OKLAHOMA GEOLOGICAL SURVEY

OF-87

Ouachita Mountains Frontal Belt Field Trip

April 2–4, 1987

Neil H. Suneson

Charles A. Ferguson

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Oklahoma Geological Survey

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With special thanks to:

Mr. Bob Franklin, Foreman, Mabry Ranch
Mr. Mike McAffee, Retherford Ranch
Mr. Les Burch, Foreman, H & H Cattle Co.
Mr. Alan Burch, Foreman, H & H Cattle Co.

INTRODUCTION

These brief notes are meant to serve as the focus for discussions on the stratigraphy and structure of the central part of the frontal belt of the Ouachita Mountains in Oklahoma. The western part of the frontal belt was mapped by Tom Hendricks in 1947 (Fig. 1). Other parts of the eastern frontal belt were mapped by students of Lewis Cline (University of Wisconsin) in the early 1960s. Still other parts were last mapped in any detail by Joseph Taff prior to 1926. Our reasons for choosing to first map the central and eastern frontal belt over the 80 other quadrangles in the Ouachita Mountains are (1) the area either has not been mapped in over 60 years or has been mapped by students, and 2) there is considerable gas potential along the leading edges of many of the thrust sheets. The southern edge of the large Wilburton gas field extends south of the Choctaw Fault, but production is entirely subthrust. The Pittsburg field southwest of Hartshorne, however, produces from up to four repeated Wapanucka reservoirs.

To date, the Higgins 7½' quadrangle is finished and the Damon 7½' quadrangle nearly so.[1] This trip will focus on the geology in these two quadrangles. Time permitting, we will jump to the south to look at some of the older rocks not exposed in the frontal belt (Stanley Formation, pre-Mississippian rocks) for those who have never been to the Oklahoma Ouachitas before and possibly to the east to look at some frontal belt geology that we haven't mapped, yet. We will attempt a delicate balance between not boring those who have rubbed their noses in Ouachita geology for 30 years and not thoroughly confusing those who have never been here before.

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[1]HIGGINS. Formerly Caminet. In western Latimer County, 6 miles southeast of Hartshorne. Post office name changed to Higgins, May 28, 1903, and discontinued December 31, 1913. Named for R. W. Higgins, territorial jurist. DAMON. In Latimer County, 6 miles southwest of Wilburton. A post office from February 5, 1906, to March 15, 1934. Its name comes from the citizen of Syracuse known in history as the hostage for Pythias.

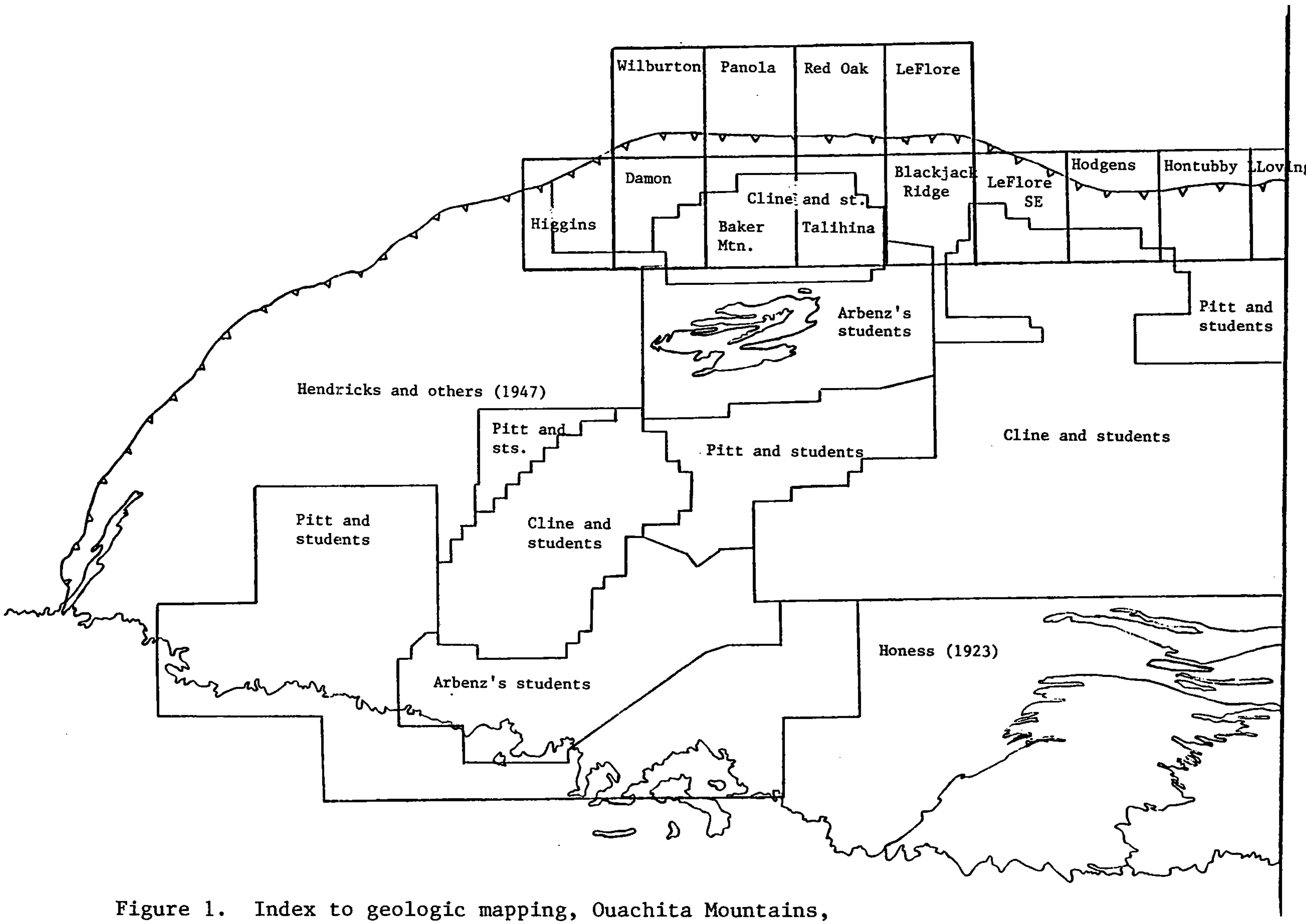

Figure 1. Index to geologic mapping, Ouachita Mountains, southeastern Oklahoma

DISCLAIMER

These brief and unedited notes are not meant to be the final word on what we will see or the geology of the area. In some cases they may be incomplete--the more geologists that we have look at any of these outcrops the more ideas we'll have a chance to test as mapping progresses to the east. In all cases, we hope the trip stops will be informative and/or provocative; if we can raise some questions and stimulate some discussion, we will consider the trip a success. This trip should be considered in light of the fact that our mapping in the frontal belt has only begun. As most of you are aware, it seems that the fervant hope of most field geologists that the solutions to all the questions you have about the quadrangle you are mapping lie in the one next door. Similarly, as you continue to answer questions posed in earlier mapping, new ones continue to arise.

GENERAL GEOLOGY

Definitions

Choctaw Fault - the geomorphic northern edge of the Oklahoma Ouachitas. This is the northernmost (leading) thrust exposed at the present erosion level. (Thrust faults are present in the Arkoma Basin north of the Choctaw Fault, but are entirely within the subsurface and die out within anticlines.) Gently tilted to flat, mostly middle and late Pennsylvanian strata to the north are within the Arkoma Basin. Faulted, folded, and steeply tilted early Pennsylvanian and older strata to the south form the Ouachita Mountains.

Frontal Belt - that part of the Ouachita Mountains between the Choctaw and Windingstair faults. Stratigraphically, all the rocks in the frontal belt are early Pennsylvanian (Morrowan and Atokan) and most (99%) are deep-water clastics, specifically, turbidites (locally, olistostromes). Structurally, strata in the frontal belt are steeply tilted, faulted, and isoclinally folded. This contrasts with the central belt of the Ouachita Mountains south of the Windingstair Fault where early Pennsylvanian and Mississippian turbidites form broad, open synclines whose northern flanks are typically thrust faulted.

Ti Valley Fault - considered by some to be the geologic northern edge of the Oklahoma Ouachitas, juxtaposes equivalent(?) shallow-water Wapanucka Limestone/Chicachoc Chert against deep-water Johns Valley Formation. The Ti Valley thrust appears to have a greater amount of displacement on it than any other fault in the Ouachitas.

Atoka Formation - what we will be seeing a great deal of on this field trip in the Higgins and Damon quadrangles, it overlies the Wapanucka Limestone/Spiro Sandstone between the Choctaw and Ti Valley faults and the Johns Valley Formation south of the Ti Valley Fault. It underlies the Hartshorne Sandstone in the Arkoma Basin; its top is not exposed in the Ouachitas. The type section is controversial; presumably it is near the town of Atoka at the western terminus of the Oklahoma Ouachitas, but there, it is largely unfossiliferous shale and the base is an unconformity. The age is controversial; conodont/foraminifera workers name the Atokan series after it whereas palynologists consider it mostly Morrowan and possibly extending into the Desmoinesian. Even the name is controversial; some recent maps call the Atoka Formation south of the Choctaw Fault the Lynn Mountain Formation.

Stratigraphy

Figure 2 summarizes the stratigraphy of the Oklahoma Ouachita Mountains. We will be concentrating on the Pennsylvanian section, specifically, the Atoka Formation and the units that directly underlie it--the Wapanucka/Spiro and Johns Valley. One of the purposes of the trip is to compare the lowermost Atoka across the various thrust faults of the frontal belt. This is one of the few places where, without biostratigraphic control, we have some idea where we are in the section. That is, of course, assuming that (1) the Wapanucka and Johns Valley are equivalent, and (2) the thick, apparently repeated olistostromal unit beneath the Atoka (as we have mapped it) is the same unit. Much of the Atoka Formation in the Higgins and Damon quadrangles is uncontrolled, that is, we have no fossil evidence to tell us where we are stratigraphically in the Atoka.

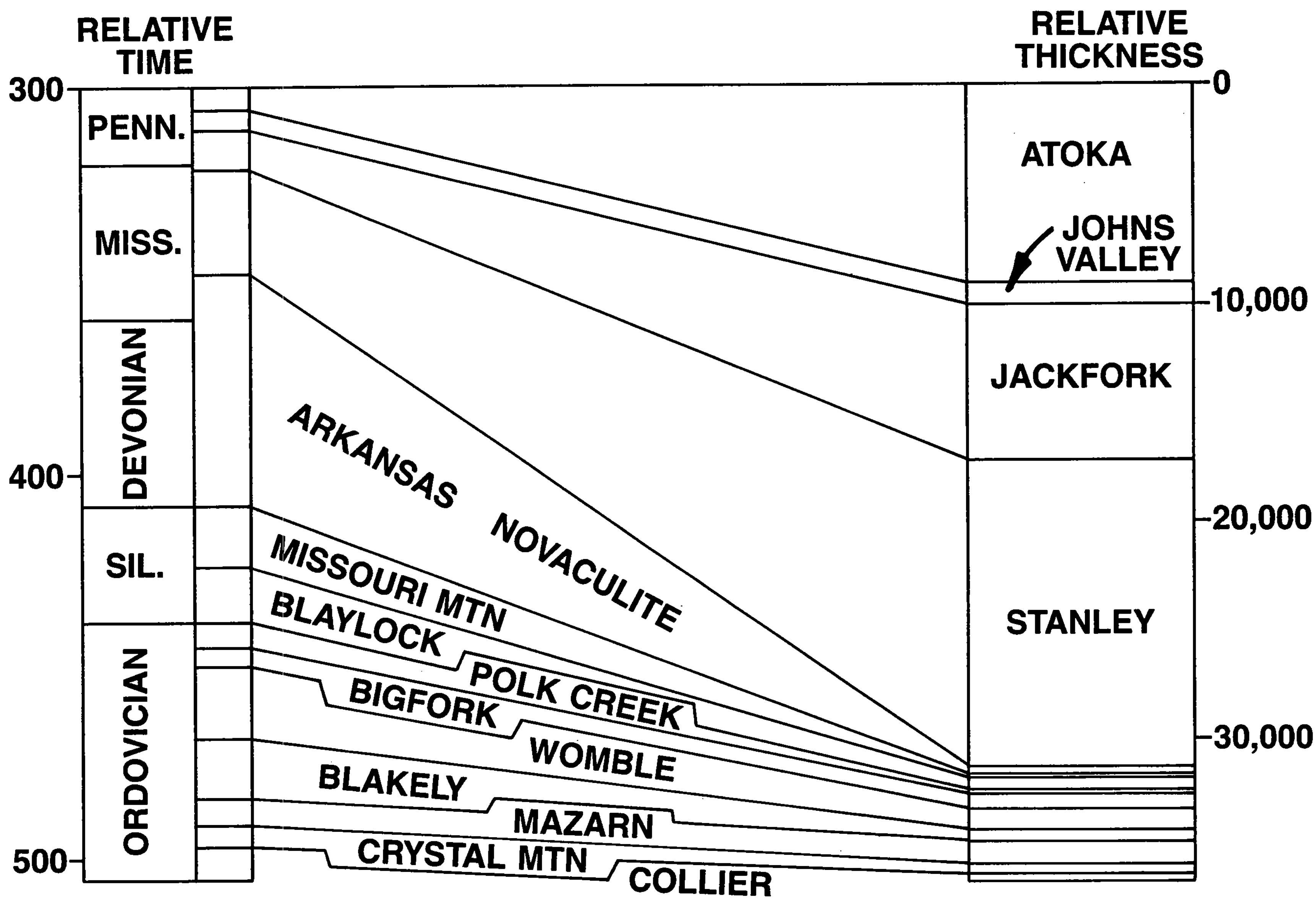

Figure 2. Generalized stratigraphy of the Ouachita Mountains, Oklahoma

Structure

The Oklahoma Ouachita Mountains are divided into the frontal belt on which we will be concentrating, the central belt, consisting mostly of broad, open synclines with thrust-faulted northern flanks, and the Broken Bow uplift--Ordovician through Mississippian rocks that have been deformed into isoclinal and isoclinal recumbent folds. The frontal belt in the Higgins and Damon quadrangles is largely characterized by east-northeast-striking, north-directed thrust faults and open to tight, upright and overturned folds with axial planes that generally parallel the faults. The most interesting structural problem encountered thus far are relations along the west side of the Higgins quadrangle. A major thrust (with substantial oblique slip?), termed the Pine Mountain Fault by Hendricks (1947), forms the eastern end of a series of ridges underlain by lower Atoka strata that mostly strike east-northeast but curve to the east and finally to almost north-south as the fault is approached. There is a mismatch in strata along Gaines Creek in the west-central part of the quadrangle. Does the Pine Mountain Fault change strike from east-northeast west of the Higgins quadrangle to almost north-south along Gaines Creek and then northwest in section 11? Or does the fault maintain its strike and form the range front north of Highway 1?

FIELD TRIP STOPS

Stop 1. Entrance to the Ouachita Mountains and Overview of the Choctaw Fault.

Location: NW/4 NW/4 9/4N/17E, Hartshorne 7½' Quadrangle.

Stop 2. Stratigraphic section of shallow-water shelf facies exposed just south of the Choctaw fault.

Location: NW¼, NW¼, sec. 5, T4N, R18E, Higgins 7½' Quadrangle.

Stop 3. Lower Atoka Formation sandstone turbidites, sedimentary structures, and west to east paleocurrents.

Location: southernmost strip of the SE¼, sec. 5, T4N, R18E, Higgins 7½' Quadrangle.

Stop 4. Olistostrome(?) in Atoka Formation.

Location: C W/2 E/2 25/4N/17E, Higgins 7½' Quadrangle.

Stop 5. Upright and Overturned Lower Atoka Formation. Flute molds, grooves, trace fossils, Bouma sequences, dish and pillar structures.

Location: C 5/3N/18E, Higgins 7½' Quadrangle.

Stop 6. Exxon Retherford No. 1 Wellsite and Outcrop of Spiro equivalent(?) Sandstone.

Location: C S/2 S/2 5/3N/18E, Higgins 7½' Quadrangle.

Stop 7. Mesoscopic, north-verging folds on the south limb of a major anticline in the Atoka Formation.

Location: center of SE¼, sec. 21, T4N,R18E, Higgins 7½' Quadrangle.

Stop 8. Cephalopod-bearing limestone and calcareous shale.

Location: Center of the east ½ of sec. 28, T4N, R18E, Higgins 7½ Quadrangle.

Stop 9. Chert Block in Atoka Formation. Olistostrome or Thrust Slice?

Location: C SW/4 28/4N/18E, Higgins 7½' Quadrangle.

Stop 10. Atoka-Johns Valley Contact. "Caney"(?) Shale lithology and limestone concretions(?), north flank of syncline.

Location: NW/4 NW/4 35/4N/19E, Damon 7½' Quadrangle.

Stop 11. Atoka-Johns Valley Contact. Famous Hairpin Curve Locality, south flank of syncline.

Location: NW/4 SE/4 3/3N/19E, Damon 7½' Quadrangle.

STOP 1. Entrance to the Ouachita Mountains and Overview of the Choctaw Fault

Location: NW/4 NW/4 9/4N/17E, Hartshorne 7½' Quadrangle

This low ridge just east of Hartshorne, Oklahoma, on Highways 1 and 63 is underlain by the Desmoinesian (upper middle Pennsylvanian) Hartshorne Sandstone. The Hartshorne is overlain by the McAlester Formation (dominantly shale) to the north--the town of Hartshorne and surrounding flats are on the McAlester. The Hartshorne and McAlester Formations, as most of the higher Arkoma Basin formations, contain significant strippable coal resources (Fig. 3). The following description is from Hendricks (1937, p. 11);

> The Hartshorne sandstone overlies the Atoka formation and grades downward into it. The character of the Hartshorne varies greatly in the different parts of the district. At Hartshorne the formation consists of about 100 feet of sandstone at the base, overlain by 50 feet of shale containing the Lower Hartshorne coal and this, in turn, overlain by a sandstone about 75 feet thick. Fossil plants are abundant in the shale immediately above the Lower Hartshorne coal. The lower sandstone of the formation ranges from massive, medium-grained, and pure in some parts of the area to thin-bedded, shaly, ripple-marked, and fine-grained at other places. However, this sandstone retains a characteristic ash-gray color on fresh surfaces in practically all exposures. The middle shale interval is present throughout the district but varies somewhat in thickness. The upper sandstone is the most variable part of the formation. At Hartshorne and on the south and east sides of the band of outcrop extending from Hartshorne to Gowen it is a massive coarse-grained pure-white, poorly cemented sandstone that weathers white and ranges from 50 to 100 feet in thickness. In other parts of the district this sandstone ranges from 10 to 50 feet in thickness and has much the same character as the lower sandstone. Locally, particularly in the southwestern part of the district, the upper sandstone of the Hartshorne grades laterally into sandy shale. Where this upper sandstone is thick the Lower Hartshorne coal crops out either between two prominent ridges formed by the upper and lower sandstones or on a terrace between the two. Where the upper sandstone is thin, however, the coal bed crops out at the base of the dip slope of the lower sandstone.

Hendricks (1937, Pl. 2) mapped the Hartshorne in this area striking about N75E, dipping 25° north.

Underlying the Hartshorne Formation is the Atoka Formation. Sandstones within the Atoka are among the principal gas-bearing reservoir rocks in the Arkoma Basin. The Atoka is also the principal formation in the frontal belt of the Oklahoma Ouachitas. Only the uppermost part of the Atoka is exposed in the Arkoma Basin; descriptions of the middle and lower Atoka come from subsurface studies (electric logs, cores, well cuttings) and from exposures in the Ouachitas. To our knowledge, all published attempts at Arkoma Basin subsurface - Ouachita Mountains surface sandstone correlations have been unsuccessful. The following description of the uppermost Atoka Formation is from Hendricks (1937, p. 10):

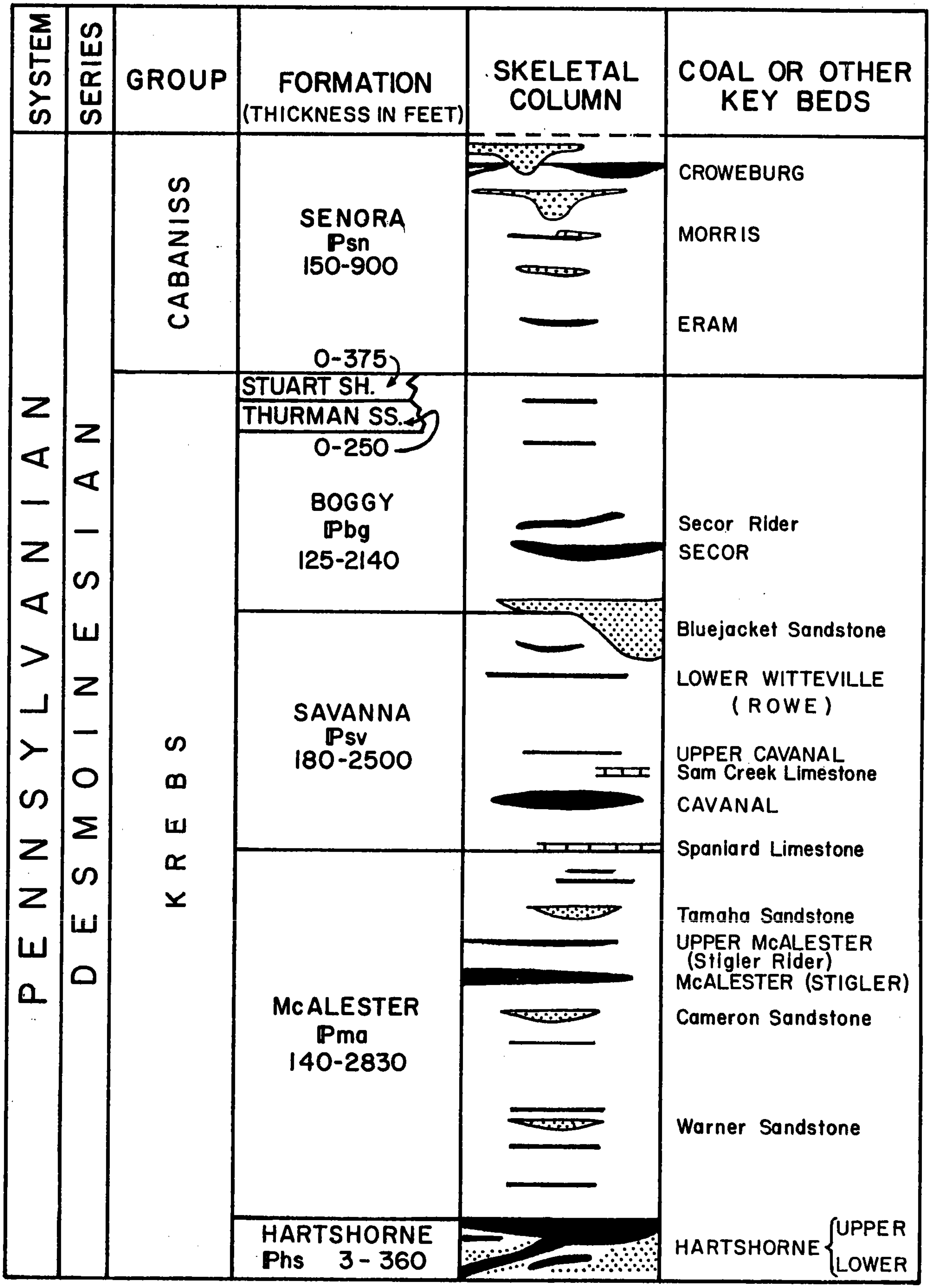

Figure 3. Generalized geologic column showing coals and other key beds of Desmoinesian age in part of the Arkoma Basin, eastern Oklahoma. (from Friedman, 1978)

The formation consists chiefly of shale, with lesser amounts of sandstone. The shale in a few outcrops is light gray or light pink, is highly fissile, and weathers into a plastic clay. In other outcrops, notably southeast of Adamson on the south side of the Hartshorne sandstone ridge, in the S½ sec. 9, T. 5 N., R. 17 E., the shale is dark gray, very sandy, and micaceous and contains much fragmental plant material. The sandstone in some exposures is brown, fine-grained, and highly micaceous, contains fragments of fern leaves, and shows considerable crinkling of bedding laminae. In other places, as in sec. 30, T. 4 N., R. 15 E., sandstone in the formation is coarse-grained, white, and pure. In the exposure just mentioned the sandstone contains fragments of plant stems and is bedded in layers 3 inches to 3 feet thick that show ripple marks on many of the bedding plants. The character of the portion of the formation present in the district but not exposed is inferred from outcrops in adjoining areas to be much the same as that of the exposed portion.

Hendricks and others (1947) map the Choctaw Fault (dashed) about .7 miles down the road (east) immediately over the first low rise behind the gas line equipment. There, the fault juxtaposes Atoka (presumably uppermost) against Atoka (lowermost). About 1.2 miles from here, they map another fault (solid line) that juxtaposes the same lowermost Atoka against Springer Formation. The Springer underlies the Wapanucka Limestone, which forms the first ridge of any significance. As you can see, the Wapanucka has been extensively quarried for roadbed material.

Information on the displacement along these two faults is afforded by the surface geology and the Mustang Sweet 1-9 (9/4N/17E) gas well (Fig. 4) drilled just west of the highway at the base of this Hartshorne ridge. It drilled the Atoka at 12,500 ft. (-11,800 ft. v.s.s.). If the Wapanucka in the Mustang Sweet 1-9 is horizontal and the dip of the Wapanucka on the ridge is constant (no flattening with depth), 19,500 ft. of shortening is indicated. If the Wapanucka in the well dips 25° (as at the surface) and the outcrop dip does not decrease, 12,500 ft. of shortening is indicated. Seismic data would clearly help our understanding of the subsurface structure (the Wapanucka is an excellent reflector) and consequently our estimates of lateral shortening.

Figure 4.

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OKLAHOMA CORP. COMM. WELL COMPLETION FILE

 WELL IDENTIFICATION SECTION

    OGS IDENTIFICATION NUMBER -   000947
    API WELL NUMBER -   12120537
    CORPORATION COMMISSION FORM ID NUMBER -   78-00494
    FORM TYPE -   1002A 7C
    DATE FORM RECEIVED -  1978 01 27
    DATE FORM SIGNED -  1978 01 26
    FORM SIGNED BY -  LESLIE BELINSKI
         BATCH NUMBER -  7C0860324A
         FORM KEYED ON -   1986 04 25

 LOCATION SECTION
    STATE POSTAL CODE -   OK
    COUNTY NAME -   PITTSBURG
    COUNTY CODE -   121

    SECTION -   09      TOWNSHIP -  04N     RANGE -   17E

    QUARTER SECTION -   SE 1/4 NW 1/4 NW 1/4

    OPERATOR NAME -   MUSTANG PRODUCTION CO
         OPERATOR ADDRESS -  1166E FIRST NATL CENTER
                             OKLAHOMA CITY
                             OK             73102

    FARM NAME -   SWEET
    WELL NUMBER -   1-9

    DRILLING STARTED -  1977 09 24    DRILLING FINISHED -   1977 12 30
    DATE OF FIRST PRODUCTION -  1978 01 12
    COMPLETION DATE -  1978 01 11
         DISTANCE FROM SL OF 1/4 SECTION (FT.) -   1560
         DISTANCE FROM WL OF 1/4 SECTION (FT.) -   1080

    ELEVATION OF DERRICK FLOOR (FT.) -  716
    ELEVATION OF GROUND (FT.) -   700

  OIL OR GAS ZONES SECTION

   ZONE NAME                                   FROM      TO
 01 ATOKA LOWER                                10440     10445

  CASING & CEMENT INFORMATION SECTION
```

REQUESTED CGS WORKING FILE RECORDS (09/17/86)

01 CASING SET / CEMENT (LINE 1)
CASING SET SIZE (INCHES) - 13 3/8
CASING SET WEIGHT (LBS/FT.) - 61
CASING SET THREADS - 8RD
CASING SET GRADE - J55
CASING SET FEET - 1229
CEMENT SACKS - 950
METHOD OF CEMENTING - PUMP

02 CASING SET / CEMENT (LINE 2)
CASING SET SIZE (INCHES) - 5 1/2
CASING SET WEIGHT (LBS/FT.) - 17 & 20
CASING SET THREADS - 8RD
CASING SET GRADE - N-80
CASING SET FEET - 10832
CEMENT SACKS - 300
METHOD OF CEMENTING - PUMP

TOOLS USED:
ROTARY TOOL USAGE FOOTAGE - 0-12560
SIZE OF ROTARY HOLE - 8 3/4

COMPLETION & TEST DATA BY PRODUCING FORMATION SECTION

01 PRODUCING FORMATION NAME - ATOKA LOWER
SPACING & SPACING ORDER NO. - 75990 134269
CLASSIFICATION GAS
PERFORATED INTERVALS - 10442-10445
NUMBER OF SHOTS - 7

INITIAL TEST DATA
TEST DATE - 1978 01 13
DURATION OF TEST (HOURS) - 2
OIL - BBL. / DAY - 0
GAS - MCF / DAY - 4800
WATER - BBL. / DAY - 0
EXTRACTION TYPE (PUMPING / FLOWING) - FLOWING
CHOKE SIZE (INCHES) - 16/64
FLOW TUBING PRESSURE - 3300
CASING PRESSURE - PACKER
PRODUCING THRU CASING OR TUBING - T

PRODUCTION DEPTHS SECTION

TOTAL DEPTH OF WELL - 12560

FORMATION RECORD SECTION

FORMATION NAMES AND DEPTHS

01 FORMATION - ATOKA
TOP DEPTH - 350
02 FORMATION - FANSHAWE
TOP DEPTH - 6700
03 FORMATION - RED OAK
TOP DEPTH - 7725
04 FORMATION - PANOLA
TOP DEPTH - 8500
05 FORMATION - ATOKA LOWER
TOP DEPTH - 10440
06 FORMATION - SPIRO
TOP DEPTH - 12395
07 FORMATION - WAPANUCKA
TOP DEPTH - 12500

COMMENTS AND REMARKS SECTION

SOURCE OF SUPPLEMENTARY INFORMATION -

USGS CORE AREA STUDY RECORD

STOP 2. Stratigraphic section of shallow-water shelf facies exposed just south of the Choctaw fault

Location: NW¼, NW¼, sec. 5, T4N, R18E, Higgins 7½' Quadrangle

This stratigraphic section (Fig. 5) is exposed in a north-flowing creek on the north slope of the northernmost ridge of the Ouachita frontal belt. The section is through a south-dipping (~60°) up-to-the-south sequence of calcareous shale (Springer) overlain by bioclastic limestone (Wapanucka), and cross-stratified sandstone (Spiro). These shallow-water facies rocks are directly overlain by deep-water facies noncalcareous olive-gray shale of the Atoka Formation. This facies change records the foundering of the southern edge of the North American continental shelf in early Pennsylvanian time. A conodont biostratigraphic study by Groves and Grayson (1984) places the Morrowan-Atokan boundary in the upper part of the shallow-water sequence. The shallow-water to deep-water transition occurs above the Morrowan-Atokan boundary, and although it is thought to be a conformable contact, it is biostratigraphically unconstrained. In the western Ouachita Mountains, near the town of Atoka, the Wapanucka-Atoka contact is clearly an unconformity (Zachry and Sutherland, 1984). The shallow-water facies limestone and sandstone intertongue with each other in this part of the frontal Ouachita belt. Locally the sandstone or the limestone may pinch out and limestone is not always overlain by sandstone. In some areas (in particular the next thrust slice to the south) limestone overlies sandstone.

The stratigraphic section is exposed just south of the north-directed Choctaw fault. Looking northwest from here, the first ridge is composed of the uppermost Atoka Formation capped by the shallow-water coal-bearing Hartshorne sandstone. There is approximately 12,000 ft. of south-side-up vertical displacement across the Choctaw fault, and certainly a significant south to north displacement as well. Looking to the south, the broad ridge is composed of the lower Atoka Formation. The lowermost 500 ft. of the Atoka in the frontal Ouachita frontal belt is almost all shale, and consequently it forms valleys. The low area directly south of the top of this stratigraphic section is underlain by the lower Atoka shale. The Atoka Formation overlying this shale consists of 5 cm to 1 m thick sandstone beds alternating with shale. These rocks are best exposed at the next stop which is in the lower part (stratigraphically) of the next thrust slice to the south.

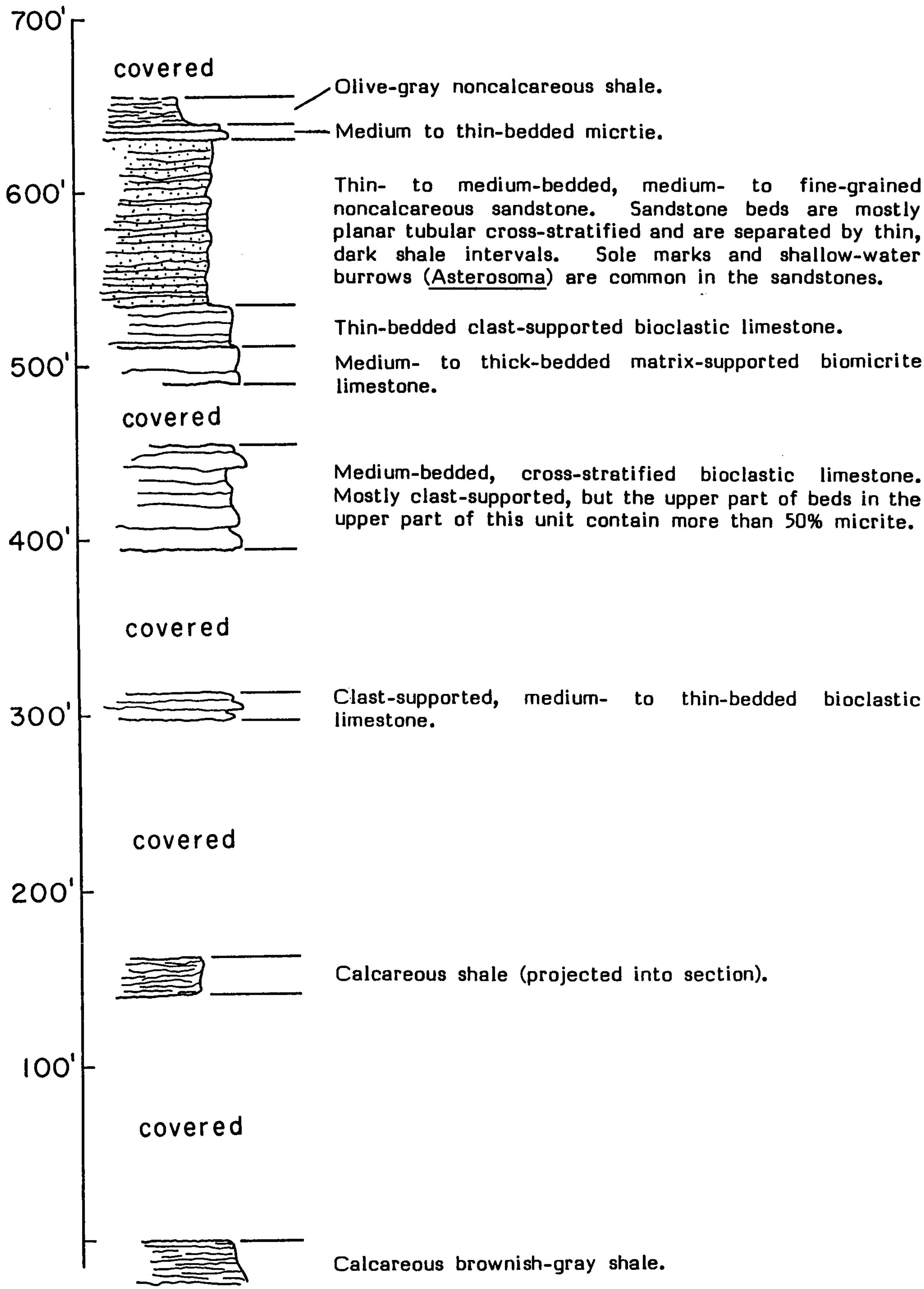


Figure 5. Stratigraphic section measured in north-flowing creek through Springer shale, Wapanucka Limestone/Spiro sandstone and the lowermost Atoka Formation. Note that the uppermost sequence of Atoka Formation shale may or may not be exposed depending on how "clean" or "clogged" the creek bottom is.

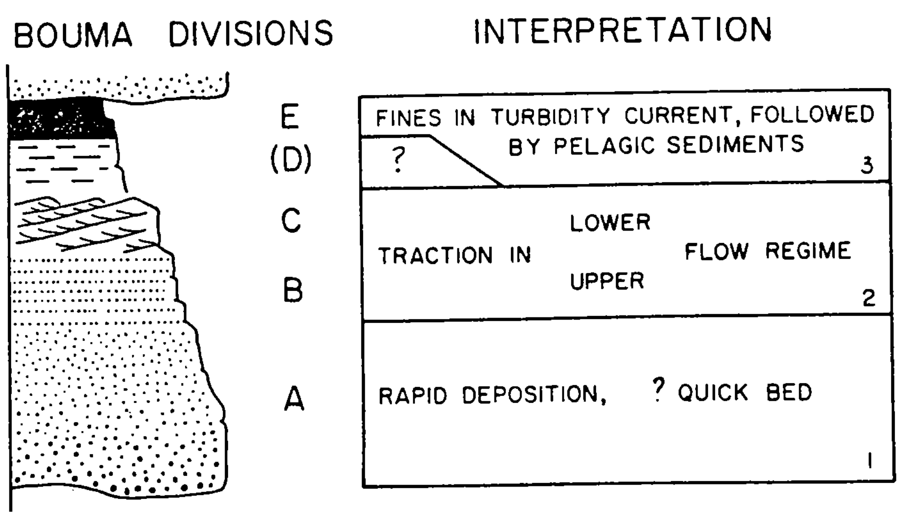
STOP 3. Lower Atoka Formation sandstone turbidites, sedimentary structures, and west to east paleocurrents

Location: southernmost strip of the SE¼, sec. 5, T4N, R18E, Higgins 7½' Quadrangle

The prominent strike-parallel valley here is underlain by the lower Atoka shale. This shale overlies a steeply south-dipping ridge of Spiro sandstone on the north side of the valley. Just north of the Spiro ridge is the first major thrust fault encountered south of the Choctaw fault. The major ridges that flank the valley are composed of south-dipping (60-85°) south-facing Atoka Formation sandstone and shale.

A continuous sequence of Atoka Formation sandstone turbidites (10 to 60 cm thick) interbedded with shale is exposed in the borrow ditch along the road that heads diagonally up the hill to the south. These rocks are dominantly Tce or Tbce Bouma sequences (see Figure 6a for an explanation of Bouma sequence abbreviations).

Flute molds are common on the underside of many of the sandstone beds in this part of the Atoka Formation. The average paleocurrent direction from sandstones in this sequence is to the northeast (azimuth of 40°). Previous paleocurrent studies of the Atoka Formation in the Ouachita Mountains and Arkoma Basin (Briggs and Cline, 1967 report that the dominant transport direction is to the west and southwest. During our mapping of the Higgins quadrangle we discovered two distinct populations of paleocurrent directions. In the northernmost thrust slices, where Atoka Formation directly overlies shallow-water facies Wapanucka-Spiro, the transport direction is consistently to the east and northeast. In thrust slices to the south, where Atoka Formation overlies the deep-water facies equivalent of the Wapanucka (Johns Valley shale), the transport direction is consistently to the west and southwest. This paleocurrent data, along with a discussion of the geologic implications, is being prepared for publication in the Oklahoma Geology Notes. Figure 6b is a simplified map showing paleocurrent azimuths from Upper Paleozoic rocks (mostly Atoka Formation) in the Higgins and Damon quadrangle.



Five divisions of the Bouma model for turbidites: A—graded or massive sandstone; B—parallel laminated sandstone; C—ripple cross-laminated fine sandstone; D—faint parallel laminations of silt and mud, bracketed to emphasize that in weathered or tectonized outcrops it cannot be separated from E—pelitic division, partly deposited by the turbidity current, partly hemipelagic. Interpretations of depositional process are grouped into three main phases, see text.

Figure 6a. Explanation of Bouma sequence abbreviations. This is Figure 1 of Walker, 1979.

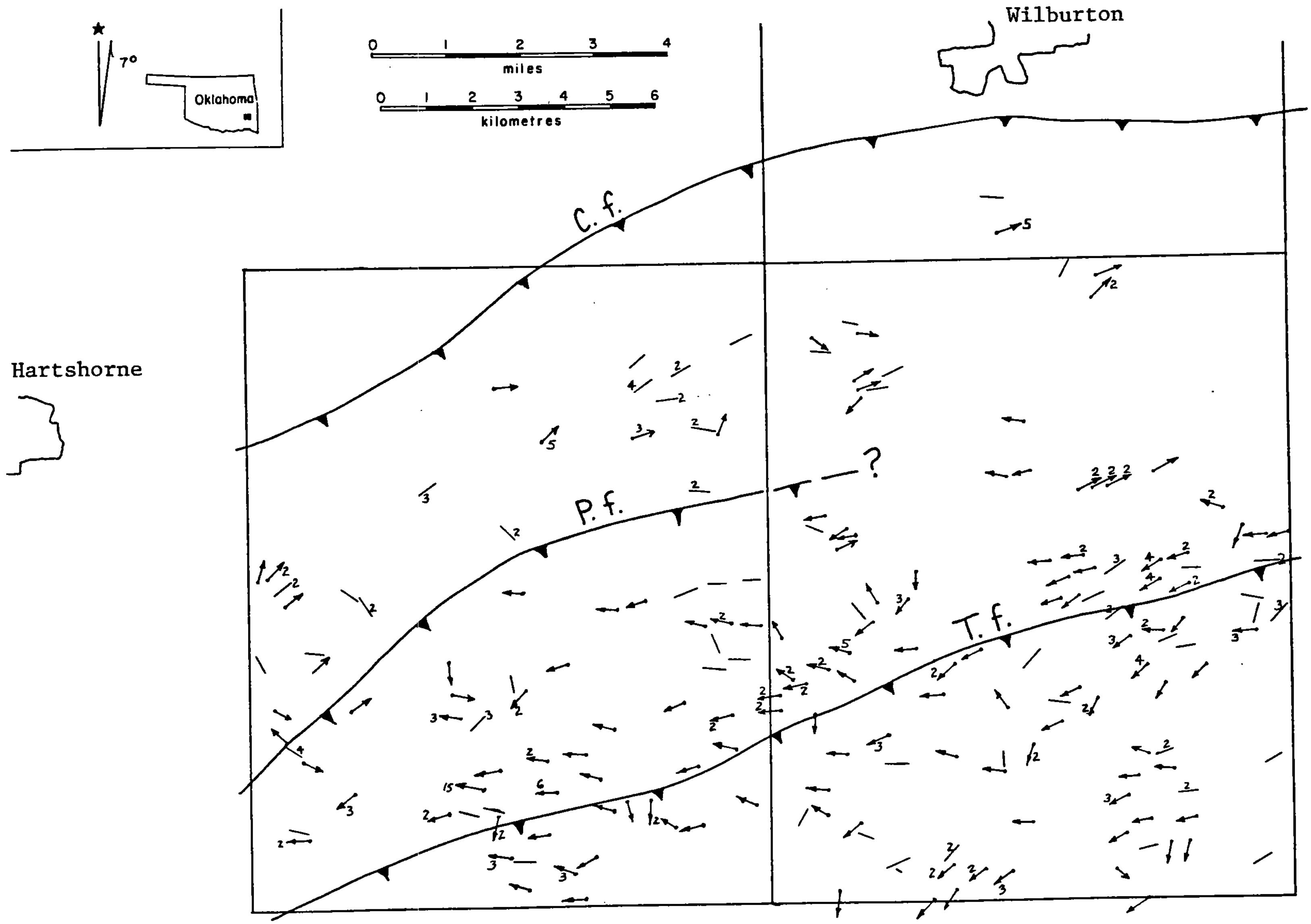


Figure 6b. Simplified geologic map of the Higgins and Damon 7.5' quadrangles. Paleocurrent azimuths were measured from flute molds in Upper Paleozoic turabidites (mostly Atoka Formaton). Directional azimuths are shown with an arrow. C.f. = Choctaw fault, P.f. = Pine Mountain fault, and T.f. = Ti Valley fault.

STOP 4. Olistostrome(?) in Atoka Formation

Location: C W/2 E/2 25/4N/17E, Higgins 7½' Quadrangle

Description of outcrop:

Approximately 900 ft. downstream (north) of the best exposure of the olistostrome is a poor exposure of shale, 1 to 2 in. thick siltstones, and 2 to 6 in. sandstones striking about N50E, vertical. Facing direction is unknown, but may be to the south based on good outcrops to the west. About 25 ft. upstream (south) of the shale is a dismembered 3 ft. thick sandstone overlain(?) by a 4 ft. thick gray, micritic limestone with abundant brachiopod fragments. The attitude of the limestone is roughly parallel to what appears to be local structure. A little further upstream are 4 ft. by 4 ft. blocks of microcrystalline, platy (½ to 1 in.) yellowish gray limestone. Chert cobbles and boulders, fragments of a black siliceous shale or chert, and fragments of a very clean, Spiro-like sandstone are present in some of the small gullies on the west side of the stream. Are the chert fragments foreland-derived or from the south (Arkansas Novaculite)?

The stream-cut outcrop of the olistostrome is predominantly shale with some sandstone striking about N25W84SW at the south end; facing is unknown. (Further upstream the attitude of a poorly exposed sandstone in the cut bank is N10W35W.) Rounded cobbles and boulders (largest is about 6 ft. by 3 ft.) of soft, light gray, siliceous shale or chert are floating in an olive black shale. Rare chert cobbles are also present, and black chert and a fossil hash fragment are at the base of the outcrop. A few round nodules containing pyrite, fossils, or nothing are scattered throughout the shale.

Discussion:

At this location we are about 2 miles northwest of where we or anyone else has mapped the Ti Valley Fault. Turbidite sandstones and shales surround us on all sides although exposures are extremely poor for about a mile to the north. Although we might place ourselves somewhere in the middle of the Atoka Formation, large limestone blocks and chert boulders indicate that olistostromes similar to those in the Johns Valley extend considerably higher in the section than had been previously thought. This outcrop raises several questions, and the implications of the answers are critical from several standpoints:

1. This outcrop is Morrowan Johns Valley Formation, and the Ti Valley Fault is just north of here. Implication: If the Ti Valley Fault juxtaposes the equivalent shallow-water Wapanucka Limestone and deep-water Johns Valley Formation, and Wapanucka is present at 7,880 ft. in the Exxon Retherford No. 1 (see Stop 6) and possibly 7,151 ft., then at this locality, the Ti Valley is a very low-angle thrust fault. Furthermore, exploration companies are very reluctant to drill behind the Ti Valley Fault (why?) and placing it here reduces interest in this area.

2. This olistostrome is within the Atokan Atoka Formation. Implication: Throughout the frontal belt of the Oklahoma Ouachitas, olistostromal deposits have always been called the Morrowan Johns Valley Formation. Rocks under the Johns Valley are Jackfork and over the Johns Valley are Atoka. If olistostromes occur within the Atoka, then a great deal of previous stratigraphic work must be subject to critical review and remapping. Palynomorphs, conodonts, or any other microfossils from the shaly matrix of this and other "out-of-place" olistostromes may be our only hope of determining whether these deposits are Atokan or Morrowan.

3. These rocks (limestones and cherts) are dragged up by a fault immediately north of this outcrop. Implication: The least likely of the three possibilities presented here. Stops 8 and 9 are more likely candidates for fault slices. This outcrop is very Johns Valley-looking.

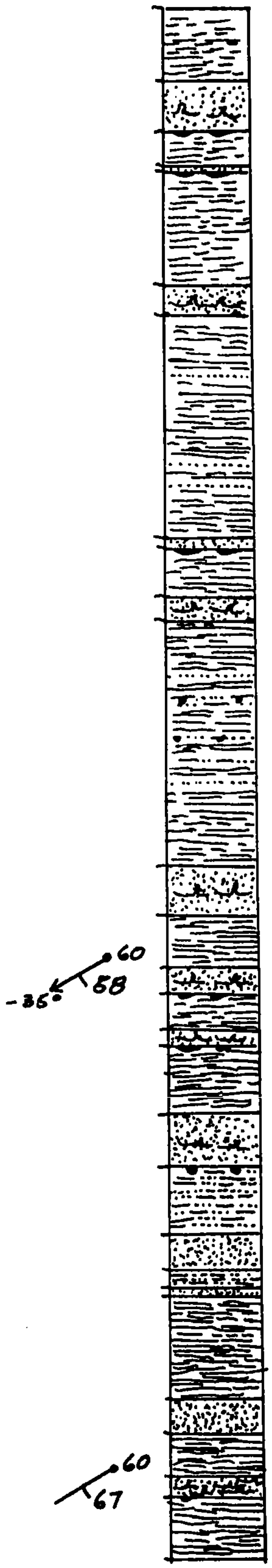
STOP 5. Upright and Overturned Lower Atoka Formation.
Flute molds, grooves, trace fossils, Bouma Sequences, Dish and Pillar Structures

Location: C 5/3N/18E, Higgins 7'½ Quadrangle

The Ti Valley Fault crossed the road immediately over the ridge to the north of us. If we walked up hill to the north and followed the ridge to the west, basal Atoka Spiro (-equivalent?) Sandstone crops out on top. The ridge (and sandstone) swing to the south, and limestone boulder-bearing Johns Valley Formation is present in the gully in the southeast corner of sec. 1, 3N, 17E. The sequence Johns Valley, Spiro(?), then these turbidites convinces us we are in the lower part of the Atoka Formation. This sequence of lower Atoka turbidites consists of about 205 ft. of shale with minor siltstone, 83 ft. (Tb)Tc(Td) sandstones, and 240 ft. covered (Fig. 7). Of the exposed part, 71 percent is shale and siltstone and 29 percent is sandstone. We have not measured enough sections of turbidites throughout the Atoka to know if these numbers are representative or not.

An interesting question is why are the rocks on one side of the gully overturned, whereas they are upright on the other side. Is there a fault in the gully?

Figure 7
MEASURED SECTION - LOWER ATOKA FORMATION - EXXON RETHERFORD NO. 1 DRILL ROAD



4' Shale, poorly exposed

3' Sandstone. Flutes. 22" D&P'd Tc, 14" Lam'd Tc

2' Shale

3" Sandstone. Small flutes, 1" Tc, 2" Lam'd Td

7' Shale

1½' Sandstone. Msv. Tc. D&P'd, flat base. Poss 1" Td at top

13' Dominantly shale, ½-3" Tc Sandstone topped by Td siltstones. Approx. 90% shale, 10% sandstone and siltstone

8" Sandstone, Tc, small flutes

3' Shale

1½' Tc Sandstone. D&P'd, especially upper half. No Tb. Poss v thin Td

14' Shale, siltstone, 1" Td lam'd siltstones to 6" Tc sandstones +/- 1" Td siltstones at top. Siltstones loc w/ abundant T/Fs

3' Sandstone. Msv, par Lam'd 1' at base (Tb?), 1' D&P'd Tc (Msv), 1' platy/lam'd Tc and Td(?) at top

3' very poorly exposed shale and thin siltstones

1½' Sandstone. Msv, D&P'd, prob Tc sandstone w/ abun flutes

2' Shale

1' Sandstone, Tc. Small flutes and grooves, D&P'd, approx. 2" Td siltstone at top

4' Shale

3' Sandstone. 6" Td siltstone at top, lam'd approx. 2-3 mm, 1' strat'd Tc ss, loc small D&P strucs, 1½' msv Tc ss w/ either par or gently inclined lams. Large chondrites T/Fs at base.

4' Shale and par lam'd siltstone and 1 3" Tc ss. Prob 70% siltstone

2' Sandstone. Msv, prob Tc

1' Siltstone, lam'd

6" Sandstone. Msv, no lams. Tc? Very flat base

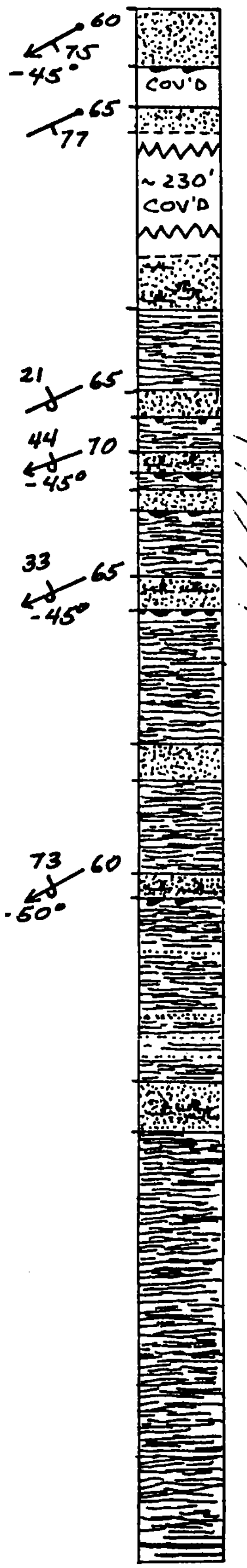
6' Shale and less than 5% lam'd siltstone

2' Sandstone. Msv. All par lams, all Tb?

2½' Shale

1¼' Sandstone. 1-2" Td at top, rest is Tc. V highly D&P'd, nice x-lams at base. Very poor flutes at base.

3½' Shale



3½' Sandstone. 6" Td at top, 10" Tc - low incl beneath, then 8" Tb. Repeat with 3" Tc, 4-1½" Tb at base. Amalgamated ss. Flutes.

2½' covered, probably shale

Minimum 1½' Sandstone, prob Tc and Td, base cov'd by road

Covered by road and gully

3' Sandstone. 1½' Td, sltly D&P'd at top (poss some v thin, low incl Tcs in here). 1½' D&P'd Tc at base - msv

Approx. 5' Shale. Attitude changing

1½' Sandstone. 2" Td at top, rest Tc - low incl. D&P's in Tc. Bottom 3" of Tc msv, upper part platy. Small T/Fs at base.

2' Shale

1¼' Sandstone. All Tc. Middle 6" highly D&P'd, bottom msv but w/ exc x-lams. Flutes

1' Shale

1¼' Sandstone. Very similar to sandstone above

4' Shale

2' Sandstone. 11" Tb, 10" Tc w/ D&P strucs at top 3", 2" Td. Exc v lg&sm chondrites crossing flutes

8' Shale

2¼' Sandstone. approx. 6" high incl. Tc ss at base, 9" low incl Tc ss above, 9" msv tho lam'd (mm) Td ss above, 6" platy Td at top. Msv Td loc platy

5½' Shale

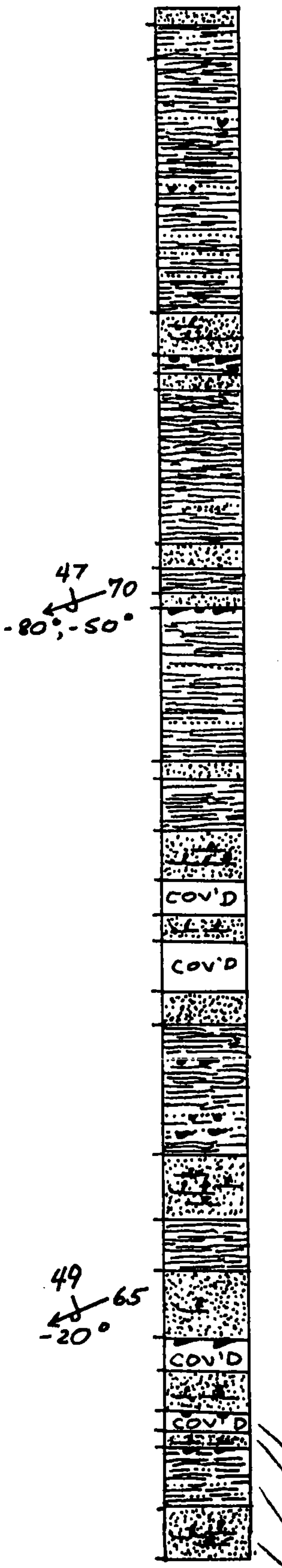
1½' Sandstone. Bottom 1' Tc ss - D&P'd in upper 4", 5" par lam'd (mm) Td ss or ext low incl Tc. Top 1" is low incl Tc ss. Flutes

11' Shale w/ 1-4" Tc sandstones and Td siltstones

3' Sandstone. Tc at base, middle D&P'd, ext low incl Tc or Td at top.

26' Shale with less than 5% 1-6" Tc sss under Td siltstones, Td siltstones w/o Tc sss, shale. Very abun T/Fs, small scours in thin sss.

Bottom 3' w/ approx. 15% ½-1" hard, siliceous siltstone



1' Sandstone. Par lams (mm) to very gently incl lams. Tc trans to Td? Basal 1-2" good Tc. Top loc good high incl Tc.
2' Shale with 2-3" siliceous siltstones

15' Shale with 5% 1-4" Tc sss, typically with v abun small T/Fs

2½' Sandstone. 4" Tb at base, 4" platy Tc at top, middle is msv but strat'd, highlyD&P'd Tc ss. T/Fs - lg and sm, small scours at base
1' Shale
1' Sandstone. Msv - no stratn visible. Poss 1" Td at base

9' Shale w/ poorly exposed 1' Tb/Tc ss. CULVERT

1½' Sandstone. 6" Msv, unstrat'd base, 1' Tc, poss 2" Td
1½' Shale
1' Sandstone, poss 3 1-3" Tc sss. Poss all 1 well strat'd Tc ss. Small T/Fs, sm scours w/ poss 2 diff directions at base

9' Shale, 1" Tc sss. Less than 2% ss

1' Sandstone. v poorly exposed, msv, poorly strat'd.

3' Shale, largely covered
3' Sandstone. Msv, vaguely par lam'd Tb at base (13"), rest D&P'd Tc. Very flat base
2' covered, probably shale
1½' Sandstone. Exc par lam'd Tb bottom 9", 2" high incl Tc, rest low incl Tc w/ loc, less than 1" D&P strucs.
3' covered
2' Sandstone. Poorly exposed, structureless

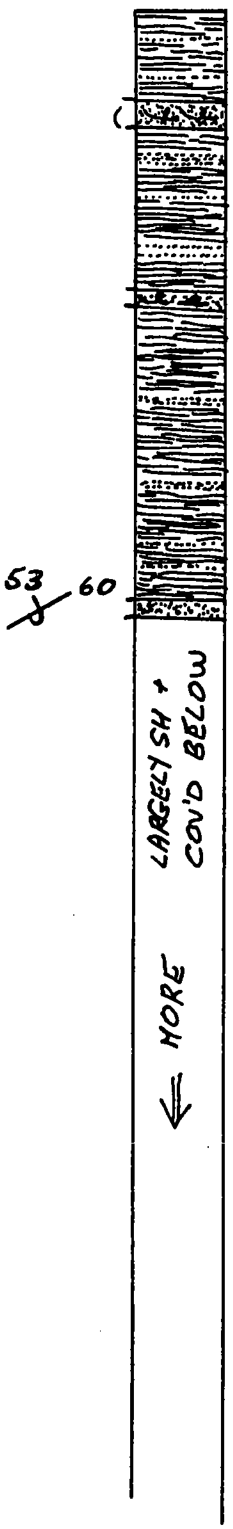
7½' Shale w/ 1" Tc sss - typically w/ small T/Fs, small scours at base

4' Sandstone. Msv. Strat'd 6" top (poss Td), un- to v poorly lam'd base (Tb), Msv Tc (w/ D&P strucs) interior. Stratn in Tc - mm

3' Shale. Poorly exposed

4' Sandstone. V vague D&P lams. All Tc? Base ext flat to w/ flutes.

2' covered
2¼' Sandstone. 4" msv, vague par lam'd base, T/Fs at base. Most rest high incl Tc w/ D&P strucs, 0-2" low incl Tc, poss 2" Td siltstone at top
1¼' covered
1' Sandstone. 3" msv, vague par lam'd Tb base, 8" high incl Tc ss w/ D&Ps, 1" strat'd platy Td siltstone. Ext sm scours at base
3½' Shale and siltstone
3' Sandstone. 2' msv, vaguely lam'd Tb, 1' D&P'd Tc



5' Shale w/ 1-4" Tc ss.

1½" Sandstone. 10" vaguely par lam'd Tb base, 6" msv Tc w/ lg D&Ps, 5" platy strat'd Tc w/ v sm D&Ps, poss 2" Td ext lam'd (mm) siltstone. Base sltly loaded - bulbous

9' Shale w/ 15% 3" to 1' (at top) Tc and Td sss. One Tbcd sandstone at top.

10" Sandstone. 1-2" vaguely par lam'd Tb base, 8" highly D&P'd Tc, poss 2" Td siltstone

16' Shale w/ 15% 2-10" Tc ss

1' Sandstone. Ext platy Tc, v low incl Tc or Td at top, 2" msv Tc at base

Largely shale, covered below. More rocks towards top of ridge

SOME SYMBOLS AND ABBREVIATIONS

D&P - Dish and Pillar

T/F - Trace Fossil

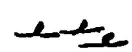
Msv - massive

Par - parallel

Incl - inclined

 - trace fossils

 - scour marks

 - dish and pillar structures

STOP 6. EXXON Retherford NO. 1 Wellsite, Outcrop of Spiro equivalent(?) Sandstone

Location: C S/2 S/2 5/3N/18E, Higgins 7½' Quadrangle.

The Exxon Retherford No. 1 is the deepest well in this part of the frontal belt of the Ouachitas Mountains. It is one of the few wells that spudded in the Ti Valley sheet and TD'd in foreland facies rocks. Exxon's tops are given in the GIS printout (Fig. 8) that follows this description, along with other significant well data. Others have made different picks in the section below 15,000 ft. and controversy exists over stratigraphic terminology in that part of the section, but for the purposes of this trip, suffice it to say that the hole TD'd in foreland "Arbuckle" facies rocks, below the Ti Valley and Choctaw faults.

In addition to Exxon's picks, our interpretation of the logs adds the following:

1,943-6,245 ft. - Atoka Formation
6,245-6,310 ft. - Spiro Sandstone
6,310-6,650 ft. - Wapanucka Limestone(?). (Sandstone on Mudlog)
6,650 ft. - Fault
6,650-7,060 ft. - Atoka Formation
7,060-7,151 ft. - Spiro Sandstone
7,151-7,408 ft. - Wapanucka Limestone(?). (Sandstone on Mudlog)
7,408-7,765 ft. - Springer Formation
7,765 ft. - Fault
7,765-7,880 ft. - Spiro Sandstone
7,880-7,929 ft. - Wapanucka Limestone. (Limestone on Mudlog)
7,929-approx. 8,250 ft. - Springer Formation
approx. 8,250 ft. - Fault
8,250-15,104 ft. - Atoka Formation
below - see Exxon picks

Our interpretation of the dipmeter log adds further constraints to any cross sections one might attempt to draw through this area. A summary of our analysis is:

2,900-8,500 ft. - N45-55E, 55-75°SE
8,500-12,500 ft. - N75-80E, 40-55°SE
12,500-13,750 ft. - N50-75E, 30°SE
below 13,750 ft. - attitudes extremely valuable, generally low dips.

We are currently working on cross sections that are faithful to the surface geology, tops as interpreted from the logs, and dipmeter data. Needless to say, seismic data from this area would be a great help.

Figure 8.

```
REQUESTED OGS WORKING FILE RECORDS (07/16/86)

OKLAHOMA CORP. COMM. WELL COMPLETION FILE

WELL IDENTIFICATION SECTION

    OGS IDENTIFICATION NUMBER -   000316
    API WELL NUMBER -   07720285
    CORPORATION COMMISSION FORM ID NUMBER -   01611
    FORM TYPE -   1002A 79
    DATE FORM RECEIVED -  1985 02 11
    DATE FORM SIGNED -  1985 02 07
    FORM SIGNED BY -  MELBA KNIPLING
         BATCH NUMBER -  790850814A
         FORM KEYED ON -   1985 08 27

LOCATION SECTION
    STATE POSTAL CODE -   OK
    COUNTY NAME -   LATIMER
    COUNTY CODE -   077

    SECTION -   05      TOWNSHIP -  03N     RANGE -   18E

    QUARTER SECTION -   NW 1/4 SW 1/4 SE 1/4

    OPERATOR NAME -   EXXON CORP
         OPERATOR ADDRESS -  PO BOX 1600
                             MIDLAND
                             TX              79702
    OPERATOR PHONE NUMBER -   (915) 686-4406

    FARM NAME -   RETHERFORD
    WELL NUMBER -   1

    DRILLING STARTED -  1984 07 25     DRILLING FINISHED -   1984 08 24
    DATE OF FIRST PRODUCTION -  1984 10 23
    COMPLETION DATE -   1985 01 17
    PLUGGING DATE -   1985 01 17
         DISTANCE FROM SL OF 1/4 SECTION (FT.) -   882
         DISTANCE FROM WL OF 1/4 SECTION (FT.) -   222

CASING & CEMENT INFORMATION SECTION

01 CASING SET / CEMENT (LINE 1)
         CASING SET SIZE (INCHES) -  20
         CASING SET WEIGHT (LBS/FT.) -   133
         CASING SET GRADE -  K55
         CASING SET FEET -   1943
         CASING TEST PSI -   1500
```

REQUESTED OGS WORKING FILE RECORDS (07/16/86)

CEMENT SACKS - 1000
CEMENT FILLUP - 1943
CEMENT TOP - SURFACE

02 CASING SET / CEMENT (LINE 2)
CASING SET SIZE (INCHES) - 13 3/8
CASING SET WEIGHT (LBS/FT.) - 88.2 72
CASING SET GRADE - SS95 P110, N80
CASING SET FEET - 7348
CASING TEST PSI - 4000
CEMENT SACKS - 5200
CEMENT FILLUP - 7348
CEMENT TOP - SURFACE

03 CASING SET / CEMENT (LINE 3)
CASING SET SIZE (INCHES) - 9 5/8
CASING SET WEIGHT (LBS/FT.) - 53.5 47
CASING SET GRADE - N80 CYT95
CASING SET FEET - 14604
CASING TEST PSI - 3840
CEMENT SACKS - 4700
CEMENT FILLUP - 14604
CEMENT TOP - SURFACE

COMPLETION & TEST DATA BY PRODUCING FORMATION SECTION

01 PRODUCING FORMATION NAME - ATOKA PENNSYLVANIA
SPACING & SPACING ORDER NO. - 640; NONE
CLASSIFICATION DRY
PERFORATED INTERVALS - 10932-10940, 10690-10714, 10642-10662, 10628-10634, 10598-10616, 10562-10586
FORMATION ACIDIZED? - YES
FORMATION FRACTURED TREATED? - YES

PRODUCTION DEPTHS SECTION

TOTAL DEPTH OF WELL - 19046
PLUGGED BACK TOTAL DEPTH - 11300

DRILL STEM TEST SECTION
DRILL STEM TEST RESULTS

FORMATION	TOP DEPTH	BOTTOM DEPTH	RESULTS
01	15200	15400	
02	18515	18669	
03	18544	18569	
04	18864	19046	

FORMATION RECORD SECTION

REQUESTED OGS WORKING FILE RECORDS (07/16/86)

FORMATION NAMES AND DEPTHS

01 FORMATION - SPIRO LIMESTONE
TOP DEPTH - 15104
02 FORMATION - SPIRO SAND
TOP DEPTH - 15189
03 FORMATION - WAPANUCKA LIMESTONE
TOP DEPTH - 15265
04 FORMATION - CROMWELL
TOP DEPTH - 16090
05 FORMATION - CANEY
TOP DEPTH - 16930
06 FORMATION - CANEY REPEAT
TOP DEPTH - 17065
07 FORMATION - MAYES
TOP DEPTH - 17171
08 FORMATION - OSAGE
TOP DEPTH - 17380
09 FORMATION - WOODFORD
TOP DEPTH - 17469
10 FORMATION - HUNTON
TOP DEPTH - 17601
11 FORMATION - SYLVAN
TOP DEPTH - 17630
12 FORMATION - VIOLA
TOP DEPTH - 17692
13 FORMATION - SIMPSON BROMIDE
TOP DEPTH - 17818
14 FORMATION - MCLISH
TOP DEPTH - 18121
15 FORMATION - OIL CREEK UPPER
TOP DEPTH - 18239
16 FORMATION - OIL CREEK BASAL
TOP DEPTH - 18336
17 FORMATION - JOINS
TOP DEPTH - 18504
18 FORMATION - ARBUCKLE
TOP DEPTH - 18678

COMMENTS AND REMARKS SECTION

SOURCE OF SUPPLEMENTARY INFORMATION - 01
REMARKS - SET RETAINER @ 14220, PUMP 200 SX CIH. SPOT PLUG @ 11610'-11300'.
THE RETHERFORD #1 WAS P & A'D ON 1-17-85 IN THE FOLLOWING MANNER: CIBP @ 9900'. TOP W/ 10 SX
TOC @ 9877' 7450-7000 W/ 175 SX CIH. 2002-1842 W/ 50 SX CIH. 3-35' W/ 8 SX CIH.

USGS CORE AREA STUDY RECORD

The rocks exposed at the drillsite are mapped by us as Spiro equivalent sandstone. They are very similar to the rocks that form the ridge to the northwest where they very clearly overlie Johns Valley olistostromal beds. We map a fault on the north side of this ridge, subparallel to the Ti Valley Fault on the north side of the ridge to the north (see Stop 5). The Spiro equivalent sandstone forms both ridges and is repeated by the fault to the north of us. (Hendricks and others [1947] mapped faults in very nearly the same place as we did.)

Description of outcrop:

At the south side of the drillpad is a massive white sandstone, possibly 60 ft. thick, consisting of many amalgamated 2 in.- to 2 ft.-thick beds. In places it appears to be a very clean quartz sandstone. Porosity varies; in places it is completely silica-cemented, in other places there is no obvious cement. No internal sedimentary structures are present. Above the sandstone (beds are overturned, striking N35E77NW) are many 2 in.- to 1 ft.-thick Tb and Tc sandstones in poorly exposed shale. The thicker Tc sandstones typically show convolute layering. A fine-grained sandstone bed near the massive white sandstone is distinctive--it is very hard, almost flinty, extremely well-laminated, partly cross-laminated, and slightly calcareous. Calcareous sandstones are almost nonexistent in the Atoka Formation.

STOP 7: Mesoscopic north-verging folds, on the south limb of a major anticline in the Atoka Formation

Location: center of SE¼, sec. 21, T4N,R18E, Higgins 7½' Quadrangle

The purpose of this stop is to look at a very well exposed sequence of thin- to medium-bedded Atoka Formation on the south limb of a major anticline. The sequence is exposed along the east bank of a major north-flowing creek. It is best to view this exposure in the mid-to-late afternoon, particularly if one is interested in taking photographs. The folds exposed in the outcrop are complex, but overall they verge to the north. The axial plane of the major anticline is about 1,000 ft. to the north of the north end of this exposure. Figure 9 is a sketch of this exposure, which is about 400 ft. long normal to strike.

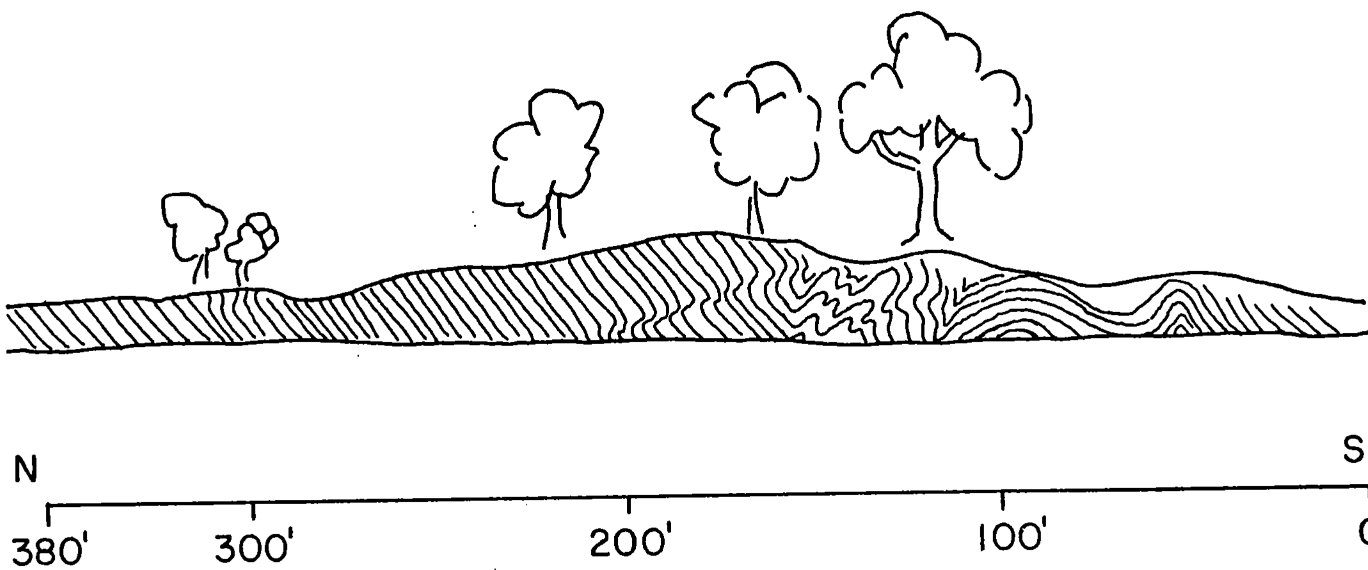


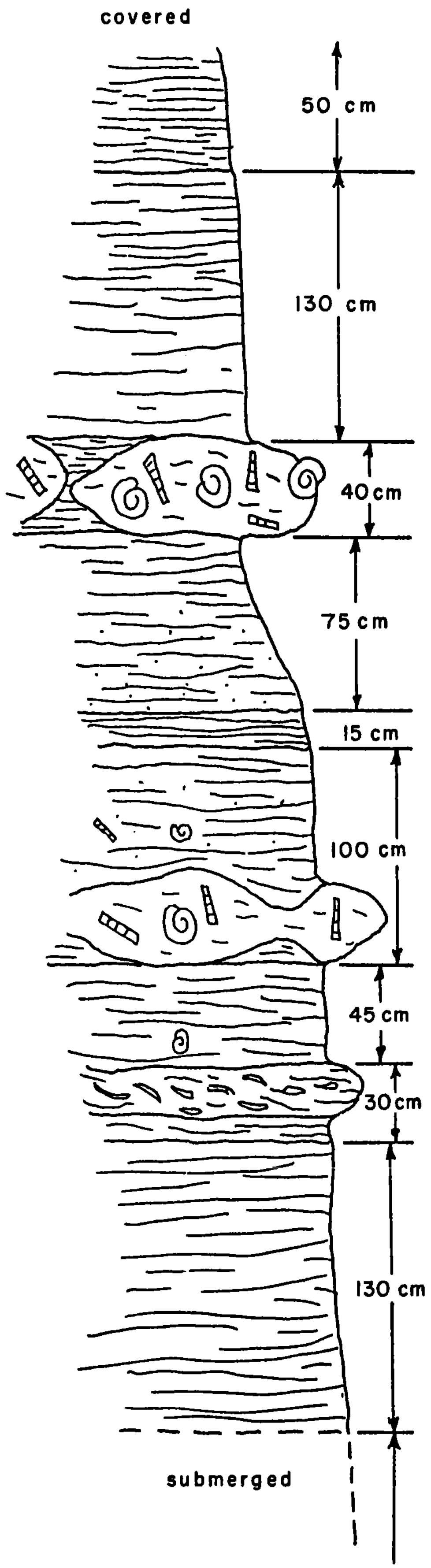
Figure 9. Sketch, looking east, of Mesoscopic folds in Atoka Formation exposed along cut bank of a major north-flowing creek.

STOP 8: Exotic block of Cephalopod-bearing limestone and calcareous shale

Location: Center of the east ½ of sec. 28, T4N, R18E.

A cephalopod-bearing limestone and calcareous shale sequence is exposed along the west side of a cut bank along a major north-flowing creek. The 10 m thick sequence crops out at the north end of low ridge composed of east-west striking steeply dipping south-facing noncalcareous sandstone and shale of the Atoka Formation. Top indicators have been found in the calcareous sequence. There is no contact exposed between the calcareous rocks and the noncalcareous rocks. A stratigraphic section (Fig. 10) was described in the calcareous rocks which dip 40° to the south. All rocks in the calcareous sequence, when broken, have a fetid odor. There are at least three 20 to 40 cm-thick beds of micritic limestone within the sequence. The micritic limestones which contain at least two species of cephalopods are thought to be autochthonous with respect to the calcareous shales.

This calcareous sequence may be part of the Atoka Formation, but the lithologies are more akin to large exotic blocks that are common in the older Johns Valley Formation. If this outcrop is part of the Johns Valley Formation, then a thrust fault must separate it from the Atoka Formation which comprises the large ridge to the north of here. A northeast-southwest trending valley just north of this exposure is a likely place for this proposed fault. A large block of chert (described at Stop 9) crops out just west of here along the proposed fault trace.



Dark-brown noncalcareous laminated shale.

Dark-brown to black calcareous massive to slightly fissile shale. Shale becomes more massive towards base.

Dark-gray micrite with at least two varieties of cephalopods floating in matrix. The limestone occurs in a distinct bed which necks out into pods and lenses along strike. Bedding in the pods is always parallel to bedding in the overlying and underlying shales. Shale laterally adjacent to the pods contains similar cephalopods.

Brownish-gray laminated to thin-bedded calcareous silty shale. Shale becomes siltier and slightly fossiliferous downwards. Shale is also lighter colored downwards.

Dark-gray to black laminated calcareous shale.

Light-gray silty fossiliferous calcareous shale. Lower 30 cm consists of pods and discontinuous layers of bedded fossiliferous (cephalopods) micrite.

Gray slightly fissile calcareous shale with rare fossils (cephalopods).

Fossiliferous micrite grading downward into slightly fissile gray-brown calcareous shale.

Gray- to dark-brown slightly fissile to fissile calcareous shale.

At least 3 m more exposure of similar dark calcareous shale and micritic limestone that is mostly underwater. This sequence is better exposed during the dry season (late summer to fall).

Figure 10. Stratigraphic section of calcareous shale and cephalopod-bearing limestone. The top of the section is to the south.

STOP 9. Chert Block in Atoka Formation. Olistostrome or Thrust Slice?

Location: C SW/4 28/4N/18E, Higgins 7½' Quadrangle

Description of outcrop:

Several different rock types make up this outcrop, but all may be grouped under the general description of "chert." Exposed here are:

1. Light gray, very fine-grained sandstone or siltstone with long (up to 8 mm) white, straight, spicules(?). Uncommon.
2. Pinkish quartzite (only as float in creek on northeast side of outcrop. Extremely rare.
3. White to gray to reddish chert, very highly fractured and healed. Layers about 1 ft. thick with ½ in. to 3 in. internal stratification. Abundant.

Discussion:

This large (1,000 ft. by 800 ft.) block of chert is surrounded by Atoka Formation turbidites and, unlike the olistostrome at Stop 4, there are good outcrops of flysch in all directions. Very large sponge spicules are present in at least one place in the chert, but overall, the chert is unfossiliferous. Is this chert a foreland facies chert (e.g., Pinetop) or a deep-water chert (Arkansas Novaculite, Bigfork) from the south? Is it a block caught along a thrust fault that strikes northeast up the valley? Hendricks and others (1947) mapped several fault slivers of Pinetop Chert and Woodford Chert along the Pine Mountain fault system about 25 miles to the west, but most extend for 1 to 2 miles along strike. This outcrop seems to be a more or less equant block of chert. Is this big block another olistostrome within the Atoka? What is the relation of the chert to the limestone observed at Stop 8? Both lie in the same (fault?) valley but are of completely different character.

STOP 10. Atoka-Johns Valley contact, "Caney"(?) shale lithology and limestone concretions(?), north flank of syncline.

Location: NW/4 NW/4 35/4N/19E, Damon 7½' Quadrangle

From the intersection of Highways 1 and 2 about one-half mile back to here, the road is on Johns Valley Shale. Several small landslips have occurred in the oversteepened bank south of the highway. For some reason, the Johns Valley seems particularly prone to failure. More spectacular examples are on Highway 82, north of Talihina, where landslides in the Johns Valley have removed half the roadbed in two places.

Description of outcrop and discussion:

This shale is very atypical of the Johns Valley Shale as we will see at Stop 11. It is a hard, black shale, more reminiscent of a "Caney"-type lithology than anything else. If it is "Caney," then is this entire outcrop allochthonous? In this area, pieces of black shale similar to this outcrop are common as float in gullies in the Johns Valley; however, this is the only black shale outcrop this size that we have mapped so far. If this black shale is allochthonous, its attitude (EW40S) is about that of the overlying Atoka (N65E46SE, upright). There are several limestone "boulders" scattered throughout the shale; where they can be observed in place, stratification within the limestone is the same as the surrounding black shale. Are the limestones "exotic" in an "exotic" shale or are they diagenetic? Questions similar to these have plagued workers in the Ouachitas for over 50 years, and the "Caney-like" shale in the Johns Valley led Cline and most of his students to conclude that the Johns Valley and underlying Jackfork Group were Mississippian. The Johns Valley and Jackfork are now generally accepted to be Pennsylvanian.

The very basal Atoka here consists of several amalgamated sandstones up to about 25 ft. thick. At least one of the sandstones contains relatively abundant brachiopod fragments. Grooves in the base of one bed indicate a rotated current direction azimuth of about N85E-S85W. Beds above the lowermost Atoka are rippled Tbc sandstones with rare dish and pillar structures.

Stop 11. Atoka-Johns Valley Contact. Famous Hairpin Curve Locality, south flank of syncline

Location: NW/4 SE/4 3/3N/19E, Damon 7½' Quadrangle

This is the famous hairpin curve locality that was first visited on a field trip led by Tom Hendricks for the Tulsa Geological Society in 1947. Virtually every field trip that has driven through the frontal Ouachitas in this area has stopped here, and we will, too. Figure 11 is Tom Hendricks's measured section of the contact; we have not examined the contact in any additional detail.

Some features to note are the pebbly sandstone in the Johns Valley and flute molds in the Atoka. Current directions in this basal Atoka are east-northeast to west-southwest, compared to the west-to-east current directions in the basal Atoka at Stop 3. If we have time, we'll walk into the gully west of the curve and look at some (poor) flute molds in sandstones that are clearly in the Johns Valley. These indicate a north-to-south current direction, not surprising considering the general consensus on the origin of the exotic blocks in the Johns Valley, but never reported in the literature. (If you doubt a current direction based on these poor-quality flute molds, suffice it to say that we have measured north-to-south flute molds in sandstones in the Johns Valley elsewhere.) We plan to compare the composition of three suites of sandstone specimens. The three suites are defined by the transport direction that deposited them, east to west, west to east, and north to south.

Figure 11. Stop 14. Upper boulder bed of Johns Valley shale. Section of the Johns Valley shale and lower part of the Atoka formation on hairpin turn. S½ sec. 3, T. 3 N., R. 19 E., Latimer County, (see fig. 8). Measured in 1939 by T. A. Hendricks and Paul Averitt.

Atoka formation

	Feet
1. Alternating sandstone and shale. The shale is gray and fissile: the sandstone is gray, fine- to medium-grained, and well bedded and makes up about 40 per cent of the section	625
** 2. Sandstone, fine-grained, with some greenish gray siliceous shale laminae	1
** 3. Shale, siliceous, black well laminated, weathers to large blocks and small angular fragments	1½
4. Alternating sandstone and shale, similar to unit 1	150
5. Shale, gray	4
6. Sandstone, greenish gray, fine- to medium-grained, massive	3

Johns Valley shale

7. Sandstone and shale interbedded in beds two to four inches thick	3
* 8. Mudstone, gray to tan, weathers to some shaly structure, contains fairly abundant erratic boulders up to one foot in diameter	30
9. Shale, gray, clayey, weathers tan	8
10. Sandstone, gray to brown, fine-grained, lenticular	2
11. Shale, dark gray to black, well bedded, flaky, contains limonite bands, weathers gray to tan	12
12. Covered	10
* 13. Mudstone, with some irregular shaly bedding, gray, weathers tan to mustard colored. Contains abundant erratic boulders up to five feet in diameter in the lower part and smaller ones in the upper part. Elongate boulders lie at random angles to the general bedding	50
14. Sandstone and shale interbedded. Shale is gray to black and clayey; sandstone is fine-grained and light gray	18
* 15. Mudstone, with some shaly structure where weathered, tan to gray, contains abundant small erratic boulders (¼ inch to six inches in diameter). Elongate boulders lie at random angles to the general bedding	4½
16. Sandstone, chocolate-colored, massive, fine-grained	1½
17. Shale, gray, clayey, contains one-inch limonite bands, weathers gray to olive	?
18. Shale, black, soft, clayey, blocky where fresh, weathers flaky gray to tan	1
19. Sandstone, greenish gray, fine-grained, hard, irregularly laminated	2
20. Shale, gray, clayey, well bedded, nonfissile, contains limonite bands, weathers gray-green and tan and more deeply to a mustard color	20
* 21. Shale, weathered to tan clay and poorly exposed, small limestone boulders noted in place in one exposure. Forms landslide area on west side of road	150
* 22. Shale, intermittently exposed, gray, weathers tan, contains scattered limestone, chert, and shale boulders and some limonitic concretions	75
* 23. Shale, weathered to tan clay contains very abundant limestone boulders less than one inch to more than three feet in diameter. Some boulders are cemented together by sandy, clayey, limonitic material. The boulders are rounded to subrounded	6
24. Shale, dark gray, clayey, flaky, contains limonite bands and concretions, weathers tan to mustard-colored	25
25. Shale, deeply weathered to mustard-colored clay, appears to contain small erratic limestone boulders	50
26. Covered in fill at sharp bend in the road	200
27. Shale, dark gray with greenish tinge, evenly banded, very flaky, clayey, contains thin beds of limonite and sandstone similar to those below	65
28. Sandstone, gray, micaceous, fine-grained, alternating with dark gray clay shale containing limonite bands	7
* 29. Shale, dark gray, very clayey, weathers tan to mustard-colored. This zone contains scattered limestone boulders up to four feet in diameter, numerous limonitic concretions up to three feet in diameter, large erratic masses of Caney shale, and lenses of fine-grained, gray, micaceous sandstone. The largest mass of Caney shale measured 550 x 30 feet in continuous exposure. The bedding of the Caney shale is parallel to that of the Johns Valley shale and is undistorted, whereas, that of the Johns Valley shale is highly contorted.	100

Base of exposure near base of Johns Valley shale in fault contact with Jackfork sandstone to the south.

* Beds containing erratic boulders. There are six general zones in this section.

** This is the zone of siliceous shale and spiculite consistently present 100 to 200 feet above the base of the Atoka formation in the part of the area south of the Ti Valley fault. It is extremely valuable in mapping, as it enables one to distinguish the Atoka formation from the Jackfork sandstone in belts adjacent to Johns Valley shale. For a discussion of the boulder problem of the Johns Valley shale, see the article by Henry C. Rea.

REFERENCES CITED

Briggs, G., and Cline, L. M., 1967, Paleocurrents and source areas of Late Paleozoic sediments of the Ouachita Mountains, southeastern Oklahoma: Journal of Sedimentary Petrology, v. 37, p. 985-1,000.

Friedman, S. A., 1978, A field guidebook to Desmoinesian coal deposits in part of the Arkoma Basin, eastern Oklahoma: Oklahoma City Geological Society, 62 p.

Groves, J. R., and Grayson, R. C., Jr., 1984, Calcareous foraminifers and conodonts from the Wapanucka Formation (Lower-Middle Pennsylvanian), frontal Ouachita Mountains southeastern Oklahoma: Oklahoma Geological Survey Bulletin 136, p. 81-89.

Hendricks, T. A., 1937, The McAlester district, pt. 1 of Geology and fuel resources of the southern part of the Oklahoma coal field: U.S. Geological Survey Bull. 874-A, p. 1-90.

Hendricks, T. A., Gardner, L. S., Knechtel, M. M., and Averitt, P., 1947, Geology of the western part of the Ouachita Mountains of Oklahoma: U.S. Geological Survey Oil and Gas Investigations Preliminary Map 66, 3 sheets, scale 1:42,240.

Tulsa Geological Society, 1947, Guidebook: field conference in western part of the Ouachita Mountains in Oklahoma: Tulsa Geological Society, 56 p.

Walker, R. G., 1979, Turbidites and associated coarse clastic deposits, in: Facies models, Walker, R. G., editor, Geoscience Canada, p. 91-107.

Zachry, D. L., and Sutherland, P. K., 1984, Stratigraphy and depositional framework of the Atoka Formation (Pennsylvanian) Arkoma Basin of Arkansas and Oklahoma: Oklahoma Geological Survey Bulletin 136, p. 9-17.