on a nearby well log also is characteristic of a delta-front deposit.

Description of Units (Fig. 71):
McALESTER FORMATION:
Warner Sandstone Member:

7. Sandstone. Fine-grained. Highly trough-cross-stratified, ripple-marked (Fig. 74). Similar to unit 5. Poorly exposed.

6. Covered. Road.

5. Sandstone and minor shale. Fine- to very fine grained, abundant mica on bedding planes. Conformable with unit 4. Highly cross-stratified on small scale and ripple-marked, flaser-bedded, thin shale locally draped across tops of ripples. Foresets appear to dip in many directions, locally appear bidirectional. Lower 3.5 ft well exposed at top of cliff; upper part poorly exposed.

4. Shale and sandstone. Sandstone very fine grained, quartzose. Conformable with unit 3 (Fig. 75). Unit characterized by very regular repetition of 1- to 2-in.-thick shale beds separated by 0.5- to 0.75-in.-thick sandstone beds. Sandstone beds have flat bases, ripple-marked tops, are very continuous to lensoid. Common unidirectional small-scale cross-stratification; foresets dip generally west. Shale and some sandstones draped over ripples. In upper half, sandstone beds slightly thicker, highly cross-stratified, flaser-bedded.

3. Shale, siltstone, and minor sandstone. Conformable with unit 2. Unit characterized by repeating 1.5-in.-thick shale beds

Figure 76. Cyclic deposition of siltstone and very fine grained sandstone in unit 3, Warner Sandstone, New Spiro Lake measured section (Stop 13). Small-scale cyclic deposition is evidence for tidal reworking in this delta-front deposit. Hammer for scale.

separated by 0.5-in.-thick siltstone (Fig. 76) and very fine grained sandstone beds that are slightly lenticular-bedded showing slight pinch-and-swell. Top of unit marked by sandstone bed that thickens from 1 in. to 10 in. over a distance of ~50 ft from east to west.

2. Sandstone and siltstone. Sandstone very fine grained, quartzose. Conformable with unit 1. Laminated to very slightly wavy bedded to lenticular-bedded. Siltstone generally draped over thin, discontinuous sandstone lenses; lenses typically cross-stratified on very small scale.

1. Shale, slightly silty. Fissile, laminated. Weathers spheroidally.

Retrace route to U.S. 59/271.

32.8 7.5 Immediately before intersecting with U.S 59/271, turn left (east) on County Road E-1260 (also section-line road).

33.5 0.7 Road turns left (north).

33.6 0.1 Road turns right (east) and crosses Kansas City – Southern railroad tracks. Immediately after crossing railroad tracks, turn left (north) on dirt driveway adjacent to tracks.

33.7 0.1 Park in front of gate before road proceeds up hill to private residence. For permission to visit this outcrop, contact Mr. Wayne Conger, Roadmaster, Kansas City – Southern Railroad. Phone (318) 676-6261, or (501) 683-0126.

Stop 14. Warner Sandstone Panama Railroad Cut Measured Section

Location: Railroad cut along Kansas City – Southern railroad tracks ~1.5 mi north of Panama, Oklahoma and ~0.75 mi east of the intersection of U.S. Highway 59 and Oklahoma State Highway 31. Railroad crossing immediately south of cut is called Coal Creek on some maps. NW¼SE¼SW¼ sec. 3, T. 8 N., R. 25 E., Panama 7.5' quadrangle. UTM: 15S 348915 E 3895350 N.

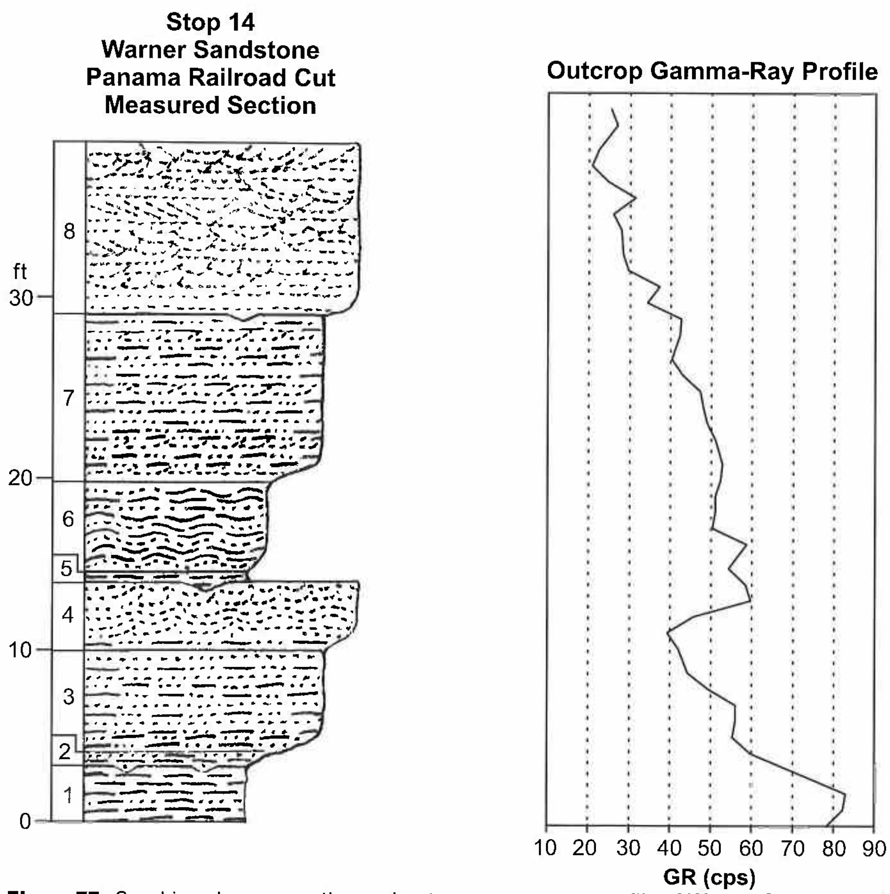


Figure 77. Graphic columnar section and outcrop gamma-ray profile of Warner Sandstone at Panama Railroad Cut measured section (Stop 14). This outcrop is similar to that measured at the New Spiro Lake (Stop 13). Here a pair of coarsening-upward sequences are correlated with middle Booch parasequences 3 and 3A. It is also reminiscent of the Warner Sandstone at the AOK Railroad, Haileyville measured section (Fig. 15). However, the upper part of the AOK Railroad cut is a delta-plain deposit, whereas the upper part of this outcrop is within the delta front. All three outcrops show evidence for tidal reworking.

Discussion and Interpretation:

Stop 14 is a gently north-dipping (20°) outcrop of Warner Sandstone (Fig. 77) on the south flank of the Coal Creek Syncline (Knechtel, 1949, pl. II). This is a small feature located on the south flank of east-west-to northeast-southwest-trending Bokoshe Syncline (crest ~1.75 mi to north) and the north flank of east-west-trending thrust-cored Backbone Anticline (trace of fault ~0.75 mi to south; crest of anticline just south of fault). Here, the Kansas City Southern railroad cuts through a long ridge of Warner Sandstone (Fig. 78). Knechtel (1949, p. 67) measured 35.5 ft of sandstone and shale here, and, while some parts of his description are of little use for interpreting the environment of deposition, other parts are useful. Knechtel (1949) describes the sandstone as olive-drab to dark gray, fine-grained, hard, and micaceous. He accurately describes the sandstone in the upper part of the section (unit 8, this report) as "massive, cross-bedded" and the underlying unit (unit 7, this report) as a shale "interbedded with many evenly spaced thin sandstone beds" (p. 67).

Figure 78. Kansas City Southern train at Panama Railroad Cut measured section (Stop 14). Putting coins on the tracks prior to trains passing is a favorite pastime of geologists studying this outcrop.

The Sunwest No. 34-16 Cox (SW¼SE¼SE¼ sec. 34, T. 9 N., R. 25 E) (Fig. 73) is located ~1.5 mi northeast of this outcrop. The log profile of the Warner Sandstone in this well closely resembles the outcrop gamma-ray profile (Fig. 77). In addition, the thickness of the Warner in the No. 34-16 Cox (55 ft) is similar to the outcrop thickness (~40 ft).

The Panama Railroad Cut outcrop consists of two coarsening-upward sequences separated by what appears to be an angular unconformity (Fig. 77) (discussed below). The basal unit (no. 1) of the outcrop is a prodelta or distal marine shale. Its upper contact is an erosional disconformity with as much as 4 in. of relief. Units 2, 3, and 4 are a coarsening-upward sequence typical of delta-front strata, but all contain abundant evidence for tidal reworking as evidenced by lenticular bedding, flaser bedding, and draping. Unit 2 represents the transition from marine shale to the lower part of a distributary-mouth bar (bar-transition strata). Unit 3 was deposited in a lower-bar environment and unit 4 in an upper-bar environment. The abundant trough-cross-stratified sandstone in unit 4 is evidence for a high-energy depositional environment and the presence of coaly laminations is evidence for abundant large plant debris in a near-shore environment.

The base of the upper coarsening-upward sequence (unit 5) probably is the boundary between parasequences 3 and 3A of Boyd (2005). The contact between units 4 and 5 appears to be an angular unconformity based on the variable thickness of unit 4 (0 ft to 4 ft). This angular unconformity is not tectonic but likely represents the time during which sea level rose and the parasequence 3A prodelta and delta front (units 1 through 4) deformed due to slumping, dewatering, or some other soft-sediment process. These sediments were then eroded and overlain by unit 5. Unit 5, a marine or prodelta shale (generally similar to unit 1), was deposited on an erosion surface with as much as 6 in. of relief, but one where at least 4 ft of unit 4 was eroded. The base of the upper coarsening-upward sequence is similar to the base of the lower sequence. Unit 6 represents the transition from marine shale to distributary-mouth bar and unit 7 is a lower-bar deposit. Units 6 and 7 show evidence for tidal reworking, including draping. The sandstone and shale beds in unit 7 are conspicuously repetitive (also noted by Knechtel, 1949) and clearly were deposited by tides, possibly spring and neap tides. The

Figure 79. Small lateral-accretion bedsets in unit 8, Panama Railroad Cut measured section (Stop 14). Hammer for scale.

Figure 80. Cyclic alternating sandstone and shale in unit 7, Panama Railroad Cut measured section (Stop 14). The cyclicity is evidence for tidal deposition. The thickness of the repeating sequences suggests spring- and neap-tide cycles rather than diurnal cycles. Hammer for scale.

upper coarsening-upward sequence at this outcrop is capped by sandstone (unit 8) in which shale is present only as rip-up clasts. The sandstone is cross-stratified on a large scale, coarser-grained than that found elsewhere, and erodes as much as 3 in. into the underlying unit. Unit 8 probably is a distributary-channel deposit. The thin partings separating some of the bedsets may represent breaks in the otherwise high-energy environment, suggesting that the channel may have been influenced by tides.

In summary, the sequence of units in the Warner Sandstone at the Panama Railroad Cut outcrop supports Boyd's (2005) observation that it consists of two parasequences. Here, the Warner Sandstone consists of two coarsening-upward distributary-mouth-bar sequences separated by a "syn-depositional" (probably local) angular unconformity. The unconformity here is autocyclic but occurs at a regional parasequence boundary. Both sequences were reworked by tides; the lower is capped by upper-bar deposits and the upper is capped by distributary-channel deposits. Nearby well logs of the Warner Sandstone generally are similar to what is observed in outcrop.

Description of Units (Fig. 77):

McALESTER FORMATION:

Warner Sandstone Member:

8. Sandstone. Fine- to medium-fine-grained, silty. Generally conformable with unit 7; locally eroded ~3 in. into unit 7. Sandstone highly cross-stratified, including tabular and large low-angle trough. Local lateral-accretion bedsets and nested trough-crossbeds (Fig. 79). Beds separated by thin, highly micaceous partings. Many beds continuous and exhibit similar thicknesses, but do not pinch and swell. Rare small shale rip-up clasts. Rare soft-sediment deformation structures. Unit cut by small normal fault with ~3-4 in. of offset and small flexure in footwall.

7. Sandstone and shale. Sandstone very fine grained. Conformable with unit 6. Sandstone beds typically 1 in. thick, though exhibit much pinch-and-swell, and range from 0.25 to 3 in. Sandstone beds very continuous and thicken slightly upward. Tops typically ripple-marked; bases flat to slightly wavy. Highly cross-stratified with rare black partings. Rare trace fossils on bases of some beds. Shaly units 3 to 6 in. thick, fissile, wavy-bedded, consisting of very fine laminated sandstone and black silty shale. Strata are conspicuously cyclic (Fig. 80).

6. Sandstone and shale. Sandstone very fine grained. Conformable with unit 5. Sandstone stratified to laminated, low-angle wavy-bedded to less commonly plane-parallel stratified. Highly cross-stratified on small scale. Some sandstone beds continuous, though pinch-and-swell; others discontinuous. Some stratal sequences may be repetitive. Minor soft-sediment deformaton on very small scale. Abundant black and thin silty organic-rich shale partings, typically draped over underlying irregular bedding.

5. Shale, very minor siltstone and sandstone. Unconformable with unit 4 (Fig. 81). Fissile, laminated, thinly lenticular-bedded. Mica common, comminuted carbonaceous organic debris uncommon on bedding planes. Sandstone very fine

Figure 81. Unconformity (at hammer head) between units 4 and 5 at Panama Railroad Cut measured section (Stop 14). Laminae in unit 4 dip more steeply than those in unit 5, and beds in unit 4 on left side of photograph are erosionally truncated by unit 5.

grained. Total thickness varies from 0.5 to 1 ft due to irregular base.

4. Sandstone and minor siltstone. Sandstone fine- to very fine grained, quartzose. Conformable with unit 3; gradational over ~6 in. (sandstone beds thicken, siltstone beds thin). Wavy-bedded, complexly trough-cross-stratified, local climbing ripples (Fig. 82). Sandstone drapes common. Siltstone occurs as local coaly partings and as flaser-beds (Fig. 82). Total thickness varies from 0 to 4 ft due to unconformity at top.

3. Sandstone, siltstone, and minor shale. Conformable with unit 2 (Fig. 83). Sandstone very fine grained. Lenticular-bedded sandstones from a fraction to 1 in. thick, typically 0.25 in. thick, highly laminated. Wavy-bedded; sandstone and organic-rich siltstone draped over sandstone lenses.

2. Sandstone and shale. Generally conformable and gradational with unit 1 (Fig. 83); locally erodes as much as 4 in. into unit 1. Lenticular-bedded sandstone with flat bases, shale draped over sandstone lenses.

1. Shale, minor siltstone. Fissile. Spheroidal weathering. Single, 1-in. leaf fossil observed.

Figure 82. Wavy- and flaser-bedded sandstone in unit 4, Panama Railroad Cut measured section (Stop 14). The flaser beds and extensive, regularly spaced horizontal to undulatory partings are evidence for tidal reworking. Pen for scale.

Return to County Road E-1260.

33.8 0.1 Recross Kansas City – Southern railroad tracks and return to U.S. 59/271.

34.6 0.8 Turn right (north) on U.S. 59/271.

34.7 0.1 Turn left (west) on State Highway 31.

35.2 0.5 Highway makes very gentle curve to right. Heads due west after curve.

Figure 83. Units 3, 2, and 1 at Panama Railroad Cut measured section (Stop 14). Although unit 2 locally erodes into unit 1, the three units show a coarsening-upward sequence. End of hammer handle at base of unit 2.

For the next couple of miles the highway overlies poorly exposed shale in the Atoka Formation in the footwall of the steeply south-dipping Backbone Thrust. The trace of the fault is less than half a mile south of the highway; the low hills ~0.5 mi south of the highway are underlain by Atoka sandstones in the hanging wall. Mima mounds (see Mile 33.8, Day One, Fig. 39) locally dot the floor of this shale valley.

After the curve, the highway parallels the old grade of the Fort Smith and Van Buren railroad. This part of the line was built in 1901 from Coal Creek to McCurtain (named Panther until 1902) by the Fort Smith and Western Railway Company, which sold it to the KCS-controlled FS and VB in 1939.

35.9 0.5 Enter Kinta gas field.

Kinta Gas Field

The Kinta Field is the largest gas field in the Arkoma Basin. It covers parts of five counties and has 2,140 wells of which 1,655 are active. Daily gas production is 112 MMcf with cumulative production of 2.969 Tcf (IHS Energy, 2006). Production is from a variety of reservoirs, but most is from Atoka sandstones, including Atoka (undifferentiated), Alma, Brazil, Fanshawe, Gilcrease, Red Oak, and Spiro. The Hunton, Cromwell, Booch, and Hartshorne also are significant producing units.

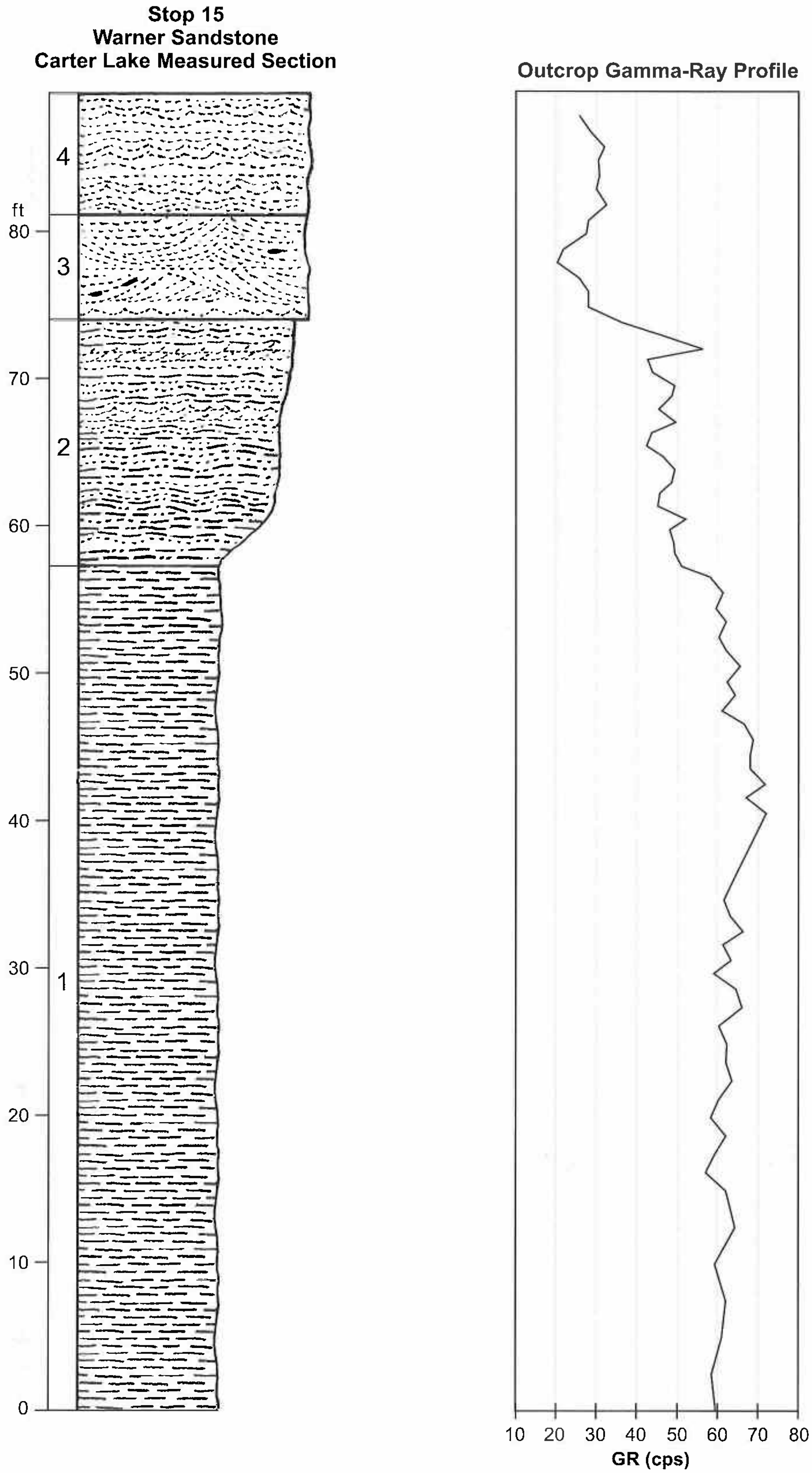


Figure 84. Graphic columnar section and outcrop gamma-ray profile of the Warner Sandstone, Carter Lake measured section (Stop 15). The gamma-ray profile shows the overall coarsening-upward character of the unit, although sharp breaks do occur. Like other outcrops, this outcrop shows variability in gamma-ray readings across apparently uniform rock types.

36.9 1.0 The Skullyville Courthouse and jail are just south of the highway in sec. 7, T. 8 N., R. 25 E. The jail is one of the few Choctaw national government structures still standing (Ruth and Fefebvre, 1970).

37.5 0.6 Turn right (north) on county road.

Knechtel (1949, pl. 1) shows the Hartshorne sandstone and Upper and Lower Hartshorne coals occurring at the surface near here and dipping 8° north-northwest. A small slope mine in the lower(?) coal is present immediately to the west. Modern strip mines in one or both of the Hartshorne coals appear on the 1968 Panama topographic map ~1.25 mi to the west-southwest.

37.9 0.4 Turn right (east) into flat area at base of large outcrop and park.

Stop 15. Warner Sandstone Carter Lake Measured Section

Location: Borrow pit along county road ~3.5 mi northwest of Panama, Oklahoma. County road intersects Oklahoma State Highway 31 ~2.8 mi west of the intersection of 31 and U.S. Highway 59 just north of Panama. Center N½NW¼SE¼ sec. 1, T. 8 N., R. 24 E., Panama 7.5' quadrangle. UTM: 15S 343100 E 3895685 N.

Discussion and Interpretation:

Knechtel (1949) mapped this outcrop (Figs. 84 and 85) as Warner Sandstone. It is the westernmost of three stops (Stops 13, 14, and 15) along a ridge of Warner Sandstone on the south flank of the Coal Creek or Bokoshe Synclines. Stop 14 is ~3.7 mi east of here and Stop 13 is ~6.2 mi to the east. Here, the Warner Sandstone dips 21° north towards the axis of the Bokoshe Syncline, the trough of which is ~1 mi to the north. The crest of the Backbone Anticline is ~1.25 mi to south and the trace of the Backbone Fault on the north flank of the anticline is ~1 mi to south. The Upper and Lower Hartshorne coals are poorly exposed near the intersection of the county

Figure 85. Carter Lake measured section, Stop 15. Unit 1 (shale) at the base of the outcrop is largely covered with debris. Unit 4 (sandstone) is the slightly parted interval at the top of the cliff.

road and Highway 31. The Lequire Sandstone, which overlies the Warner, forms a prominent ridge (Nubbin Ridge) ~0.3 mi to the north.

The Athletic Mining and Smelting Co. No. 1 Dunn (SW¼NE¼SW¼ sec. 35, T. 9 N., R. 24 E.) is located ~1.2 mi northwest of the outcrop. The log (Fig. 86) shows two prominent sandstones; the lower one is ~500 ft deep, ~40 ft thick, and is the Warner Sandstone. The log thickness is approximately the same as that measured at the outcrop (~31 ft, top covered). There are some differences between the well log and the gamma-ray profile of the outcrop (Fig. 84); these differences are discussed below.

The Warner Sandstone at Stop 15 coarsens upward from a marine shale with siderite-cemented beds and lenses (unit 1) to a relatively clean sandstone (unit 4) that is typical of a marine-bar deposition. Unit 1 is a marine shale; the absence of sandstone laminae indicates it is distal marine and not a prodelta shale. Unit 2 represents a shoaling marine bar; as pointed out by Boyd (2005), however, the proximity of fluvial systems throughout Booch deposition suggests that these bars probably are distributary-mouth bars and not detached marine bars, which would require wave action to form. Possible repetitive sequences in the lower part of unit 2 suggest that it was reworked by tides. Unlike most other outcrops on this field trip, the upper part of this outcrop, although coarser and likely deposited in shallower water, does not contain evidence for cyclic deposition. The two thick sandstone beds near the top of unit 2 clearly indicate higher-energy conditions and possibly are tidal channels.

The nested trough-crossbeds and rip-up clasts in unit 3 and its abrupt contact with unit 2 are evidence for high-energy conditions; thus, it likely is a tidal channel or a relatively thin tidally-influenced distributary channel. Unit 4 is similar to unit 3, but the draped partings suggest a higher degree of tidal reworking than is evident in unit 3.

It is difficult to compare the No. 1 Dunn (Fig. 86) with the outcrop because the well does not have a gamma-ray log. Although the thicknesses of the Warner in the well and outcrop are similar, the outcrop does not show the typical double-peaked gamma-ray character of the Warner Sandstone. It is possible that the shale that is usually at the top of PS-3A was eroded and replaced by the channel deposits of units 3 and 4, a relationship commonly seen in the subsurface.

Description of Units (Fig. 84):
McALESTER FORMATION:
Warner Sandstone Member:

4. Sandstone. Fine-grained, quartzose. Wavy-bedded, tops ripple-marked (Fig. 87). Variably parted; partings relatively continuous, clearly draped across ripple-bedded sandstone. Rip-up clasts rare.

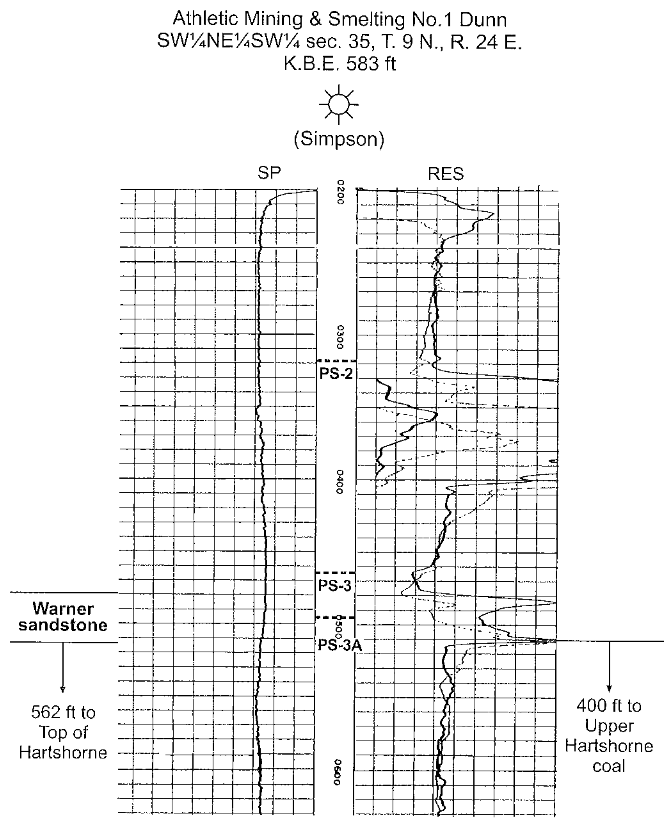


Figure 86. Part of wireline log of the Athletic Mining and Smelting No. 1 Dunn. Although the thicknesses of the Warner Sandstone in the Carter Lake outcrop and on the log are similar, the log shows the characteristic double-peaked Warner, whereas the outcrop does not. The fine-grained interval that normally separates PS-3 and PS-3A may have been eroded by unit 3.

Figure 87. Unit 4, Carter Lake measured section (Stop 15).

3. Sandstone. Fine-grained, sorted. Conformable with unit 2; base abrupt (Fig. 88). Basal sandstone: 8 in. thick, continuous, ripple-marked top, locally lenticular-bedded. Most of sandstone has low-angle, large-scale, nested trough-crossbeds (Figs. 89A and 89B). Scattered shale rip-up clasts throughout.

2. Shale and minor sandstone and siltstone. Shale slightly silty, fissile. Sandstone very fine grained. Conformable (gradational) with unit 1. Well-stratified, lenticular-bedded to wavy-bedded. Sandstone lenses plane-parallel- and cross-stratified; parted on very small scale. Sandstone beds vary from lensoid and discontinuous to very continuous; shale beds continuous (Fig. 90). Sandstone beds thicker and more numerous upward (Fig. 91); some with ripple-marks. Lower part includes possible repetitive sequences consisting of 0.5- to 1-in.-thick sandstone beds separated by 2 to 3 in. of shale. Apparent cyclicity absent in upper half of unit. Near top, two 5- to 7-in.-thick sandstone beds separated by 2-in.-thick fissile siltstone; relatively continuous, but thin slightly along outcrop to northwest. Beds gradational with underlying strata. Sandstone very fine grained; beds locally highly parted, wavy-bedded and cross-stratified. Comminuted carbonaceous organic debris uncommon; trace fossils not observed.

1. Shale. Fissile. Contains siderite-cemented beds and lenses. Has a distinct "tinkly" sound characteristic of distal marine shales.

Return to county road and continue north.

38.3	0.4	Top of ridge underlain by Lequire Sandstone dipping 8° north on south flank of Bokoshe Syncline (north flank of Backbone Anticline). The Lequire Sandstone is 80 ft thick in the nearby No. 1 Dunn well (Fig. 86).
38.5	0.2	Road makes short jog to right at intersection. Continue straight (north).
38.9	0.4	Cross trough of Bokoshe Syncline.
39.5	0.6	Road intersection. Bear left (northwest) up low ridge.
39.6	0.1	Top of ridge underlain by Lequire Sandstone dipping 10° southeast on north flank of Bokoshe Syncline (Knecthel, 1949).
39.8	0.2	Top of second ridge is underlain by Warner Sandstone dipping 14° southeast.
40.2	0.4	Low ridge underlain by Hartshorne sandstone dipping 22° southeast.

Knechtel (1949) shows many slope mines in the Hartshorne coal immediately above the sandstone. Here, the Lower and Upper Hartshorne coals have merged to form a single coalbed. The Hartshorne coal has been extensively strip mined along this outcrop.

40.5	0.3	Road intersection with east-west section-line road. This very low ridge and the two ridges immediately to the north are underlain by gently southeast-dipping sandstones in the Atoka Formation.
40.9	0.4	Intersection with U.S. 59/S.H. 9. Turn left (west).
41.6	0.7	Cross crest of Milton Anticline cored by Atoka Formation. Strata for the next several miles dip gently to the northwest.
42.5	0.9	Leave Panama 7.5' quadrangle; enter extreme northeast corner of Bokoshe 7.5' quadrangle.

Figure 88. Contact (arrow) between units 3 and 2, Carter Lake measured section (Stop 15). The contact is sharp, but conformable.

42.6 0.1 Leave Bokoshe 7.5' quadrangle; enter Robert S. Kerr Dam 7.5' quadrangle.

43.1 0.5 Cross strip-mined Hartshorne coal dipping about 10° northwest.

43.3 0.2 Intersection of U.S. 59 and S.H. 9. Turn right (north) on U.S. 59.

43.9 0.6 Cross low ridge underlain by Warner Sandstone dipping 8° northwest.

44.5 0.6 Cross very low ridge underlain by Cameron Sandstone. Knechtel (1949, pl. I) mapped two prospects in the McAlester coal ~1 mi northeast of here.

46.4 1.9 Leave Kinta Gas Field.

46.5 0.1 Intersection with paved county road. Tucker to right (east) and Cowlington to left (west). Continue straight (north).

47.6 1.1 Low ridge underlain by basal sandstone of the Savanna Formation.

48.7 1.1 Enter floodplain of Arkansas River. Flat-topped hill to left (west) is Short Mountain and is underlain by the basal Bluejacket Sandstone Member of the Boggy Formation.

49.7 1.0 Cross Arkansas River just below Robert S. Kerr Dam.

50.0 0.3 Leave floodplain of Arkansas River. Leave Le Flore County; enter Sequoyah County.

Robert S. Kerr Lock and Dam and McClellan-Kerr Arkansas River Navigation System

(The following information is from the U.S. Army Corps of Engineers website http://www.swt.usace.army.mil/PROJECTS/civil/civil_projects.cfm?number=30, retrieved April 26, 2005.)

The Robert S. Kerr lock and dam is located on the Arkansas River at navigation mi 336.2, ~ 8 mi south of Sallisaw in LeFlore [*sic*] County, Oklahoma. Construction began in April 1964 and closure occurred in October 1970. The lock and dam became operational for navigation in December 1970. The total length of the structure, including the spillway, powerhouse intake, and navigation lock, is 7,230 ft. The maximum height is 75 ft above the streambed. The drainage area above the dam site is 147,756 square miles with 22,24 [*sic*] not contributing to flows.

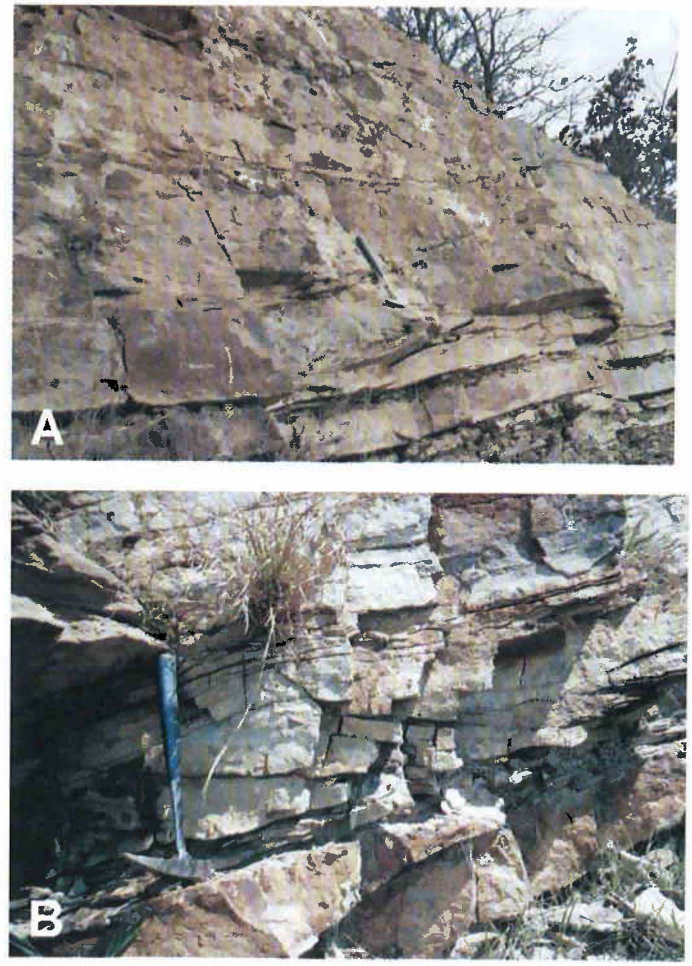


Figure 89 A & B. Large-scale nested trough crossbeds in unit 3, Carter Lake measured section (Stop 15) located near middle of figure 88. The crossbeds are evidence that this unit is a channel deposit, possibly a tidally influenced distributary channel. Hammer for scale.

The most recent geologic map of southern Sequoyah County is by Marcher (1969), which is copied from Miser (1954). Miser (1954), in turn, is based on unpublished mapping by C.C. Branson and Crumpley (1949). These maps show Atoka Formation exposed in the banks of the Arkansas River and lower elevations covered by a veneer of Quaternary terrace deposits underlying the gently rolling area immediately to the northwest.

50.3 0.3 Enter Brent Gas Field (Boyd, 2002).

Brent Gas Field

The Brent Gas Field consists of three wells (one active) that produce from the Cromwell Sandstone. The cumulative production from the field is 1.3 Bcf and the field is producing about 117 Mcf gas per day (IHS Energy, 2006).

50.7 0.4 Highway intersects east-west county road (also section-line road). Continue straight (northwest).

Figure 90. Well-stratified, rippled, lenticular-bedded sandstone and shale in lower part of unit 2, Carter Lake measured section (Stop 15). Pen for scale.

51.7 1.0 Leave Brent Gas Field.

51.9 0.2 Highway intersects north-south county road (also section-line road). Turn right (north) onto county road.

52.0 0.1 Leave Robert S. Kerr Dam 7.5' quadrangle; enter Sallisaw 7.5' quadrangle.

52.1 0.1 Cross State Highway 141. Continue straight (north).

The relatively flat area for the next mile is underlain by Quaternary terrace deposits.

53.3 1.2 Road turns left (west) and climbs south side of Wildhorse Mountain.

53.5 0.2 Road turns right (northeast). Stop and park on outside of bend facing uphill.

Stop 16. Warner(?) Sandstone Wildhorse Mountain Measured Section

Location: Roadcut along county road, south side of Wildhorse Mountain, ~1 mi east of U.S. Highway 59; ~5 mi south of Sallisaw, Oklahoma. SW¼NE¼SE¼ sec. 30, T. 11 N., R. 24 E., Sallisaw 7.5' quadrangle. UTM: 15S 336535 E 3918185 N.

Discussion and Interpretation:

The surface geology of this part of Oklahoma is poorly known. The most recent geologic map of the area is by Marcher (1969). His map is based on Miser (1954) and Miser's (1954) map of the area is based on Crumpley (1949) (Fig. 1). Despite having only a planimetric base map and the reconnaissance nature of his study, Crumpley's (1949) geologic map is still the most modern and presumably the most accurate. Crumpley (1949) does not identify the unit capping Wildhorse Mountain, but did identify a coal just below it. Miser (1954) shows this coal and another on the west side of Pine Mountain ~3.5 mi to the east to be in the Hartshorne Formation. If Miser's (1954) map is correct, the overlying sandstone is in the lower part of the McAlester Formation. In contrast, Friedman (1982, pl. 4) maps the coal on Pine Mountain as the Stigler (McAlester) coal. If Friedman (1982) is correct and the coal on Pine Mountain is the same as the coal just below the capping sandstone on Wildhorse Mountain, then the sandstone is in the upper part of the McAlester Formation, possibly the Tamaha Sandstone, which Boyd (2005) does not consider to be a Booch sandstone. Friedman (1982), however, does not correlate the coal on Pine Mountain with that on Wildhorse Mountain; he places the coal on Wildhorse Mountain immediately above the Warner Sandstone. If Friedman (1982) is correct, the sandstone at this stop is Lequire or possibly Cameron. In summary, most authors agree that this sandstone is in the McAlester Formation; however, it may be the Warner, Lequire, Cameron, or Tamaha.

This outcrop of McAlester sandstone consists of several coarsening-upward sequences var ying in thickness from ~2 ft to 13 ft (Fig. 92). The outcrop gamma-ray profile (Fig. 92) also suggests that the entire unit coarsens upward. Sedimentary structures and the coarsening upward profile suggest this sandstone is a marine bar. The abundance of plant debris (e.g.,

Figure 91. Well-stratified sandstone and shale in upper part of unit 2, Carter Lake measured section (Stop 15). Unit 2 contains more sandstone upsection, which is typical of distributary-mouth-bar deposits. Hammer for scale.

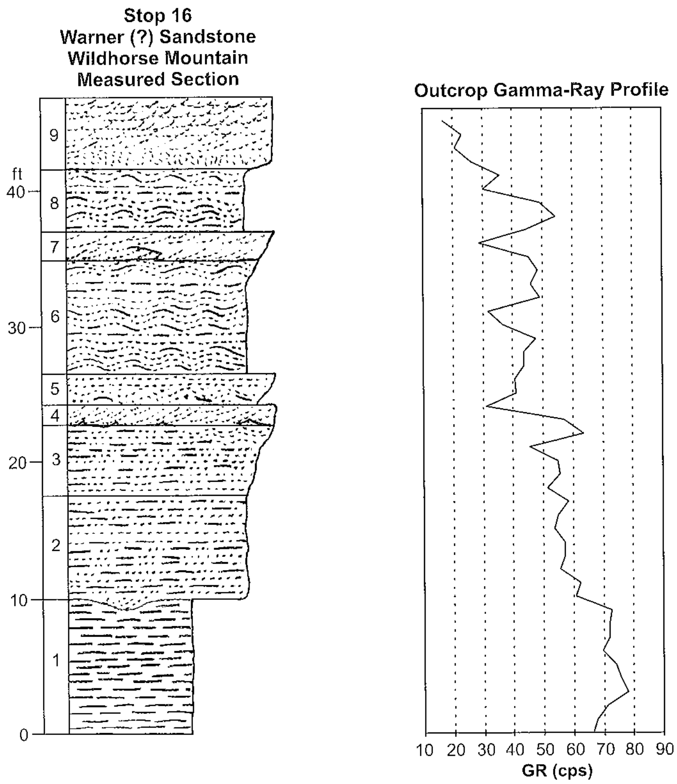


Figure 92. Graphic columnar section and outcrop gamma-ray profile of a McAlester (Booch) sandstone, possibly the Warner Sandstone, Wildhorse Mountain measured section (Stop 16). The gamma-ray profile shows the characteristic coarsening-upward character typical of many McAlester (Booch) sandstone intervals. The apparent absence of the McAlester coal, the long distance across a structurally complex terrain to the Hartshorne coal, and the absence of nearby wells with shallow logs makes the identification of this sandstone uncertain.

coalified logs in unit 2, comminuted plant debris in units 4 and 8) is evidence for proximity to a river. Thus, this outcrop most likely is a distributary-mouth-bar deposit. Flaser bedding and draping, which are common, are evidence for tidal reworking. The relatively coarse grain size and presence of large-scale trough-stratified beds suggests that units 4 and 9 are upper-bar or channel-fill deposits. The cyclicity exhibited in this outcrop probably is caused by distributary-channel switching or tidal influences rather than a eustatic sea-level change.

Description of Units (Fig. 92):

McALESTER FORMATION:

Warner(?) Sandstone Member:

9. Sandstone. Conformable with unit 8. Medium-fine-grained, quartzose, abundant comminuted carbonized plant debris. Varies from unstratified to highly large-scale trough-cross-stratified (Fig. 93) with much pinch-and-swell of individual beds. Base flat. Rare rip-up clasts.

8. Sandstone and siltstone. Conformable with unit 7. Sandstone occurs as lenses in siltstone and as more continuous thin, ripple-marked beds that pinch and swell. Siltstone laminated and wavy-bedded, typically draped across sandstone lenses and ripple marks.

7. Sandstone and minor siltstone. Conformable with unit 6 (Fig. 94). Lower part: sandstone fine-grained, quartzose, angular grains. Individual beds wavy-bedded, cross-stratified, with ripple-marked tops and bases flat to irregular. Minor thin siltstone draped across ripples. Upper part: sandstone medium-grained, quartzose. Individual beds 2- to 4-in. thick, generally thicker than those in lower part. Large-scale trough-cross-stratified; locally contains rip-up clasts.

6. Sandstone and minor siltstone. Conformable with unit 5. Sandstone: fine-grained, quartzose, angular grains. Sandstone occurs as approximately 1-in.-thick ripple-marked, cross-stratified beds and 0.5-in.-thick lenses with flat bases and rippled tops in laminated, slightly wavy-bedded sandstone and siltstone (Fig. 95). Some ripple marks appear truncated and draped by sandstone or laminated sandstone and siltstone.

5. Sandstone and very minor siltstone. Conformable with unit 4. Consists of two sandstones. Lower: sandstone fine-grained, quartzose. Individual beds 0.1- to 4-in. thick, locally separated by fissile siltstone. Sandstone beds laminated, wavy-bedded, exhibit pinch-and-swell, draping. Upper: sandstone fine-grained, quartzose. Beds generally thicker than those in lower part and typically have ripple-marked tops, irregular bases filling underlying ripples. Rare cross-stratification.

4. Sandstone. Conformable with unit 3. Medium-grained, rounded grains, abundant comminuted carbonaceous plant debris. Load casts locally present on base. Consists of several

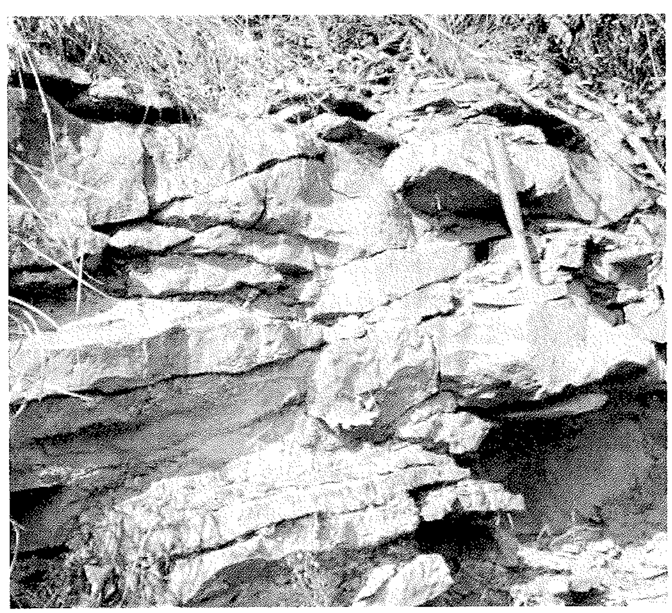


Figure 93. Large-scale trough-cross-stratified sandstone in unit 9, McAlester sandstone, Wildhorse Mountain measured section (Stop 16). Hammer for scale.

Figure 94. Contact between units 6 and 7 showing coarsening-upward character (McAlester sandstone, Wildhorse Mountain measured section, Stop 16). Hammer for scale.

3- to 6-in.-thick beds separated by thin partings; individual beds vary from unstratified to highly trough-cross-stratified to plane-parallel laminated.

3. Sandstone, minor siltstone and shale. Conformable with unit 2. Sandstone: medium-fine-grained, quartzose, light gray. Occurs primarily as continuous 1- to 6-in.-thick beds that pinch and swell, with ripple-marked tops (Fig. 96). A conspicuous 6-in.-thick cross-stratified sandstone near the top contains abundant shale rip-up clasts. Trace fossils rare. Sandstone also lenticular-bedded to more commonly flaser-bedded to wavy-bedded; individual sandstone beds and interbedded siltstone and shale very continuous. Siltstone and shale laminated and draped over sandstone lenses (Fig. 96).

2. Sandstone, siltstone, shale. Disconformable (erosional) with unit 1 (Figs. 97A and 97B); locally eroded 8 in. into unit 1. Basal sandstone: light gray, quartzose, well silica-cemented. Present as shallow channel eroded into unit 1. Highly small-scale trough-cross-stratified. Upper part: sandstone, siltstone, and shale. Sandstone fine-grained, lenticular-bedded and cross-stratified to flaser-bedded (Fig. 98). Tops of some beds ripple-marked. Muddy siltstone finely laminated and draped across sandstone lenses, some of which show truncated crossbeds. Siltstone locally contains abundant comminuted carbonized plant debris, trace pyrite. Base of upper part of unit 2 contains abundant coalified logs as much as 8 ft long and 1 ft wide (Fig. 99), now compressed to 1.5 in. thick.

1. Shale, slightly silty. Medium gray. Fissile; exhibits pencil structure. Weathers to rust-color on fractures and some bedding planes. Trace carbonized comminuted plant debris on some bedding planes.

Return to U.S. 59.

55.1	1.6	Intersection with U.S. 59. Go left (southeast) on U.S. 59. Continue south to S.H. 9.
65.2	10.1	Intersection with S.H. 9. Turn right (west) on S.H. 9.
65.5	0.3	Highway curves gently to left and heads due west.
65.8	0.3	Cross low ridge underlain by Warner Sandstone dipping 10° northwest (Knechtel, 1949). This is the same outcrop belt as at Mile 50.1.
68.2	2.4	Leave Le Flore County; enter Haskell County. Oakes and Knechtel (1948) mapped the geology of Haskell County.

The very low ridge ~0.5 mi to the left (north) is underlain by gently north-dipping Cameron Sandstone; a strip mine in the McAlester coal is immediately north of the ridge (overlying the Cameron Sandstone).

70.2	2.0	Intersection with north-south county road (also section-line road). Turn left (south).
70.9	0.7	Leave Robert S. Kerr Dam 7.5' quadrangle; enter Bokoshe 7.5' quadrangle.
72.2	1.3	Intersection with east-west county road (also section-line road). Turn left (east) into small village of Cartersville. For the next mile, the road climbs a gentle dipslope underlain by what Oakes and Knechtel (1948) mapped as the Warner Sandstone. This may be the Lequire Sandstone.

Figure 95. Rippled and cross-stratified sandstone beds interbedded with slightly wavy-bedded sandstone and siltstone in unit 6, McAlester sandstone, Wildhorse Mountain measured section (Stop 16). Hammer for scale.

Figure 96. Sandstone beds interbedded with siltstone and shale (unit 3). Finer beds draped over thin sandstone lenses. McAlester sandstone, Wildhorse Mountain measured section (Stop 16). Hammer for scale.

72.5 0.3 Intersection with north-south county road (also quarter-section-line road). Turn right (south).

73.2 0.7 Road curves left and descends through gently northwest-dipping Warner(?) Sandstone.

73.7 0.5 Road turns left (east) at base of ridge.

74.1 0.4 Intersection with county road (also section-line road) to south. Turn right (south).

74.5 0.5 Cross large strip pits in Hartshorne coal. This is the same Hartshorne coal outcrop belt that was crossed at Mile 43.1. Here, the Hartshorne coal dips gently northwest.

Oakes and Knechtel (1948, pl. 1) map a thin sandstone between the Warner(?) Sandstone exposed near Mile 73.2 and the Hartshorne coal here. If it is present it has very little topographic expression. This contrasts with the same sandstone as it is exposed at Stop 17 (see below).

74.8 0.3 Very low ridge is underlain by Hartshorne sandstone dipping 8° northwest.

Cross Missouri – Pacific railroad grade. This is an extension of the old Midland Valley railroad (later Texas and Pacific, and still later Missouri – Pacific) that originally ended in Bokoshe, ~3 mi southeast of here (Mile 14.3, Day Two).

75.0 0.2 Road turns right (west) and follows the boundary between Le Flore County to the left (south) and Haskell County to the right (north).

75.3 0.3 Road curves left (southwest). Enter Le Flore County.

75.9 0.6 Ridge to right (north) underlain by Hartshorne sandstone.

76.4 0.5 Intersection with east-west county road (also section-line road). Turn right (west).

Hills to left (south) are underlain by gently to moderately dipping sandstones in the Atoka Formation near the axis of the Milton Anticline. The anticline is cored by several thrust and normal faults (Knechtel, 1949, pl. I).

77.6 1.2 Low ridge underlain by Hartshorne sandstone dipping 12° northwest.

77.9 0.3 Leave Bokoshe 7.5' quadrangle; enter McCurtain 7.5' quadrangle. Intersection with north-south county road (also section-line road). Turn right (north).

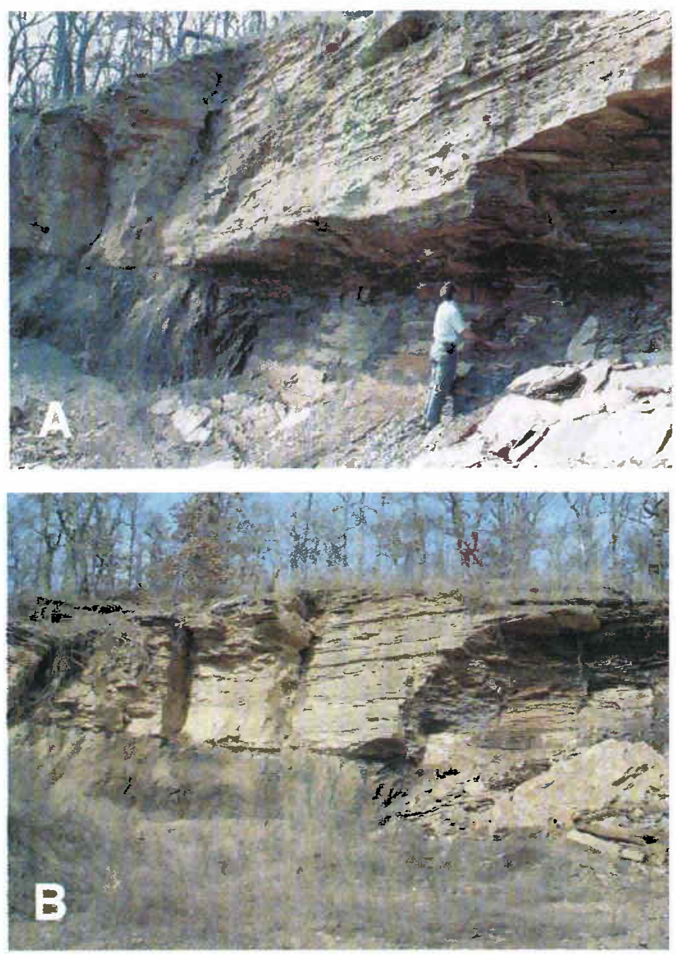


Figure 97 A and B. Contact between units 1 and 2, McAlester sandstone, Wildhorse Mountain measured section (Stop 16). The ledge over the geologist (A) has since collapsed (B).

The California Road

This broad valley is underlain mostly by shale in the uppermost part of the Atoka Formation, the Hartshorne Formation, and the McCurtain Shale. It is bounded on the northwest by Campground Spring Mountain or a prominent ridge of Warner(?) Sandstone and on the southeast by northwest-dipping Atoka sandstones near the crest of the Milton Anticline. Here the valley contains the California Road. Although far less well known than the Santa Fe, Oregon, and Mormon Trails, the California road was one of the most-used emigrant trails to the California goldfields. The exact location of the "road" is unknown, but it probably passed through the valley about a half-mile southeast of this bend in the road.

Dott (1960, op. 154-155) documented the reasons for the road's evolution from a trade route to one of the principal roads used by thousands of emigrants crossing the country:

> "The Santa Fe Trail from Independence, Missouri, to Santa Fe, New Mexico, already was an important trade route. During this fifth decade [1840-1850], a wagon road was opened up the North Platte River and westward through South Pass to Utah, California, and Oregon [Oregon Trail].
>
> "News of the discovery of gold in California set off a tide of migration that demanded additional routes of travel. Steamboats plied the Missouri River to Independence and St. Joseph – the jumping-off places for the Santa Fe and the [Oregon] trails, respectively.
>
> "Boats also reached Fort Smith, Arkansas, which thus became a natural gateway for a route west along the Arkansas and the Canadian rivers. It was thought that this route would be as easy as the more northerly routes, and probably a little shorter.
>
> "Congress instructed the War Department to find a suitable route south of the Canadian River, from Fort Smith to Santa Fe and on to California. The assignment was given to Captain Randolph B. Marcy who started out from Fort Smith with his command on April 5, 1849, to establish such a road and, also, to escort a large party of California "gold seekers" who cared to travel with him."

Although first surveyed and described by Capt. Randolph B. Marcy and his surveyor, Lieut. James H. Simpson, in 1849, that part of the route between Ft. Smith and Santa Fe appears to have been established by the James and McKnight party in 1823 (Foreman, 1925). By 1849, this road (and others) in Indian Territory were well-established trade routes. Marcy accompanied one of the large groups of emigrants from Ft. Smith; his wagon train consisted of 18 wagons, one 6-pounder iron gun, and a traveling forge, each drawn by six mules.

On April 6, 1849, Capt. Marcy and his party camped at Camp Creek, now called Coal Creek (Dott, 1960, p. 162). Dott (1960) suggests that the camp may have been located in sec. 31, T. 9 N., R. 24 E., ~1.5 mi east-northeast of here. Marcy (in Foreman, 1925, p. 107) briefly described the area as it appeared more than 150 years ago: "Camp Creek – road crosses a prairie of three miles in length then enters a heavy forest. The camp is on a small branch with grass plenty in a small prairie about four hundred yards to the left of the road." After leaving Camp Creek, Marcy's party continued following and surveying the road, which passed near the present-day Oklahoma towns of McCurtain, Kinta, Quinton, Blocker, Stuart, Calvin, Ada, Byars, Wayne, Washington, Hinton, Weatherford, Custer City, Putnam, Leedey, Roll, Crawford, and Durham.

Unfortunately, the winter of 1848-49 was unusually cold and the spring of 1849 unusually wet; therefore, the following picture of life on the California Road probably was atypical:

> "For a distance of fifty miles from Fort Smith the road was marked by almost a continuous line of emigrants and their outfits, struggling to get along, or having abandoned the effort, settled in camps along the way. Under the blow and impredations of their drivers, oxen and mules were straining to pull the wagons through the mud. Exasperated and discouraged emigrants were seen with spades and poles, rocks and jacks, digging and prying at wheels far down in the bottomless muck. Camps were pitched along the roads through the Choctaw Nation where deep-mired wagons defied efforts to move further, and thus they stood for days at a time, resting to recruit their strength and resolution to renew the struggle for a few more miles of progress." (Foreman, 1939, p. 29-30).

Many companies abandoned this southern route – the California Road – for a more northern route along the Canadian River.

> "Though he does not mention them in his journal, Captain Marcy had to listen to many grievances and criticisms by the emigrants, of his road, and of the Fort Smith influences that induced them to travel from there. Nearly every one of these inexperienced travelers, trying to go through the mud with overloaded wagons, believed the particular road he was traveling over was worse than any other." (Foreman, 1939, p. 398).

In 1853, Lieut. A.W. Whipple resurveyed the California Road for a possible railroad route to California. Part of his description of the road included the local geology:

> "Fort Smith is situated on the upper carboniferous or coal measures and several mines of Bituminous Coal begin to be explored in the environs. This carboniferous formation extends to Camp 14 [near present-day Stuart] near Shawnee Village over an interval of 100 miles. Coal crops out in several places especially on San Bois and Coal [near present-day Haywood in Pittsburg County] creeks. Many ordinary wells in Choctaw territory 40 to 50 feet deep traverse beds of "Honille grasse" 2 to 3 feet thick. Besides bituminous coal this formation contains sandstones and limestone excellent for construction of bridges and viaducts." (Wright and Shirk, 1950, p. 256)

(Authors' note: "Honille grasse" probably is misspelled and should be "Houille grasse," which is French for bituminous coal.)

78.0 0.1 Large gob piles associated with strip mines in the Hartshorne coal occur on both sides of the road. Here, the coal dips 8° northwest.

78.1 0.1 Road begins to climb Campground Spring Mountain and curves to left (west). Park on dirt road to right, which leads to Campground Spring.

Stop 17. Warner Sandstone Campground Spring Mountain Measured Section

Location: Roadcuts and bar ditch along county road ~2 mi north-northwest of Milton, Oklahoma. Road climbs from south to north to the top of Campground Spring Mountain. Most of section is in NE¼SE¼SE¼ sec. 4; top of section is in the west side of SW¼NW¼ SW¼ sec. 3, T. 8 N. R. 23 E., McCurtain 7.5' quadrangle. UTM: 15S 329180 E 3895680 N.

Figure 98. Lenticular-bedded and flaser-bedded sandstone, siltstone, and shale in upper part of unit 2, McAlester sandstone, Wildhorse Mountain measured section (Stop 16). Siltstone and shale typically are draped across sandstone lenses. The sedimentary structures in this unit are evidence for tidal reworking. Quarter (upper left) for scale.

Discussion and Interpretation:

Campground Spring Mountain is a 5.5-mi-long, east-northeast-trending ridge rising abruptly almost 200 ft above the narrow valley on its southeastern side (Fig. 100). The northwest side of Campground Spring Mountain slopes gently to the northwest. Unlike most high ridges in the Arkoma Basin, Campground Spring Mountain ends abruptly to the northeast and southwest (Fig. 100), although a low, narrow, discontinuous ridge extends southwest from the mountain.

Figure 99. Underside of bed in lower part of unit 2, McAlester sandstone, Wildhorse Mountain measured section (Stop 16) showing coalified log at top of photo.

The Warner Sandstone at this locality dips 5° north and is on the south flank of Cowlington Syncline (trough ~6 mi to northwest) and on the north flank of Milton Anticline (crest ~1.5 mi to south). The Hartshorne coal was extensively strip-mined at the base of Campground Mountain.

Knechtel (1949) and Oakes and Knechtel (1948) mapped Campground Spring Mountain as a sandstone lens within the McCurtain Shale Member of the McAlester Formation. Boyd (2005), however, notes that the lowest major sandstone in the McAlester Formation is the Warner Sandstone and that there are no thick valley-fill (see below) sandstones below his PS-3/3A (Warner equivalent). Knechtel (1949) describes the sandstone as follows: "The (McCurtain Shale) member ... includes a rather persistent sandy unit which, in most of the northern part of T. 8 N., R. 23 E., contains sandstone beds aggregating 175 ft in thickness, many of which are massive in character with swarms of shale pellets in some layers. This sandstone zone here forms prominent cliffs, but at the Haskell County line and in other part of northern Le Flore County it crops out in relatively inconspicuous, low ridges, is commonly about 10 ft thick and is made up mostly of thin flaggy sandstone beds, in some place showing abundant ripple marks" (p. 20). The description by Oakes and Knechtel (1948) is essentially the same. Both geologic maps show the sandstone underlying Campground Spring Mountain overlying the Hartshorne coal, which has been extensively strip mined since the maps were published. At this location (Stop 17) (Fig. 101), the base of the sandstone is ~175

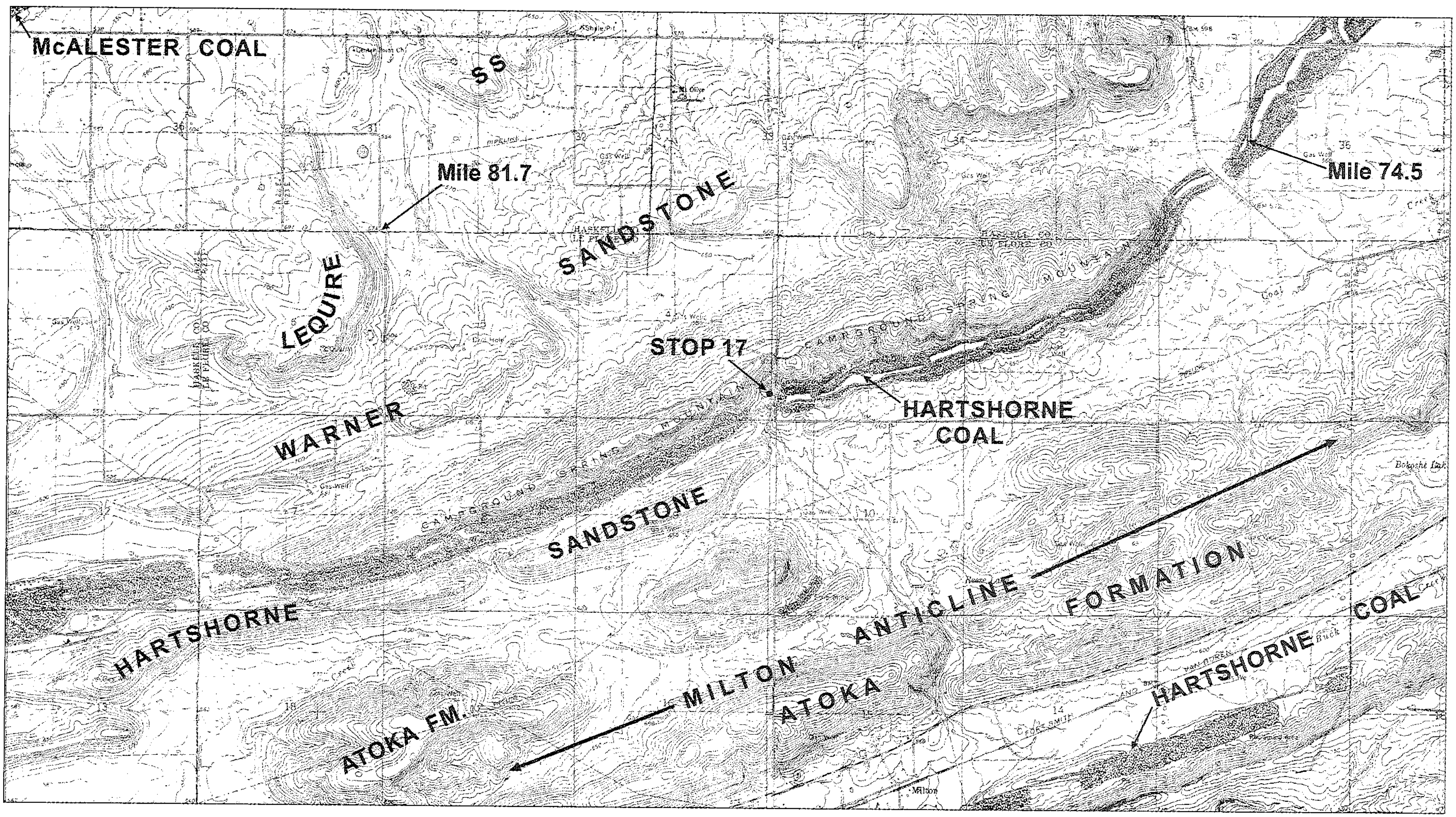


Figure 100. Topographic map of Campground Spring Mountain showing location of Stop 17. Ridges are labeled with names of underlying sandstones as designated by Oakes and Knechtel (1948). The Hartshorne coal has been strip-mined on the north and south flanks of the Milton Anticline and forms a key stratigraphic marker. A strip mine in the McAlester coal is shown in the upper left corner of the map. Note that the Warner and Lequire Sandstones are shown as underlying prominent ridges north of the outcrop. Campground Spring Mountain (name in very small print) terminates to the east and becomes a very low, barely visible ridge to the west. The topographic expression of Campground Spring Mountain suggests that the sandstone that underlies it, although thick, is relatively narrow.

ft above the Hartshorne coal, assuming the dips measured by Knechtel (1949, pl. I) are accurate. The variable thickness and topographic expression of the sandstone is important for interpreting its depositional environment.

The variable nature of the sandstone is reflected in nearby well logs. For example, the Stephens No. 4 Evans, located in the SW¼SE¼NW¼ sec. 34, T. 9 N., R. 23 E. and ~1 mi northwest of the ridge, did not drill any sandstone from 0 to 800 ft based on a cased-hole gamma-ray log. In contrast, several wells located ~4.5 mi southwest of this outcrop on the south flank of the Milton Anticline drilled a thick sandstone, the base of which is ~500 ft above the Hartshorne Formation (Figs. 102 and 103). The Amoco No. 3 Birckel (SW¼NE¼SW¼ sec. 29, T. 8 N., R. 23 E.) and the Pan American No. 1 Williams (CE½SE¼NW¼ sec. 36, T. 8 N., R. 22 E.) show a thick (170 ft and 225 ft, respectively), massive sandstone above the Hartshorne similar to that described by Knechtel (1949) on Campground Spring Mountain and to that described below.

The outcrop at this stop consists of ~20 ft of stratified siltstone and shale overlain by 120 to 150 ft of mostly unstratified sandstone (Fig. 101). Only the basal 50 ft of the sandstone was carefully measured and described; the upper part occurs as poorly exposed, weathered bar-ditch outcrops. However, the gamma-ray signature of the entire sandstone was measured (Fig. 101) and shows the sandy character of the unit. Although exposures are discontinuous, nothing more fine grained than sandstone appears to be present. The thickness of the upper part is based on a 5° to 9° dip. Sedimentary structures in the sandstone are uncommon; the most important are the numerous shale rip-up clasts, some of which are concentrated in layers that parallel bedding planes. These clasts and the medium-sized grains are evidence for a high-energy depositional environment. The thickness of the sandstone, its sharp (erosional) basal contact with the underlying siltstone/shale sequence, the unusual topographic expression of Campground Spring Mountain, and Knechtel's (1949) observation that the unit varies greatly in thickness are evidence that this sandstone is a multi-story channel-fill within an incised valley.

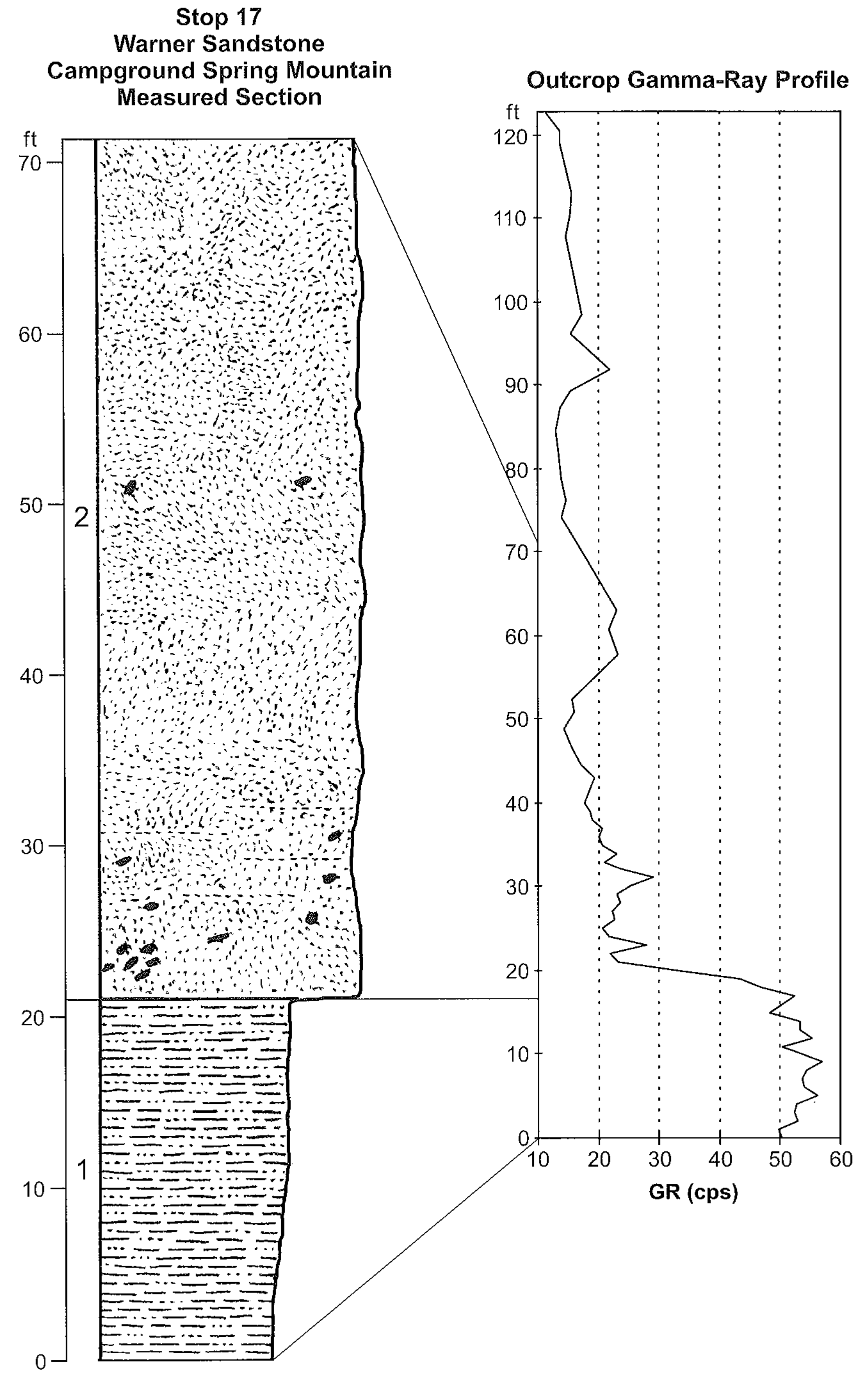


Figure 101. Graphic columnar section and outcrop gamma-ray profile of Warner(?) Sandstone, Campground Spring Mountain measured section (Stop 17). This sandstone is distinctive not only for its thickness but for its coarse grain size. Variations in gamma-ray readings probably reflect the concentrations of disseminated clays and/or shale rip-up clasts in an otherwise monotonous sandstone. The upper ~50 ft of sandstone was not described. It is poorly exposed in the roadbed, bar ditch, and low, weathered roadcuts.

The blocky log character of the sandstone in wells to the southwest also support an incised-valley-fill origin for the sandstone. Furthermore, the absence of the sandstone in wells immediately to the north supports regional work showing the orientation of incised valleys in this area to be generally northeast-southwest. This incised valley likely also trends northeast, approximately following the axis of the Milton Anticline, where evidence for it has been eroded. The Warner Sandstone

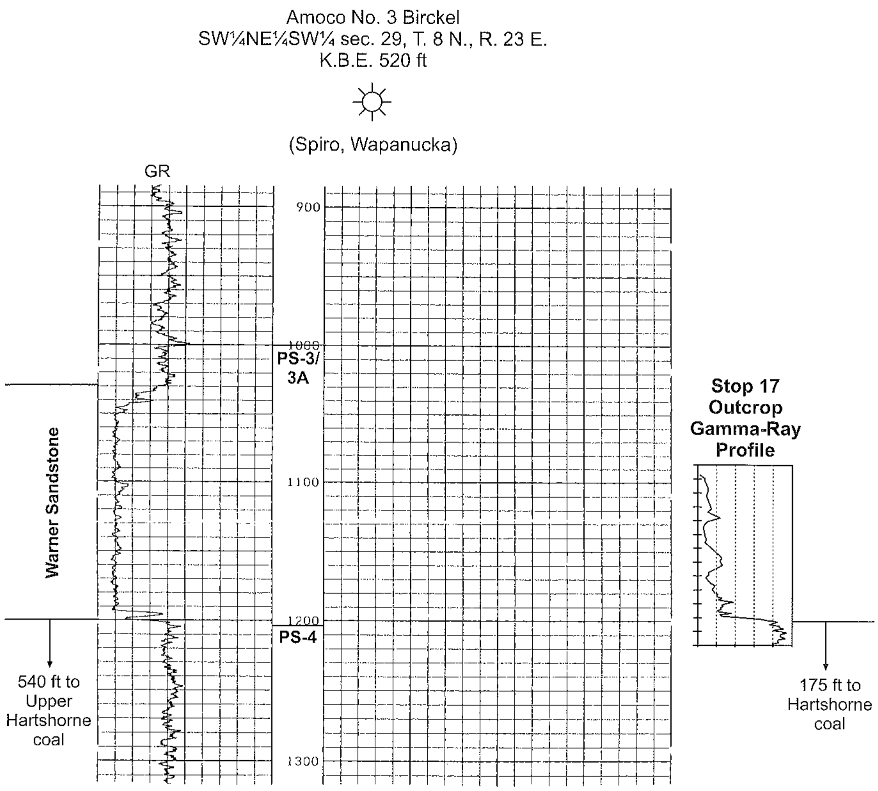


Figure 102. Part of gamma-ray log from the Amoco No. 3 Birckel and outcrop gamma-ray profile from the Campground Spring Mountain measured section. The Warner Sandstone in the No. 3 Birckel is interpreted as a multi-story incised-valley-fill sandstone. The similarity between the log and profile suggests that the sandstone at Campground Spring Mountain also fills an incised valley. Note the difference in apparent stratigraphic thickness to the Hartshorne coal between the outcrop and the log.

at Campground Spring Mountain probably is on the western margin of a northeast-trending paleovalley. Abrupt sandstone pinch-outs are characteristic of valley fill and here it appears that it thins from as much as 150 ft to 0 ft in just over a mile. Boyd (2005, pls. 3 and 6) shows incised valleys near here in PS-2 (equivalent to the Lequire Sandstone) and PS-3/3A (Warner Sandstone). Boyd (2005) also noted that "maximum progradation … occurred during PS-3/3A time" (p. 21). A reinterpretation of Knechtel's (1949) and Oakes and Knechtel's (1948) geologic maps in light of Boyd's (2005) sequence-stratigraphic study suggests that this incised-valley-fill sandstone is the Warner Sandstone (PS-3/3A).

One question remains. The base of this sandstone is ~175 ft above the Hartshorne coal, whereas the base of the sandstone in the No. 3 Birckel and the No. 1 Williams is 450 – 550 ft above the Hartshorne. Evidence that this sandstone and those in the wells are the same includes identical log character, proximity, and regional subsurface correlations – the only major McAlester sandstone bed in the area is the Warner Sandstone (PS-3A and PS-3 of Boyd, 2005). The reason for the unusually thin section below the sandstone here is unknown; it may either be structural or stratigraphic.

Description of Units (Fig. 101):

McALESTER FORMATION:

Warner Sandstone Member:

2. Sandstone. Medium grained, moderately to poorly sorted, subrounded grains, highly iron-oxide stained. Porous, soft. Locally highly fractured; fractures cemented with iron-oxide minerals. Unconformable (erosional) with unit 1, although contact poorly exposed. Faintly plane-parallel stratified. Contains rounded siltstone and shale rip-up clasts throughout, locally numerous and highly concentrated (Fig. 104). Basal part well-exposed; middle and upper parts poorly exposed in bar ditch, roadbed, and as sandy soil in low road-cuts.

1. Siltstone and minor shale. Well-stratified; mostly plane-parallel stratified. Poorly exposed; have to dig.

Return to vehicles and continue up road to top of ridge.

78.3 0.2 Top of ridge. Road curves sharply to left (west).

For the next ~2 mi, the road gradually descends the dip slope formed by the Warner Sandstone on the north side of Campground Spring Mountain.

80.0 1.7 Road turns right (north).

80.2 0.2 Road turns left (west). The low ridge to the right (north) is underlain by Lequire (this report) or Warner (Knechtel, 1949) Sandstone dipping gently northwest.

80.6 0.4 Intersection with north-south county road (also section-line road). Turn right (north).

81.4 0.8 Ridge to left (west) underlain by Cameron or Lequire Sandstone.

81.7 0.3 Road makes short jog to left, then right. Leave Le Flore County; enter Haskell County. Road now follows half-section line.

82.2 0.5 Road turns left (west).

82.6 0.4 Low ridge underlain by Cameron or Lequire Sandstone dipping 7° west.

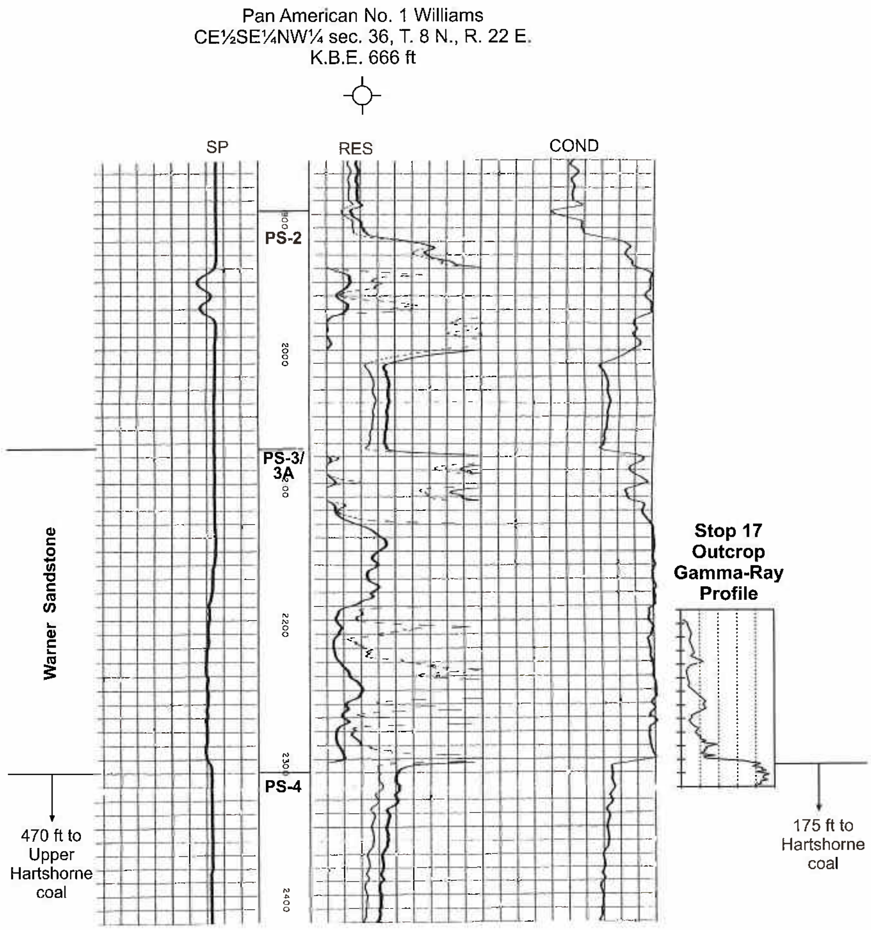


Figure 103. Part of wireline log from the Pan American No. 1 Williams and outcrop gamma-ray profile from the Campground Spring measured section. The Warner Sandstone in the No. 1 Williams and in the outcrop are interpreted as multi-story incised-valley-fill deposits. Although there is no gamma-ray log, the sharp upper and lower contacts are obvious from the resistivity logs. Note the difference in apparent stratigraphic thickness to the Hartshorne coal between the outcrop and the log.

82.7 0.1 Intersection with north-south county road (also section-line road). Turn right (north).

For the next mile the road gradually descends a low and nearly featureless Cameron or Lequire Sandstone dip slope.

83.2 0.5 Cross east-west county road (also section-line road). Approximately 3 mi west of here the Keota Sandstone Member of the McAlester Formation contains an extensive vertebrate and invertebrate trace-fossil assemblage in a tidal-flat sandstone (Lucas and others, 2004).

Continue straight.

84.2 1.0 Intersection with county road (also section-line road) to right (east). Continue straight (north).

84.4 0.2 Very low hill underlain by Cameron(?) Sandstone dipping gently northwest.

85.0 0.6 Cross small strip mine in McAlester coal.

85.1 0.1 Leave Kinta Gas Field.

85.2 0.1 Intersection with east-west county road (also section-line road). Continue straight (north).

The small community of Ironbridge is 2 mi west and 0.5 mi south of here.

85.3 0.1 Enter Keota Gas Field (Boyd, 2002).

Keota Gas Field

The Keota Gas Field, which includes the Keota Northeast Field, is a "satellite" of the Kinta Field. The field was discovered by the Clearly 1-32 Garland which spudded on October 28, 1969 and was completed on November 22, 1969 in the Spiro sandstone from 6,050 to 6,110 ft. The field consists of 27 wells (22 active) (IHS Energy, 2006) and has produced more than 29.5 Bcf gas. The field still produces ~1.6 MMcf gas per day, mostly from the Spiro sandstone, with lesser amounts from the Cromwell Sandstone.

Figure 104. Poorly stratified sandstone, unit 2, Campground Spring Mountain measured section (Stop 17). Large bleached siltstone and shale rip-up clasts are visible at base of outcrop. Hammer for scale.

Ironbridge, Oklahoma, and the Iron Bridge Skirmishes

The following history is from http://members.tripod.com/~mccurtain_2/war/civilwar.html, retrieved May 18, 2005.

The community is located ~ 1 mi east-southeast of an iron bridge that was built over San Bois Creek in 1859 by a French engineer for the U.S. government. The bridge, located in the NW¼ sec. 22, T. 9 N., R. 22 E., is now inundated by the Robert S. Kerr Reservoir. The bridge was on a branch of the California Road used by immigrants during the California gold rush of 1849.

> "The (road) was being modernized with a series of iron bridges for a Pony Express mail route to California, but the route was never fully operational due to the start of the Civil War.
>
> "Brigadier General Stand Watie was confronted by a superior Federal force following the capture of the Federal supply ship, *J.R. Williams*, at Pleasant Bluff (adjacent to Tamaha) [see Mile 92.9, Day Two, this guidebook] on June 15, 1864. That day he dispatched a detachment of 150 men of the Chickasaw Battalion to hold the iron bridge over San Bois Creek. Early the following morning the advance guard of General James G. Blunt's Federal forces arrived shortly after the Confederates and a skirmish ensued. The Federals retreated toward Fort Smith. The Chickasaw Confederates remained in the area and another skirmish occurred three days later when the Federal troops returned on June 19, 1864. There are no details of the second encounter. There are reputed to be three casualties from the battles buried by the bridge.
>
> "The Iron Bridge was later also known as the Whiskey Trail Crossing, due to bootleggers using this road to transport moonshine. The remains of the Iron Bridge were sold for scrap iron during World War II, but part of the footings remain."

85.4 0.1 Cross low ridge underlain by the Tamaha Sandstone dipping 5° northwest.

85.5 0.1 Leave McCurtain 7.5' quadrangle; enter Keota 7.5' quadrangle.

85.7 0.2 Cross railroad tracks on south side of town of Keota, Oklahoma. This is the same Missouri – Pacific railroad that the field trip crossed at Mile 74.8, Day Two. The railroad ran from Bokoshe to Muskogee, Oklahoma.

Turn left (west) at end of road, then follow curve in road to right (northwest) onto 5th Street.

Keota, Oklahoma

(The following description of Keota is from Fugate and Fugate, 1991, p. 59-60):

> "Keota began in the early 1900s as a tent-town trading post. In 1903, pioneers Al Jennings and Chad Sewell staked lots and hitched teams of horses and mules to plows and drags to make streets. The Midland Valley railroad, later the Texas and Pacific, arrived in 1904 with Major W.C. Wells as a "townsite man." The orator William Jennings Bryan was brought in to speak at a picnic of July 4, 1904, to promote and sell the community as an ideal place to live and establish businesses.
>
> "For a while Keota prospered from coal mining. Today, its location on the Robert S. Kerr Reservoir is its most profitable asset."

85.9 0.2 Intersection with S.H. 9. Cross highway; continue northwest on 5th Street.

The low ridge here is underlain by the lower of two Keota Sandstone beds mapped by Oakes and Knechtel (1948, pl. I). This bed dips about 6° northwest.

86.1 0.2 Turn right (northeast) on Franklin Avenue. (This is the second right after crossing S.H. 9.)

86.5 0.4 Five-way intersection. Bear left onto north-south county road (also section-line road) on north side of Keota.

86.7 0.2 Low ridge is underlain by the upper of the two Keota Sandstone beds mapped by Oakes and Knechtel (1948, pl. I) in this area.

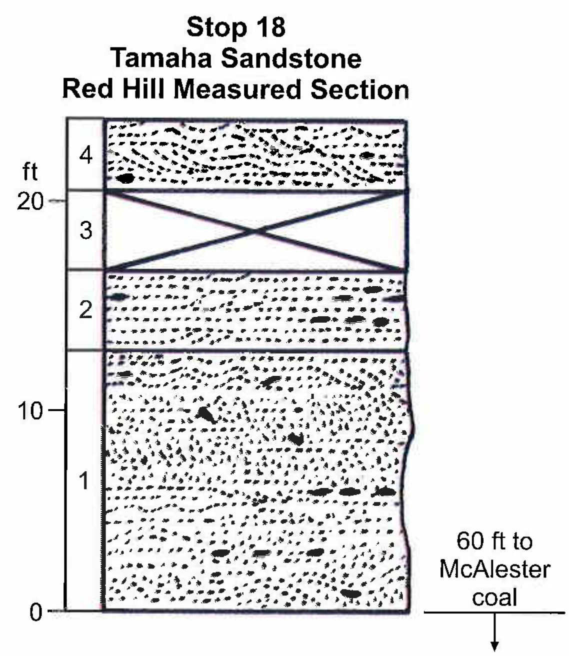


Figure 105. Graphic columnar section of the Tamaha Sandstone at the Red Hill measured section (Stop 18).

Tamaha and the Sinking of the *J.R. Williams*

Tamaha ("town" in Choctaw), one of the oldest towns in the Choctaw Nation, was originally established as an agricultural trading post, river port, and site for crossing the Arkansas River. Prior to the Civil War steamboats transporting goods between Ft. Smith and Ft. Gibson would regularly stop at the town. People wanting to cross the river would take the ferry; poles or oars would be used rather than cables or motors. After the Civil War cotton and corn were the principal commodities shipping out of Tamaha. In 1884 a post office was established in the town. The last steamboat visited the town in 1912; shortly afterwards a flood moved the Arkansas River ~2 mi to the north. A fire in 1919 destroyed much of the town, but it was rebuilt. A second fire in 1926 heralded the beginning of the town's decline.

Although perhaps "best" known as the type area of the Tamaha Sandstone Member of the McAlester Fo rmation (Wilson, 1935, p. 509; revised by Oakes and Knechtel, 1948, p. 40), Tamaha is also a special Civil War battle site. The following description is from the McCurtain (Oklahoma) Genealogical Society website http://members.tripod.com/~mccurtain_2/war/civilwar.html, (retrieved May 18, 2005).

> The Pheasant (or Pleasant) Bluff Springs site was (on) the northeast edge of Tamaha along the Arkansas River where the city park is today. There was a church there.
>
> Brigadier General Stand Watie's Confederate troops; a cavalry party; and a three-gun artillery battery operating from Camp Pike, attacked and captured the Federal supply steamer *J.R. Williams* on June 15, 1864.
>
> The ship was bringing supplies (valued at $120,000) to Fort Gibson for Federal troops and Indian refugees from Bloody Kansas.
>
> There were 16,000 people to care for at Fort Gibson. The supply ship was grounded by the crew on the opposite side of the river and its military guard of 25 men under Lt. Horace A.B. Cook fled. Watie and his men steered the boat across the river to near the ferry landing and unloaded the provisions on a sand bar. There were no wagons available and so the supplies could not be moved easily. Some of Watie's men took the supplies they could carry and deserted.
>
> Federal troops from the salt works and lime kiln at Gore arrived the next morning under the command of Colonel John Ritchie. Watie's reduced forces could not maintain their position and they burned some supplies and a sudden rise in the water level washed the rest away. Watie set fire to the steamer and it sank in the river channel where it probably still remains buried now in the sand at the bottom of the Robert S. Kerr Lake.

The capture and sinking of the *J.R. Williams* is cited by Ruth and Fefebvre (1970) as the most inland "naval engagement" of the Civil War.

87.5 0.8 Intersection with east-west county road (also section-line road). Continue straight (north).

88.3 0.8 Road begins to curve to left (northwest) around base of Hancock Mountain to left (west).

Hancock Mountain is capped by the Bluejacket Sandstone Member of the Boggy Formation. The Bluejacket Sandstone is preserved within the trough of the northeast-trending Cowlington Syncline on top of Hancock Mountain and Follet Mountain to the northeast.

88.9 0.6 Causeway over San Bois Creek arm of Robert S. Kerr Reservoir.

89.4 0.5 Bridge over reservoir.

90.1 0.7 County road to left (west). Continue straight (north). Leave Keota Gas Field.

The geology shown by Oakes and Knechtel (1948, pl. I) for the next mile and a half is complex and consists of small fault slivers and small folds involving the uppermost part of the Atoka Formation, the Hartshorne Formation, and the lower part of the McAlester Formation.

91.7 1.6 Road curves to left (northwest) and begins to climb Bellow Mountain which is capped by Tamaha Sandstone. Unexposed McAlester coal occurs near here.

92.0 0.3 Top of Bellow Mountain. Intersection with county road (also section-line road) to left (west). Small outcrop of Tamaha Sandstone dipping gently northwest on right (west).

For the next half mile, the road descends the Tamaha Sandstone dipslope. The road crosses the trace of a northeast-striking, down-to-the-southeast normal fault near the base of dipslope; this fault causes the Tamaha Sandstone to be repeated.

92.7 0.7 Road turns left (west) and begins to climb Red Hill. Unexposed McAlester coal occurs near bend and Oakes and Knechtel (1948, pl. I) show two prospects along its outcrop.

92.9 0.2 Road turns right (north) at top of Red Hill. Park on back (north) side of hill.

The view to the north from the top of Red Hill is of Saylor Bottom in the floodplain of the Arkansas River. The town of Tamaha is ~5 mi to the northwest.

Stop 18. Tamaha Sandstone Red Hill Measured Section

Location: Roadcut along county road at top of long ridge (Red Hill) ~6 mi north of Keota, Oklahoma. Road is a section-line road for most of its length, but turns east-west and then north-south as it ascends/descends Red Hill. Most of section measured on north and east side of road (inside of bend) in N½SE¼NE¼ sec. 14, T. 10 N., R. 22 E., Keota 7.5' quadrangle. UTM: 15S 323665 E 3912625 N.

Discussion and Interpretation:

This sandstone, named the Tamaha Sandstone for outcrops near the town of Tamaha ~4 mi to the northwest, is part of the McAlester Formation (Oakes and Knechtel, 1948). Although similar in environment of deposition to the Booch sandstones, most of the petroleum industry places sandstones above the McAlester coal in the Savanna Formation.

The geology of this area is complex. The Tamaha Sandstone here dips 4° northwest and is between the Stigler (trough ~5.5 mi to northwest) and Cowlington Synclines (trough ~4 mi to southeast). But Oakes and Knechtel (1948, pl. II) show many small and discontinuous branching faults and folds between the two major folds. Despite the complexity, the presence of several coal prospects in the Stigler (McAlester) coal at the base of the ridge just below the sandstone confirms that this outcrop (Fig. 105) is the Tamaha. Oakes and Knechtel (1948) describe the Tamaha as follows: "... its thickness and other characters are different from place to place. (Locally) it is more than 20 ft thick and massive ... but (elsewhere) it is so shaly and nonresistant that it hardly makes a mappable outcrop" (p. 42).

The Redwine No. 1 Scrivener (CNE¼NE ¼ sec. 31, T. 10 N., R. 23 E) (Fig. 106) is located ~3.5 mi to the southeast. The well spudded near the base of the Bluejacket Sandstone (Boggy Formation) and drilled a significant coal bed marked by a gamma ray low and resistivity high that probably is the McAlester coal. The coal is overlain by ~120 ft of shale and silty shale, which are overlain by a more sandstone-rich interval. This interval probably is the Tamaha Sandstone.

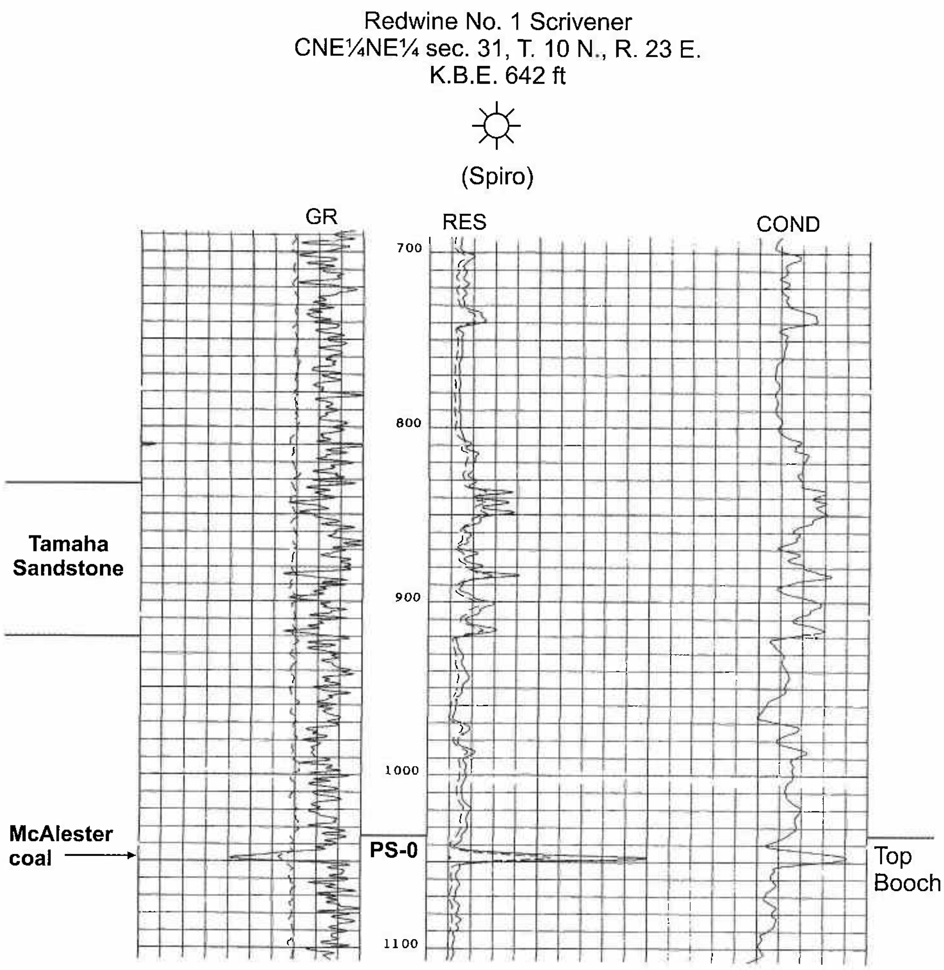


Figure 106. Part of wireline log from Redwine No. 1 Scrivener showing log character of Tamaha Sandstone and McAlester coal. Although it is in the upper part of the McAlester Formation, the Tamaha Sandstone is not considered a Booch sandstone by the petroleum industry because it rarely produces oil or gas.

The depositional environment of the Tamaha Sandstone is poorly known. The description of the unit by Oakes and Knechtel (1948) is not helpful. The log character shows a highly irregular pattern, particularly on the gamma-ray log, with no clear fining- or coarsening-upward textural trend (Fig. 106). Based on logs the sandstone beds probably are thin and fine-grained; with most of the Tamaha interval probably consisting of siltstone and shale. Not surprisingly, these finer-grained lithologies are rarely exposed. The Tamaha Sandstone at Stop 18 was deposited in a high-energy environment; the abundant cross-stratification, absence of shale (except as rip-up clasts), and local truncation of beds is suggestive of deposition in a channel. Because the base of the section is not exposed, the presence of an erosional contact cannot be confirmed. However, the absence of 20-ft-thick sandstones on nearby logs is evidence that the channels probably are narrow. The Tamaha Sandstone in this area probably represents a series of poorly developed marine bars, possibly distributary-mouth bars, and their associated distributary channels.

Figure 107. Planar-tabular cross-stratified sandstone in unit 1, Tamaha Sandstone at the Red Hill measured section (Stop 18). Hammer (circled) for scale.

Description of Units (Fig. 105):

McALESTER FORMATION:

Tamaha Sandstone Member:

4. Sandstone, fine-medium-grained. Bedding planes typically tilted; much trough-cross-bedding and wavy bedding. Rip-up clasts rare.

3. Covered interval. Probably sandstone based on exposure on west side of road.

2. Sandstone, fine-medium-grained. Well-stratified, plane-parallel to trough-cross-stratified. Much pinch-and-swell. Rip-up clasts locally abundant, typically weathered-out.

1. Sandstone, medium- to fine-medium-grained, poorly sorted, porous. Generally poorly stratified; bedding planes irregular and discontinuous to wavy to trough- or more rarely planar-tabular - cross-stratified (Fig. 107). Tops of cross-stratified strata locally truncated (Fig. 108). Stratification locally defined by concentrations of flat shale rip-up clasts as long as 4 in. Channeling rare.

Return to vehicles and retrace route south to Mile 90.1 immediately on north side of Robert S. Kerr Reservoir.

95.7 2.8 Turn right (west) on county road.

97.2 1.5 Road turns left (south).

For the next ~2 mi, the road crosses faulted and folded Hartshorne Formation. This is part of the area of complex geology noted at Mile 90.1.

98.0 0.8 Road turns right (west).

98.5 0.5 Road turns left (south).

99.0 0.5 Top of ridge underlain by Lequire-Warner Sandstone (not separated by Oakes and Knechtel (1948)) dipping 6° southeast. The outcrop is on the southeast flank of the Round Prairie Dome – a small, northeast-southwest elongate, doubly plunging anticline.

99.3 0.3 Road turns right (west).

99.7 0.4 Road curves to left (south).

Very low hill to right (north) is underlain by Cameron Sandstone. In general, the Cameron in this area does not have any topographic expression.

100.0 0.3 Cross strip mines in McAlester coal. Continue straight (south).

101.1 1.1 Intersection with S.H. 9. Turn right (west) on S.H. 9.

102.1 1.0 Leave Keota 7.5' quadrangle; enter Stigler East 7.5' quadrangle.

102.6 0.5 Cross very low ridge underlain by Tamaha Sandstone dipping gently north.

103.2 0.6 Cross strip mines in McAlester coal.

103.3 0.1 Cross low ridge underlain by gently east-dipping Cameron Sandstone.

103.7 0.4 Begin gradual ascent up east-sloping dipslope of Lequire-Warner (undivided) Sandstone.

Figure 108. Truncated cross-stratified sandstone in unit 1, Tamaha Sandstone at the Red Hill measured section (Stop 18). Hammer for scale.

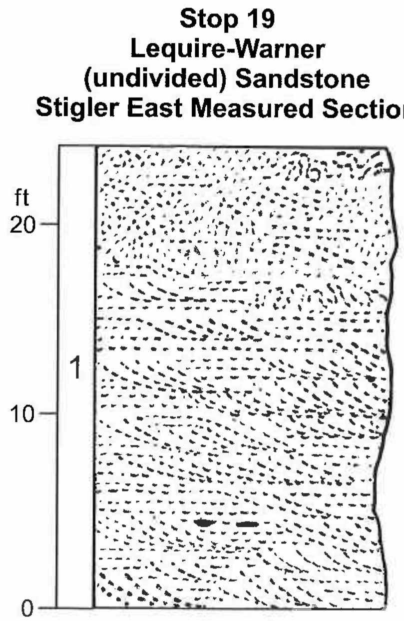


Figure 109. Graphic columnar section of the Lequire and Warner (undivided) Sandstone at the Stigler East measured section (Stop 19).

Just west of Stop 19 (below), Oakes and Knechtel (1948, pl. I) separate the Warner and Lequire Sandstones. Their map pattern shows that the sandstones there dip northwest, but they do not show an anticlinal axis. In this area the geology shown by Oakes and Knechtel (1948, pl. I) is difficult to interpret.

104.1 0.4 Highway passes beneath railroad bridge. Park on right side of highway immediately past bridge.

Stop 19. Lequire-Warner (undivided) Sandstone Stigler East Measured Section

Location: Roadcut along Oklahoma State Highway 9 ~5.5 mi east of Stigler, Oklahoma. Highway here follows section line between sections 12 and 13. Lower part of section measured on north side of highway 150 ft west of railroad bridge; upper part measured on north side of highway 125 ft west of bridge. Description based on entire outcrop on both sides of highway. Measured section - south side of SW¼SW¼SE¼ sec. 12, T. 9 N., R. 21 E., Stigler East 7.5' quadrangle. UTM: 15S 314970 E 3903640 N

Discussion and Interpretation:

Oakes and Knechtel (1948, pl. I) do not divide the Warner and Lequire Sandstones in this part of Haskell County. Because their geologic map does not show fold axes nor many strikes and dips it is difficult to interpret. This sandstone dips gently east beneath a low ridge ~0.8 mi to the east underlain by the Cameron Sandstone Member. The extensively strip-mined Stigler (McAlester) coal overlies and is just east of the Cameron Sandstone. The Cameron Sandstone is thin and poorly developed in this area, in contrast to the Warner and Lequire Sandstones, which generally are thicker and more prominent (Fig. 109). (In detail, the structure in this area is complex, but regionally this outcrop lies between the Antioch Anticline (crest ~1 mi to northwest) and Cowlington Syncline (trough ~4 mi to southeast.)

The Redwine CBM No. 1-36 Jameson well is located in the CN½NE¼SW¼ sec. 36, T. 9 N., R. 21 E., ~3.5 mi south of this outcrop. It spudded in the Lequire Sandstone (Oakes and Knechtel, 1948, pl. I) and drilled two sandstones from 302 to 332 ft and 338 to 382 ft (Fig. 110). These sandstones are separated by a 6-ft-thick shale-siltstone interval containing a coal bed. This sandstone-coal-sandstone sequence is identified by Oakes and Knechtel (1948) as the Warner Sandstone. The Hartshorne coal in the Redwine well occurs from 841 to 846 ft. Although the dip is unknown, the base of the Warner Sandstone probably is slightly less than 460 ft above the top of the Hartshorne coal.

Surface and subsurface data support the interpretation that at least some of the Lequire and Warner Sandstones in this area are channel-fill deposits. Oakes and Knechtel (1948) not-

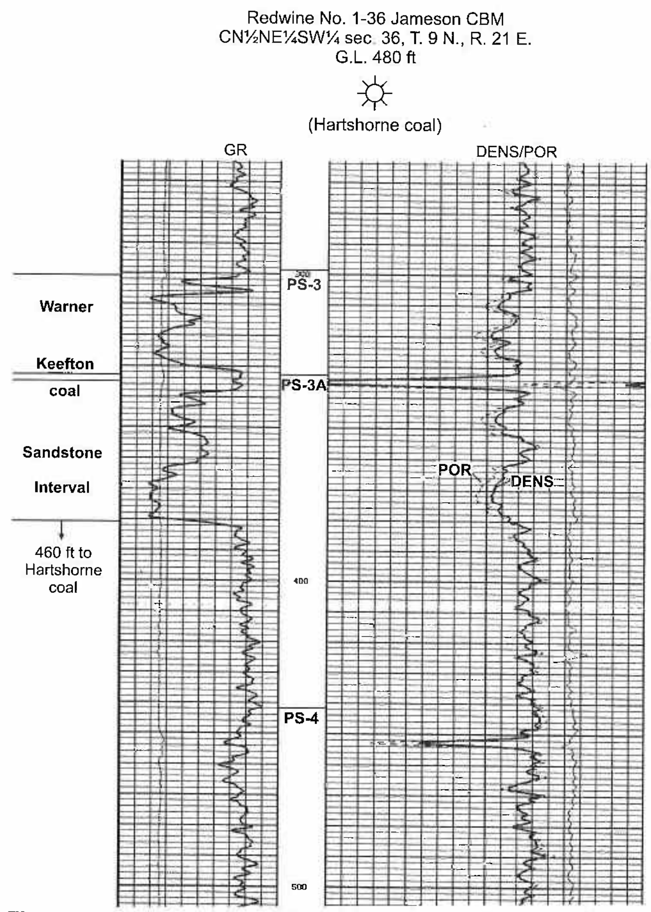


Figure 110. Part of wireline log of the Redwine No. 1-36 Jameson CBM showing the log character of the Warner Sandstone. The Keefton coal, which occurs at the top of PS-3A, is rarely preserved due to incision by the overlying PS-3. This log is reminiscent of the AOK Railroad, Haileyville measured section, in which a thin coal (Keefton?) separates the two sandstone intervals that constitute the Warner.

ed that "the Lequire sandstone member ranges greatly in both thickness and character ... in Haskell County (p. 38). In places "it is made up largely of thin, slabby beds of fine-grained sandstone," but elsewhere "contains notably thick massive beds" (p. 18). The "thin, slabby beds" may be distributary-mouth-bar deposits and the "thick massive beds" may be channel-fill deposits.

The log character of the sandstone in the No. 1-36 Jameson well (Fig. 110) and the strata and sedimentary structures in the outcrop at Stop 19 (Fig. 109) support a channel-fill sandstone interpretation for the outcrop. The abrupt basal contact (382 ft) of the sandstone in the Redwine CBM 1-36 Jameson is evidence for erosion and subsequent deposition of sand. The overlying (338 – 368 ft) interval is seriate, probably representing interbedded sandstone, siltstone, and shale that may be interpreted as a crevasse-splay and bay-fill sequence. The overlying shale and coal (332 – 338 ft) probably are interdistributary-bay deposits. These are overlain by another sandstone, likely a channel-fill deposit similar to the lower one. The strata at Stop 19 consist of 24 ft of highly trough- and festoon-cross-bedded medium-grained sandstone; shale is absent. The tops of some units are sharply truncated. All the sedimentary structures are evidence for a high-energy environment and are similar to those that are present in channel-fill deposits.

In summary, outcrop lithology and sedimentary structures, surface geologic relations, nearby log character, and regional subsurface relations provide strong evidence that the sandstone at Stop 19 is a channel-fill deposit. The proximity of the sandstone to overbank deposits and absence of bar deposits as interpreted in the No. 1-36 Jameson well is evidence that this sandstone fills an incised valley.

Figure 111. Large-scale trough crossbeds in Lequire-Warner (undivided) Sandstone, Stigler East measured section (Stop 19). The sedimentary structures and coarse grain size of the sandstone at this outcrop suggest it is a channel fill.

Description of Units (Fig. 109):
McALESTER FORMATION:
Lequire – Warner (undivided) Sandstone Member:

1. Sandstone, medium-grained, uncommonly fine-medium-grained, locally with high concentration of oxidized iron-magnesium minerals which give rock banded appearance. Bedding planes vary from plane-parallel to gently tilted to large-scale trough crossbeds (Fig. 111). Planar-tabular cross-bedding also present (Fig. 112). Tops of crossbedded units locally sharply truncated. Some beds soft-sediment-deformed, thickness varies widely from absent at measured section to 12 ft south of highway just west of bridge. Small shale rip-up clasts rare.

Continue west on S.H. 9.

106.5	2.4	Low ridge is underlain by Lequire Sandstone.
107.6	1.1	Intersection with north-south county line road (also section-line road). Continue straight (west). Relatively flat area to west underlain by Quaternary terrace deposits locally containing volcanic ash overlying shale in McAlester Formation.
107.8	0.2	Highway curves to left (southwest).
108.8	1.0	Highway curves to right (west). Enter Stigler, Oklahoma.
109.3	0.5	Intersection with State Highway 82 to left (south).

End of road log.

Figure 112. Large-scale planar-tabular crossbeds in Lequire-Warner (undivided) Sandstone, Stigler East measured section (Stop 19). Hammer for scale.

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