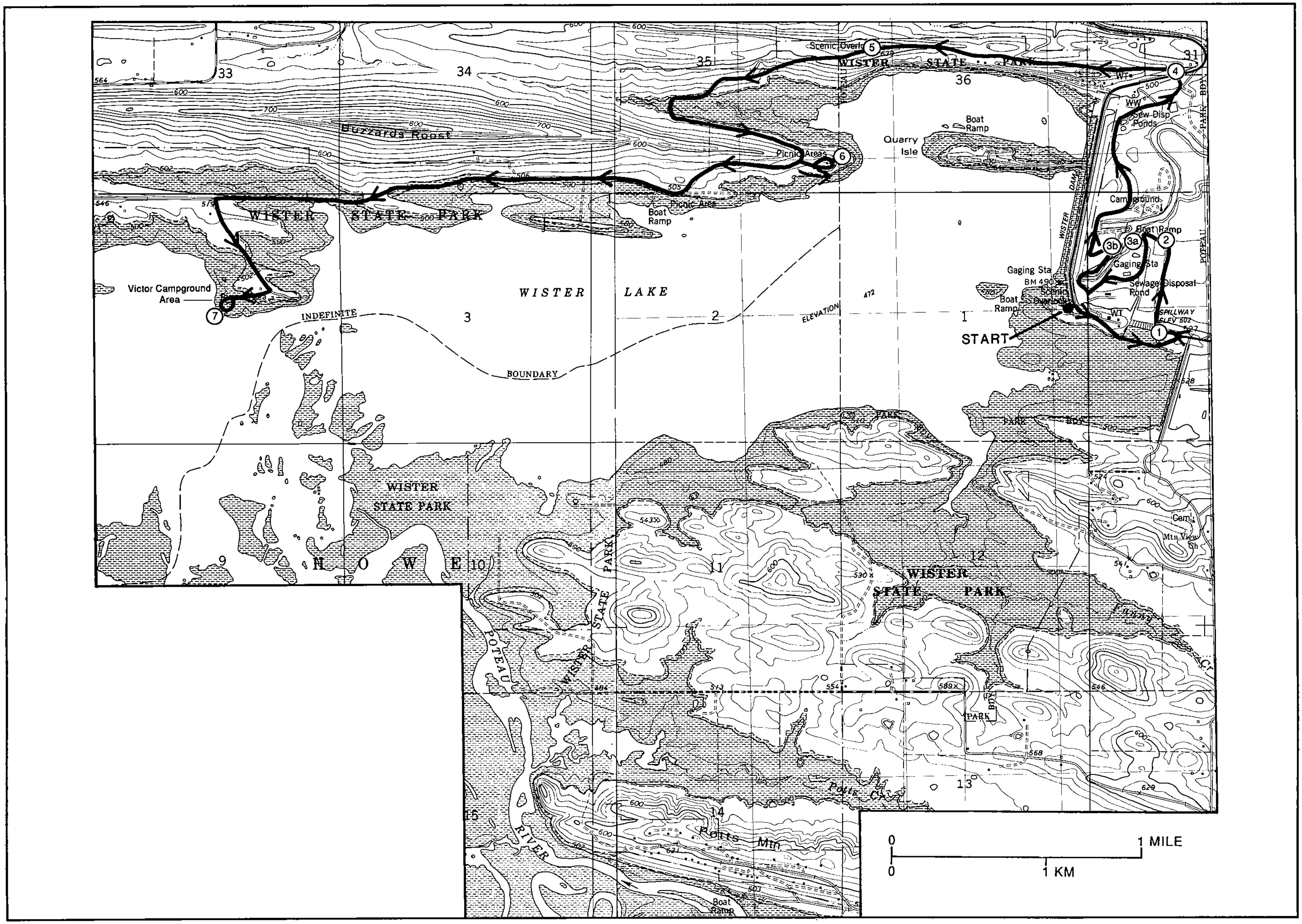
Oklahoma Geological Survey Guidebook 28

Geology of the Wister State Park Area, Le Flore County, Oklahoma

LeRoy A. Hemish



FIELD-TRIP ROUTE MAP, WISTER STATE PARK. (STOP NUMBERS IN CIRCLES.)

Oklahoma Geological Survey
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Guidebook 28

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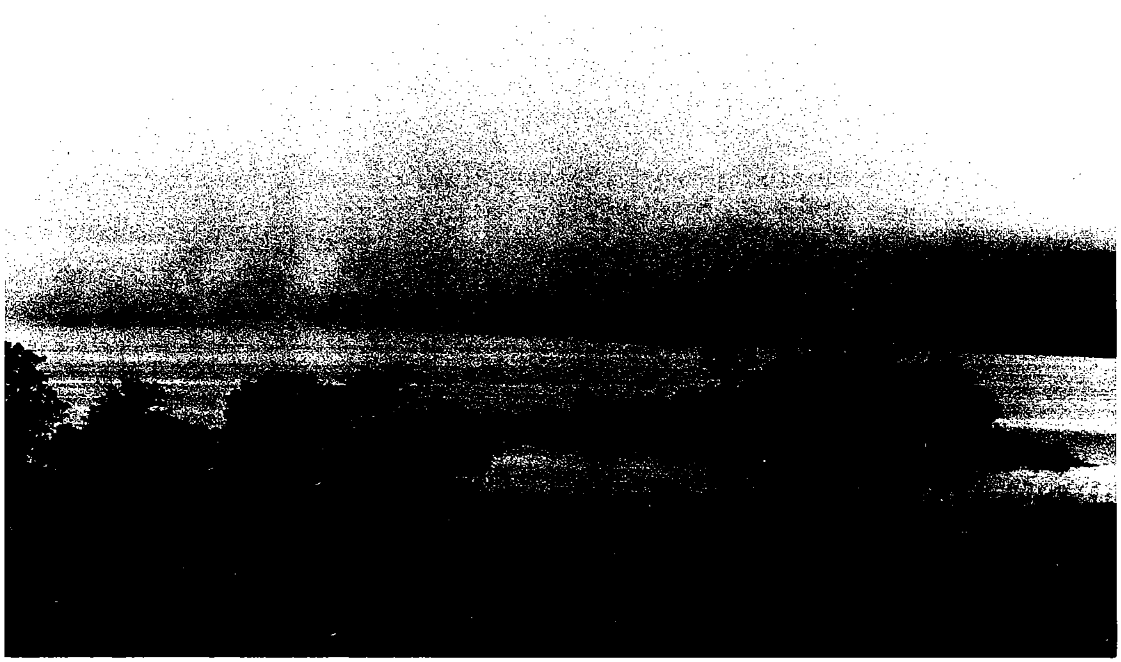

The University of Oklahoma
Norman

1993

Front Cover

Early morning mists rising from Wister Lake. View is to the northwest from scenic overlook at south end of Wister Dam.

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GEOLOGY OF THE WISTER STATE PARK AREA, LE FLORE COUNTY, OKLAHOMA

LeRoy A. Hemish

INTRODUCTION

The purpose of this guidebook is to acquaint the user with the diverse geology of Wister State Park. For those readers who have only an elementary knowledge of geology, a glossary has been included to explain the technical or unfamiliar geologic terms. Therefore, the guidebook should be of interest to amateurs and professionals alike. It is presented in a well-illustrated, easy-to-follow format.

The text contains an overview of the geologic setting, structural geology, and stratigraphy of the area. A detailed geologic map and a road log for a self-guided field trip are included. Eight stops, complete with measured sections, graphic columnar sections, and photographs give the reader the opportunity to examine most rock units present in the area, from oldest to youngest.

The guidebook and accompanying map (Pl. 1) were produced from new, detailed field mapping by the author at a scale of 1:24,000 in the Summerfield and Wister 7.5′ Quadrangles. The work was undertaken as part of the Oklahoma Geological Survey's ongoing cooperative geologic mapping project (COGEOMAP).

Thanks are extended to the personnel of Wister State Park for their cooperation. I am also grateful to the U.S. Army Corps of Engineers for their helpfulness and for the records they supplied.

Wister State Park is located ~2 mi south of Wister and ~10 mi southwest of Poteau on the Poteau River, Le Flore County (Fig. 1). The park is in the mountains of southeastern Oklahoma on U.S. Highway 270. The hilly area surrounding the 4,000-acre Wister Lake is heavily wooded, providing beautiful scenery for those who explore the park. Ridges generally rise ~100 ft or less above the level of the lake, but a high sandstone ridge known as Buzzards Roost rises 300 ft above the water just beyond the park boundary north of the Victor Campground Area. From a vantage point at the crest of Buzzards Roost, a spectacular view of the Ouachita Mountains to the south, the Sans Bois Mountains to the west, Cavanal Mountain to the north, and the mountains of Arkansas to the east makes the climb well worthwhile.

The principal accommodations of the park are all located around Wister Dam and along the north side of the lake. The southern part of the park is mostly undeveloped except for the Potts Creek boat ramp. Accommodations in the park include 15 wood cabins, one group camp, five different camping areas with 172 sites, children's playgrounds, and a restaurant. Facilities for picnicking, boating, fishing, swimming, hiking, and other activities are available.

Anyone desiring more information about the park can write to Wister State Park, Rt. 2, Box 6B, Wister, Oklahoma 74966, or phone (918) 655-7756.

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 on Wister Dam began in April 1946, and the dam was placed in full flood control operation in December of 1949.

Wister Lake provides flood protection in the valley of the Poteau River below the dam as well as along the Arkansas River. The total project includes a 5,700-ft-long, 99-ft-high embankment (Wister Dam), an earth dike 2,400 ft in length, and a 600-ft-long uncontrolled concrete chute-type spillway located between the dike and the embankment. Six vertical lift gates regulate flood control releases through the outlet works.

The conservation pool elevation is 472 ft above sea level (1 Dec. to 1 June). The 4,000-acre lake stores 27,100 acre-ft of water and has a shoreline of 115 mi.

The flood control pool elevation is 509.5 ft above sea level. There are 400,800 acre-ft of floodwater storage with a surface area of 23,070 acres. The drainage area consists of 993 mi^2 of the Poteau River watershed. (The project data above were provided by the U.S. Army Corps of Engineers, Tulsa District.)

GEOLOGIC SETTING

Wister State Park is in the northern part of the Ouachita Province (Fairbridge, 1968, p. 758). The topography consists of a series of structurally controlled, parallel ridges separated by broad, flat valleys. Both ridges and valleys follow the east–west trend of the dominant structural feature in the area—the Heavener anticline (Pl. 1).

The park is near the southern edge of the Arkoma basin, a tectonic province just north of the Choctaw fault (Fig. 2). The Choctaw fault separates the Arkoma basin from the Ouachita Mountains, visible from most vantage points within the park.

Elevations above sea level in the park range from 440 ft (below the dam) to ~640 ft at the scenic overlook north of the lake, and at the tops of ridges south of the lake. The height of topographic features is related to the dip, hardness, and thickness of the supporting rock layers. The thicker, more resistant strata form the ridges, and the shales form the valleys.

Streams selectively follow the softer, more easily eroded shales. In some places streams cut through the ridges along zones of weakness in the rocks caused by faulting (movement along fractures).

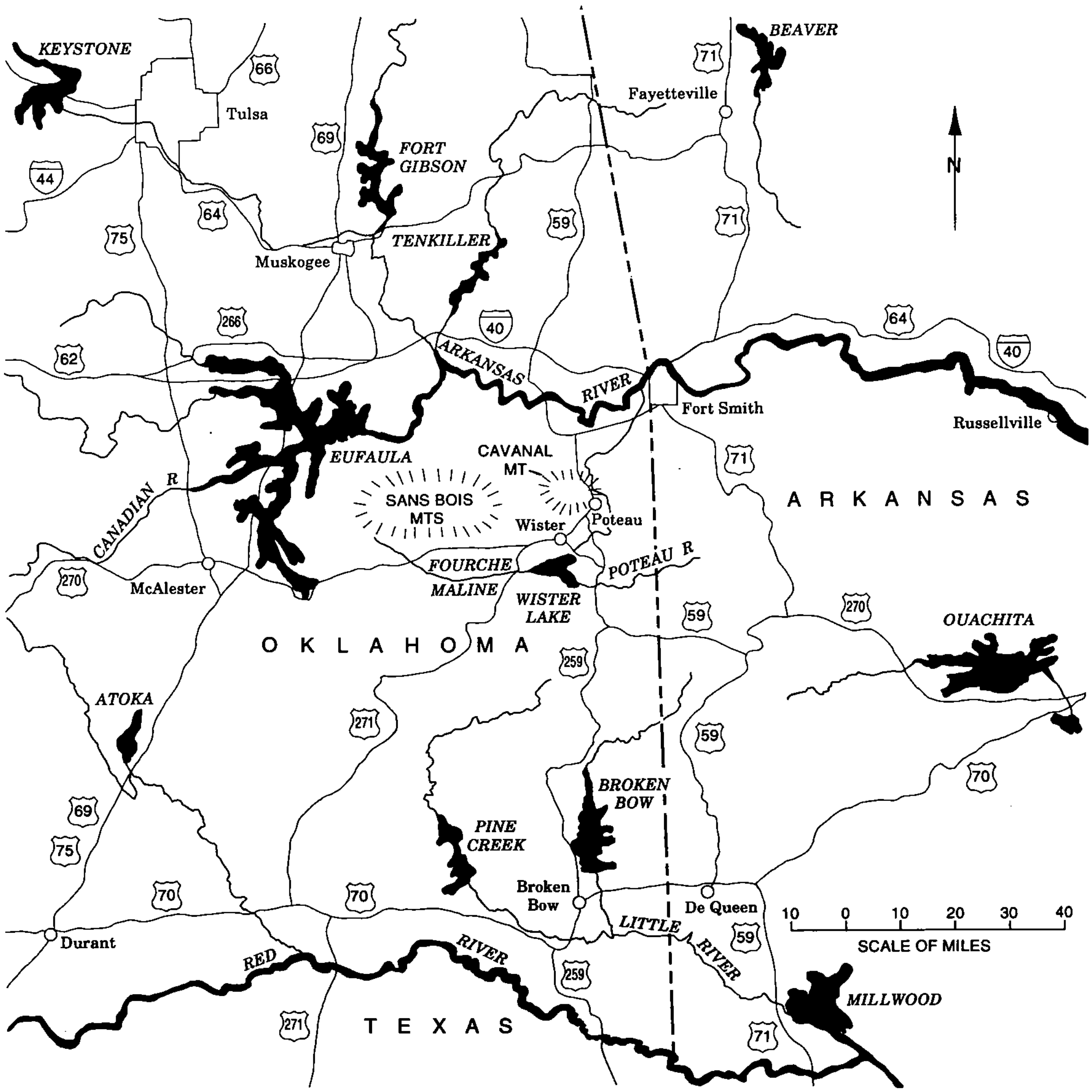

Figure 1. Map showing location of Wister Lake in southeastern Oklahoma. From U.S. Army Corps of Engineers brochure.

The Poteau River flows westward, parallel to the resistant ridge that forms Potts Mountain, then turns and enters the park from the south, cutting across several ridges that have been weakened by what has been interpreted as a zone of tear faults. The river channel (now under Wister Lake) was deflected eastward (once again parallel to the ridges) in the vicinity of Quarry Isle by a thick, resistant sandstone ridge.

In addition to the topography formed by erosion of bedrock units, other features are present within the park. Flat-topped surfaces, generally about 20–40 ft above the lake level, are remnants of terraces, which mark the former level of flood plains of older streams. Victor Campground Area is built on such a terrace. The flood plains of the Poteau River and Fourche Maline are now mostly covered by waters of Wister Lake, but flood plains of smaller streams are present in tributary valleys. The campground below Wister Dam is built on the flood plain of the Poteau River.

Wister Dam was constructed across the valley of the Poteau River. Figure 3 is a cross section showing the profile of the river valley prior to construction of the dam. About 30 ft of Quaternary alluvium is present in the vicinity of the dam according to drill-hole information from the U.S. Army Corps of Engineers, Tulsa District. Thickness of the valley fill varies and is as much as 40 ft thick (Drill Hole 41) in a levee deposit overlying a bedrock high. The valley-fill deposits consist mainly of unconsolidated sandy, clayey silt containing thin lenses of fine sand, with a mixture of clayey sand, and occasional deposits of sand and gravel ≥2 ft thick immediately overlying bedrock.

The bedrock consists of moderately hard, silty shale with interbedded thin sandstone layers and occasional thicker sandstone beds. The Quaternary valley-fill deposits rest with angular unconformity on Pennsylvanian age (~300 million years old) bedrock units that strike N.85°W. and are inclined to the north.

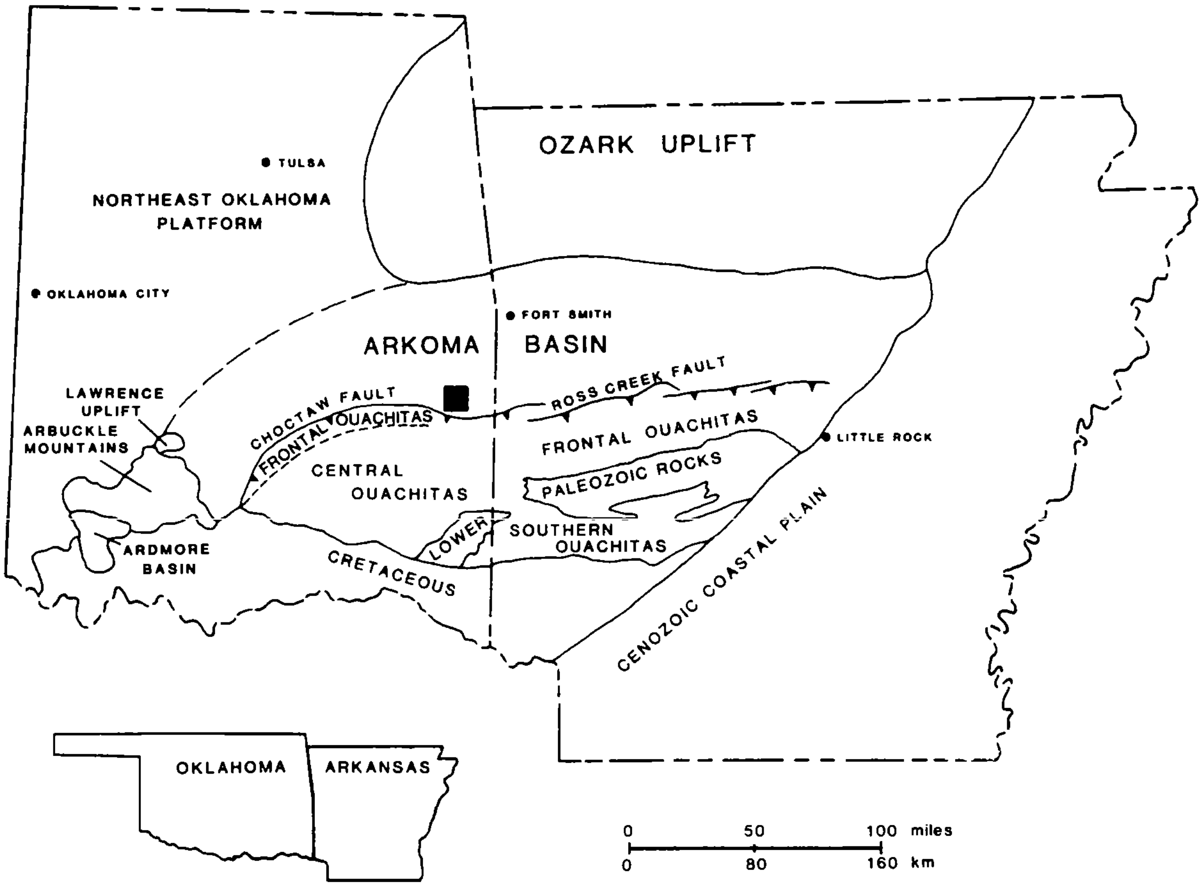

Figure 2. Arkoma basin of Oklahoma and Arkansas, and surrounding geologic provinces. Location of Wister State Park shown by black square. From Sutherland (1989, fig. 12).

STRUCTURAL GEOLOGY

Structural geology deals with the features produced in the rocks by movements after deposition, and commonly after consolidation, of the rocks. Rocks that were originally deposited horizontally have been deformed by faulting or folding to an inclined or tilted position. All bedrock units within the park have been deformed. The most prominent structural feature within the park is the Heavener anticline (Pl. 1), an upfold that trends westerly across the area and extends well beyond the park boundaries. Dip (the angle at which a rock layer is inclined from the horizontal) decreases from the anticlinal crest (where dip values may be vertical, or even overturned) to the south toward the axis of the Pine Mountain syncline (off map). Dip readings taken on sandstones on Potts Mountain near the south edge of the park are mostly to the southwest in the 20–30° range. Dip readings on the sandstone ridges at the north side of the park, on the opposite flank of the anticline, have similar values, but here the rocks tilt to the north. Wister Dam is located on the northern flank of the Heavener anticline in an area where the formations have a northward dip averaging ~25°. The shales in the vicinity of the dam are extensively jointed (fractured). Measurements indicate that the more pronounced joints trend N.82°W., N.52°W., and N.75°E., and dip steeply (55–85°) to the SW, SW, and NW respectively. These joint planes are approximately normal to the dam axis (U.S. Army Corps of Engineers, 1949).

The Heavener anticline is broken on both flanks by numerous tear faults. These faults can be mapped in the field by an abrupt change in the attitude of the rocks. In most cases an actual fault cannot be observed, but the traces of the faults can be estimated by aligning saddles in ridges, drainage patterns, water gaps, direction of drag on the rocks, and deformation of strata in the vicinity of the fault. Offset can rarely be determined but is probably not much more than 10–15 ft in most cases.

Deformation of the strata in the park was caused by compressional forces related to the Ouachita Mountains orogeny. During the Late Pennsylvanian, the Earth's crust was broken and thrust to the north to form the Ouachita range. The Ouachitas are a structurally complex area characterized by imbricate thrust faults and steeply dipping to overturned strata. The Choctaw fault is the major thrust fault nearest to the park area. It is located ~7 mi south of Wister Dam and marks the boundary between the structurally complex frontal Ouachitas and the more broad, open folds of the Arkoma basin (Fig. 2). The ridge and valley topography in the Arkoma basin (and the park area) results

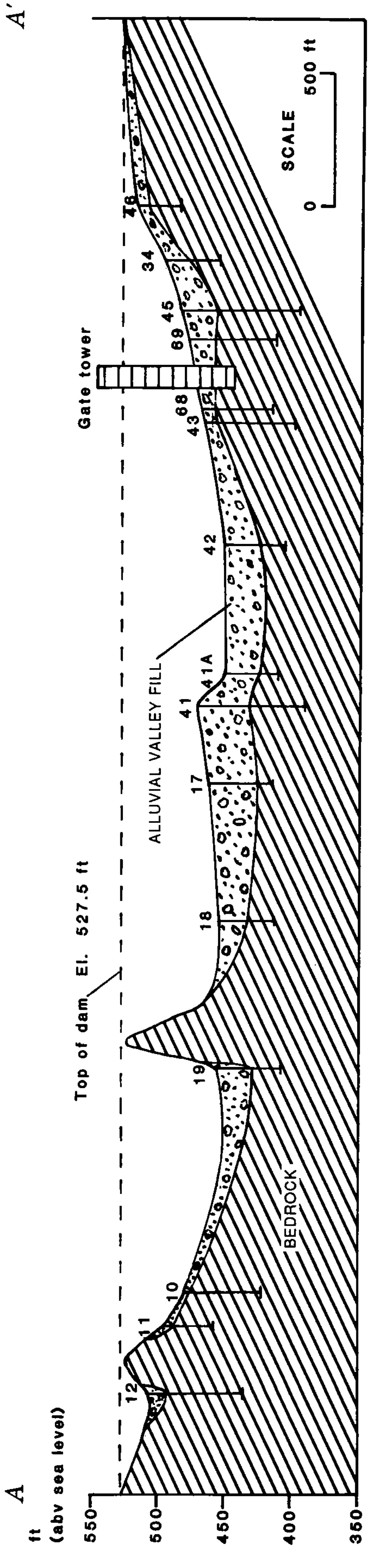

Figure 3. Preconstruction profile of the Poteau River Valley along the axis of Wister Dam showing thickness of Quaternary valley fill, and angular unconformity at erosional contact with Pennsylvanian bedrock formations (undifferentiated). Numbers (10,11,12, etc.) correspond to U.S. Army Corps of Engineers, Tulsa District, drill-hole logs. Line of cross section (A–A') shown in Plate 1.

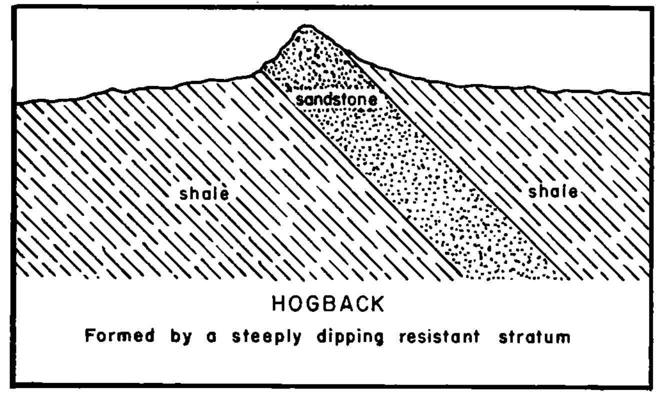

Figure 4. Diagram of a hogback. From Russell (1958, fig. 5).

from folding of the rocks and subsequent erosion. Figure 4 is a diagram showing a sharp ridge (called a hogback) that is typical of those found in the park. A hogback is a long, narrow, sharp-crested ridge formed by the outcropping edges of steeply inclined or highly tilted resistant rocks that dip at angles >20°.

Figure 5 diagrammatically illustrates typical structural features found in the Arkoma basin. In general, the topography of the Arkoma basin is an inverse reflection of the underlying structure of the strata. The upland areas (mountains) of the surface are underlain by downfolds (synclines) of strata in the subsurface, and the lower areas (valleys) of the surface are underlain by upfolds (anticlines) of strata in the subsurface (Russell, 1958). Cavanal Mountain, visible to the north of Wister State Park, is an example of a synclinal mountain. The strata on the flanks of this topographically high feature dip toward the axis of the Cavanal syncline which trends through the crest of the mountain.

STRATIGRAPHY

The rocks that crop out in Wister State Park were formed during the early part of the Pennsylvanian Period. These rocks have been assigned to three different formations for mapping purposes (Pl. 1). The oldest rocks are part of the Atokan Series (Pa, Pass). Next in succession are rock layers overlying the Atoka Formation. These strata are part of the Desmoinesian Series and include the Hartshorne Formation (Ph) and the McAlester Formation (Pm). Detailed descriptions of the formations are given in Plate 1. The rocks in the park are estimated to be ~300 million years old.

All exposed rocks in Wister State Park are sedimentary. They were deposited in layers, often referred to as strata. Sedimentary rocks are divided into two types: clastic and nonclastic. Almost all the rocks in the park are clastic. They are composed of particles derived from older or preexisting rocks that were broken into smaller pieces by processes of weathering, and then carried away (eroded) by wind and water to lower areas where they were deposited.

The depositional environment of the clastic rocks found in the park area has been interpreted as deltaic.

Figure 6 is a diagram showing typical sequences found in modern deltas, settings believed analogous to Pennsylvanian deltas. Specific reference is made to the sequences shown in Figure 6 in the various stop descriptions in the included road log.

The different kinds of clastic sedimentary rocks in the three formations found in the park are as follows:

Sandstone.—Rock composed of sand grains (primarily quartz) generally cemented together by iron oxide or silica. The size (very fine- to fine-grained), sorting, and roundness of the grains suggest transport over a considerable distance. Colors are generally shades of brown and red and depend on cementing material and impurities contained.

Siltstone.—Similar to sandstone except that individual grains are smaller and are mixed with more im-

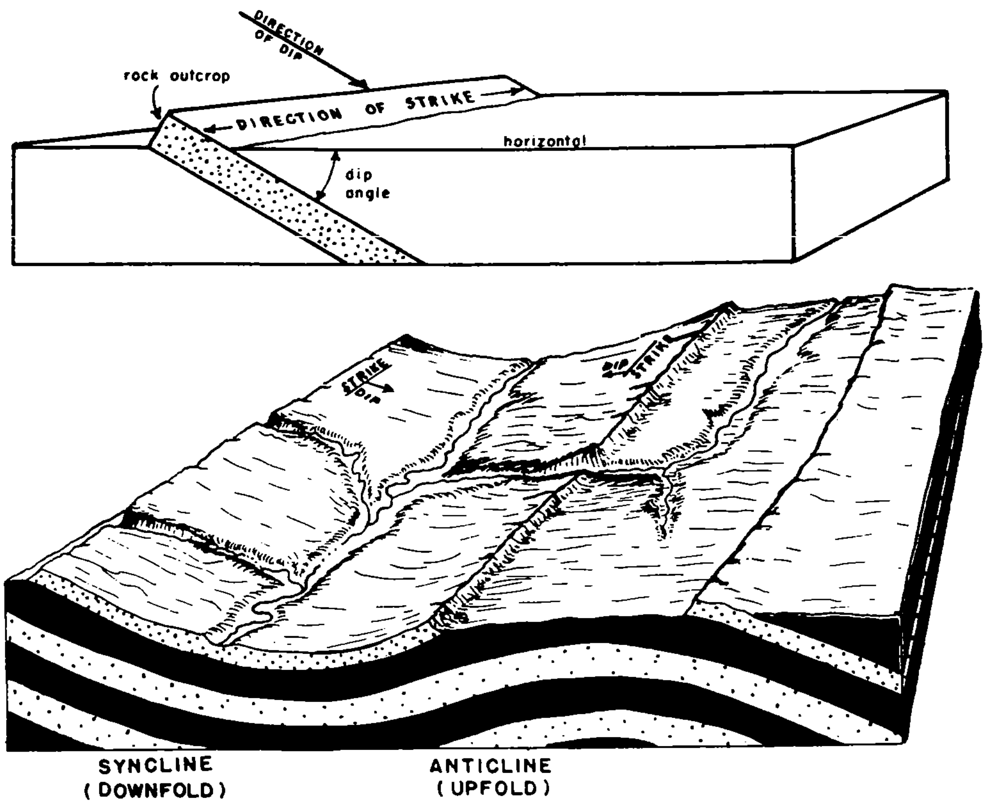

Figure 5. Block diagram of structural features. From Russell (1958, fig. 6).

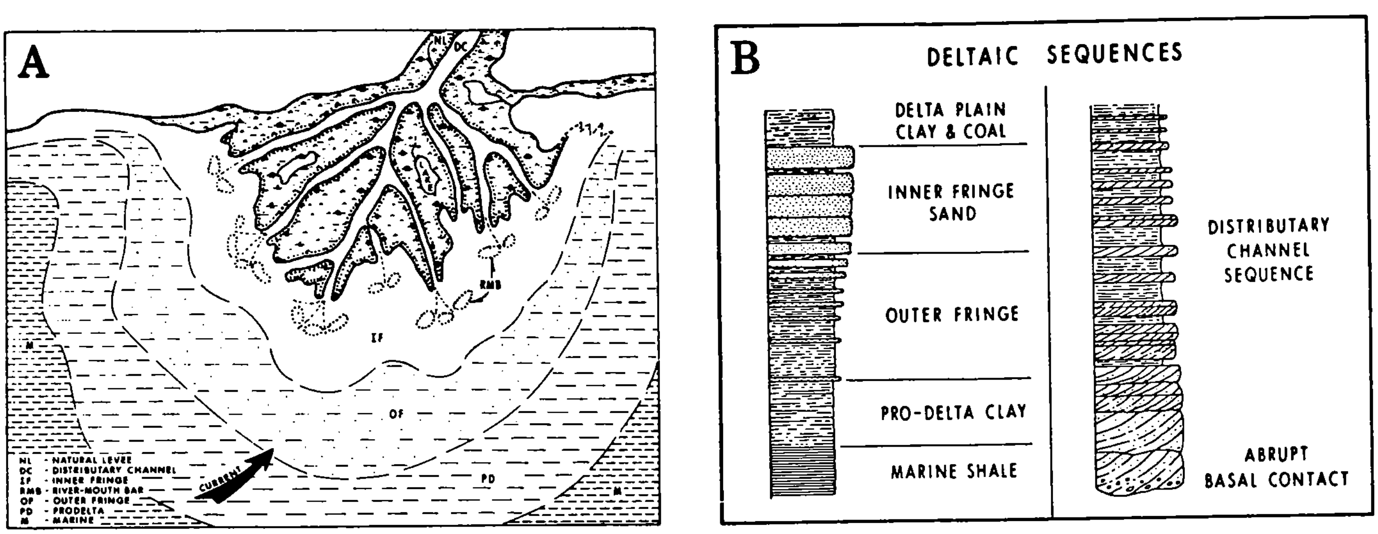

Figure 6. *A*—Depositional environments and sequences typical of modern deltas used as model for interpreting sequences seen in Wister State Park area. From Le Blanc (1977, fig. 11). *B*—Typical sequences of deltaic deposits. From Stone and others (1979, fig. 52B).

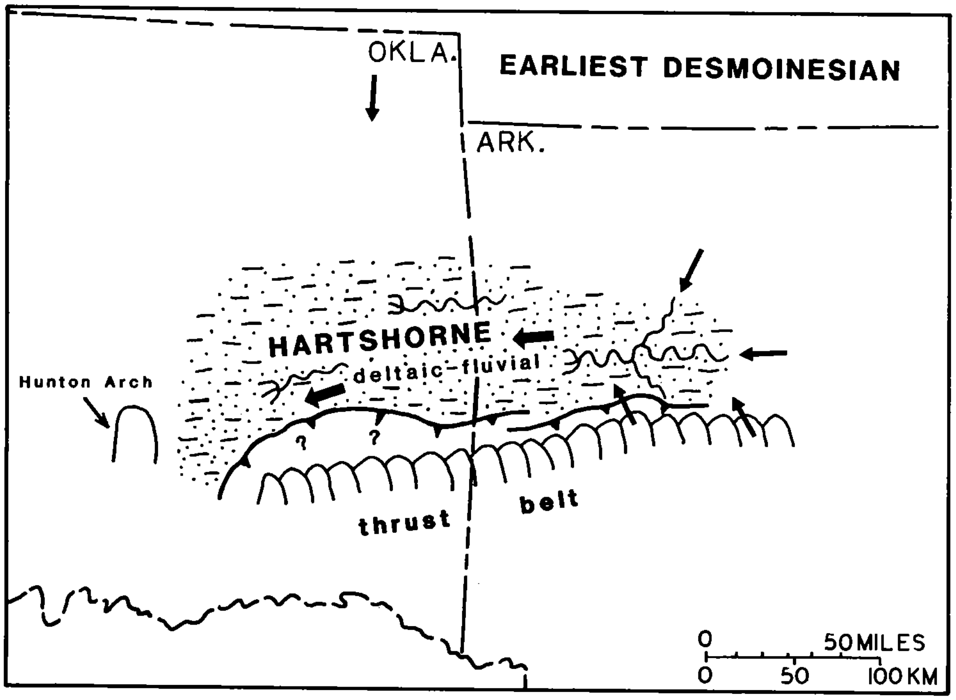

Figure 7. Earliest Desmoinesian paleogeographic map. From Sutherland (1989, fig. 21) and after Houseknecht and others (1983).

purities such as mud and clay. The colors range from olive-grays to brown.

Shale.—Composed of thinly stratified, compacted muds and clays. A shale may include minor amounts of sand grains. Ironstone concretions are common in many of the shales. The color of the shales ranges from gray to olive to black.

Interstratification of the various rock types is common and typical for certain deltaic sequences (Fig. 6).

Deposition of the sediments occurred in shallow coastal waters at a time when the Arkoma basin was sinking. Landscapes were barely above sea level. The presence of coal beds, fossil plant impressions, and disintegrated plant material in the rocks leads us to believe that abundant vegetation flourished in a warm and humid climate at that time.

The source areas for the Pennsylvanian sediments found in the park were highlands to the east and north. Paleocurrent readings by the author and other researchers (Houseknecht and others, 1983; Ferguson and Suneson, 1988) indicate that sediments of the Atoka and Hartshorne Formations were derived from erosion of the Appalachian highlands, and channeled westward through the Black Warrior and Illinois basins. The Hartshorne Sandstone was deposited in tidally influenced deltaic systems (Fig. 7) that prograded from east to west, coinciding approximately with the present-day axis of the Arkoma basin (Sutherland, 1989, p. 34).

By the time of deposition of the McAlester Formation, the source direction was from the platform area to the north (Fig. 2). The depositional pattern was nonmarine to deltaic with rapid deposition of clastics into the subsiding Arkoma basin (Sutherland, 1989, p. 34).

During the Late Pennsylvanian Period the strata that had been deposited in horizontal layers were folded and tilted to their present position. The processes of weathering and erosion have been at work ever since and are still gradually wearing down the hills, particle by particle. Streams are carrying the particles to a new resting place. Many of the particles will be deposited on the bottom of Wister Lake, while others may be deposited as far away as the Gulf of Mexico.

The following section includes the road log for a geologic field trip (Fig. 8). The trip not only acquaints the reader with the stratigraphy and structural geology of the park, but also provides a means for viewing its spectacular scenery. The excursion begins at the dam, and the first three stops are organized to give the reader a view of the components of the Wister Dam project. At each stop interesting geologic exposures created during construction of the dam can be examined.

The trip covers 9 mi, all on hard-surfaced roads, and should take about one-half day. Those wishing to examine the rocks in detail, or to take exploratory side excursions on foot, will find that it may take considerably longer.

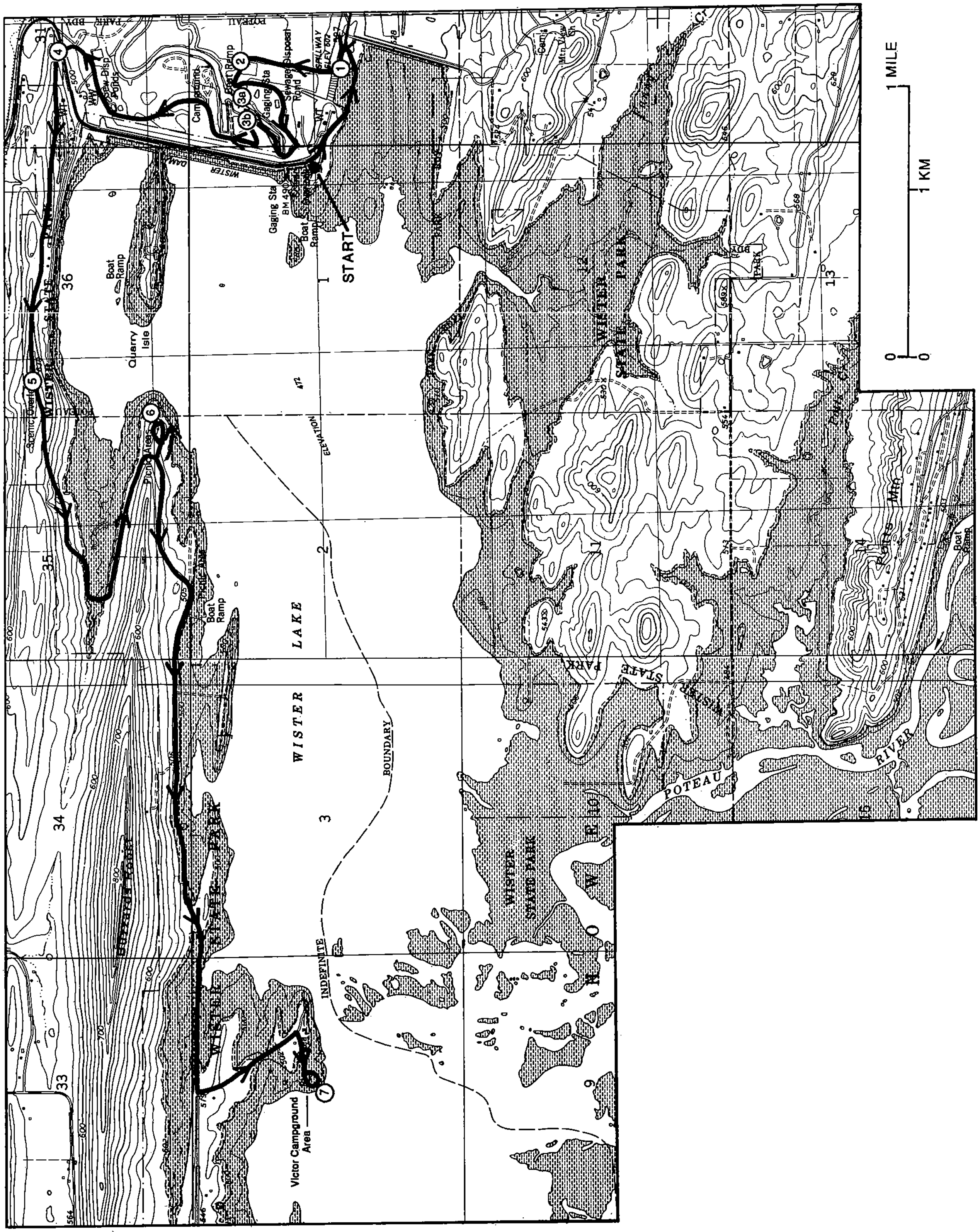

Figure 8. Field-trip route map, Wister State Park. (Stop numbers in circles.)

ROAD LOG AND STOP DESCRIPTIONS

Start trip in parking lot of scenic overlook at south end of Wister Dam. Points of interest from this vantage point include:

1) A small island, ~0.25 mi west of parking lot, which is a remnant of the second youngest, resistant, ridge-forming sandstone of the Atoka Formation (cover photo).

2) The ridge jutting westward from the dam, ~0.5 mi north of parking lot. This is Quarry Isle, site of the park headquarters. The ridge is formed by the resistant sandstones of the Hartshorne Formation.

3) Wister ridge, ~1 mi northwest of the parking lot. It is separated from Quarry Isle by waters of Wister Lake. The crest of this ridge also is formed by the Hartshorne Sandstone.

4) The high ridge north of Quarry Isle and Wister ridge. The ridge is formed by the Warner Sandstone Member of the McAlester Formation.

5) A series of ridges formed by resistant sandstones of the Atoka Formation that lie to the south and west of the parking lot. These include the oldest rocks exposed within the park boundaries.

MILES
(cumulative)

0.0 Overlook parking lot.

Turn right on U.S. Highway 270 and drive due east. The dam's 600-ft-wide spillway is to the left, and ahead to the right is a 2,400-ft-long, 40-ft-high dike. Riprap material is local sandstone.

0.5 Turn sharply left at U.S. Army Corps of Engineers "Lake Wister" sign and drive to parking area by guard rails at east side of spillway.

0.6 **STOP 1**

Observe the concrete spillway and the spectacular exposures of shales and siltstones of the Atoka Formation in the man-made channel extending due north below the spillway (Fig. 9). Next examine the exposure of Atoka Formation in the east spillway cut south of the overlook (Figs. 10,11). These are typical shallow marine, outer fringe, deltaic sequences (see Fig. 6). The outcrop is described in detail in Measured Section 1.

Figure 9. Slabby shales and siltstones in upper part of Atoka Formation dipping steeply to the north (26°). High-energy flood-waters passing through the spillway prevent growth of vegetation and maintain the rubbly appearance of the exposure. Ripple-marked surfaces are well exposed on some slabs and can be seen from the road east of the spillway. (Stop 1.)

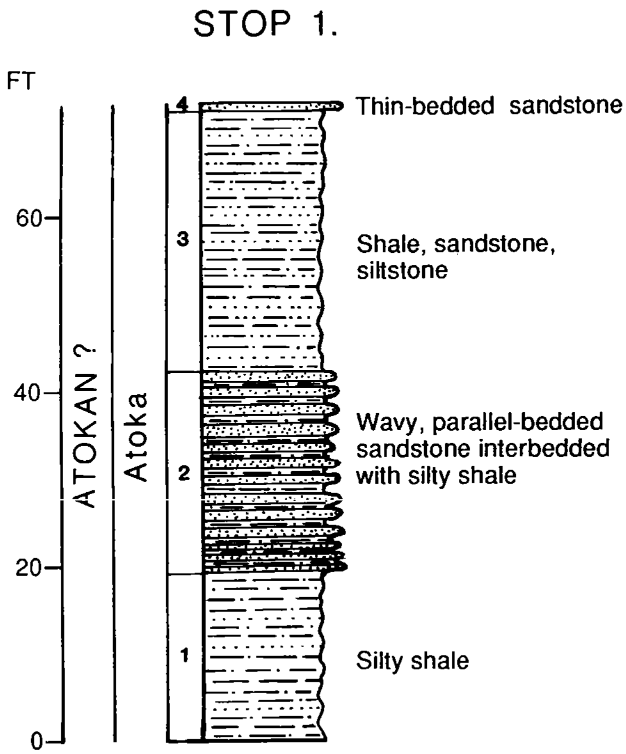

Figure 10. Graphic columnar section for Stop 1.

Measured Section 1

SW¼NW¼NE¼SW¼ sec. 6, T. 5 N., R. 25 E., Le Flore County. Measured from top of sandstone exposed in small gully just south of spillway overlook to small cedar tree ~165 ft north of U.S. Highway 270.

	Thickness (ft)
ATOKA FORMATION:	
4. Sandstone, light-brown (5YR 5/6)[1] to moderate-brown (5YR 4/4), very fine-grained, noncalcareous, porous; impure, with abundant clay-alteration products; thin-bedded, cross-bedded; surface ripple-marked	0.8
3. Shale, light-brown (5YR 5/6), interbedded with light-gray (N 8), grayish-orange (10YR 7/4) and light-brown (5YR 5/6), very fine-grained sandstone and siltstone, thin to very thin-bedded; wavy, parallel-bedded; noncalcareous, surfaces ripple-marked, weakly to moderately bioturbated; weathers to small, broken fragments on the outcrop	29.9

[1]Classifications used in Munsell color system (Rock-Color Chart Committee, 1991).

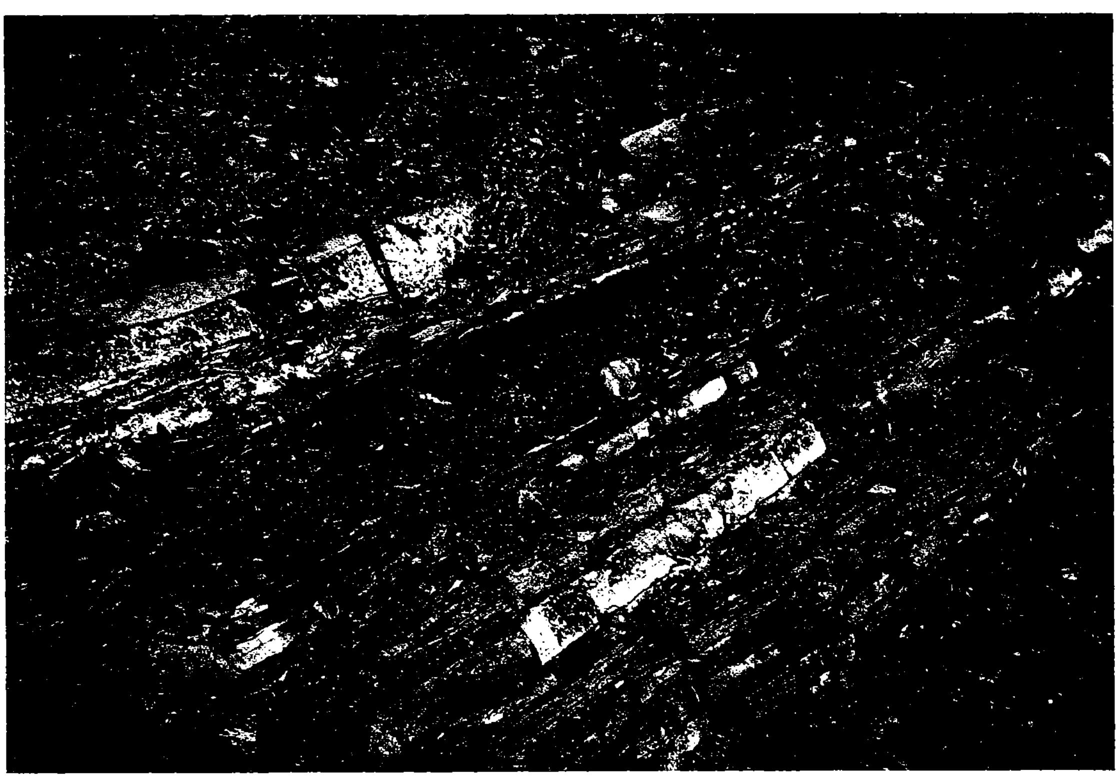

Figure 11. Wavy, parallel, thin to medium beds of sandstone interbedded with silty shale, with transition into shale at base (right) and top (left). (Stop 1.)

2. Sandstone, light-brown (5YR 5/6), moderate-brown (5YR 4/4, 5YR 3/4), and very pale-orange (10YR 8/2), rhythmically alternating with dusky-yellowish-brown (10YR 2/2) silty shale that weathers light-brown (5YR 6/4, 5YR 5/6); sandstone beds are generally about 8–15 in. thick, thin- to medium-bedded; wavy, parallel-bedded; surfaces marked with interference ripples; trace fossils on some surfaces; base gradational 22.1
1. Shale, very pale-orange (10YR 8/2) to light-brown (10YR 5/6) to brownish-gray (5YR 4/1), silty, noncalcareous, fissile; includes some moderate-brown (5YR 4/4), very fine-grained, bioturbated sandstone beds; base covered ... 19.5

Total thickness of section 72.3

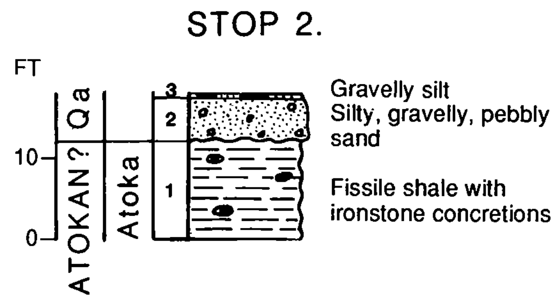

Figure 12. Graphic columnar section for Stop 2.

Return to vehicle and proceed north down gravel road on east side of spillway cut. Note the steeply dipping flat-bedded rocks and ripple-marked surfaces on some slabs at upper end of channel. Continue to gate at lower end of cut.

1.0 **STOP 2**

Parking area available just north of gate. Observe the unconformable contact (Figs. 12,13) between the Quaternary alluvial deposits and the Pennsylvanian shales described below. Approximately 300 million years of time elapsed between deposition of the two stratigraphic units. Tilting (folding) of the rocks of the Atoka Formation occurred about 280 million years ago in association with the Ouachita Mountains orogeny. The outcrop is described in Measured Section 2.

Measured Section 2

SE¼SW¼NE¼NW¼ sec. 6, T. 5 N., R. 25 E., Le Flore County. Measured in cut at northeast end of spillway, just inside hairpin turn where gated road crosses spillway.

Thickness (ft)

Quaternary alluvium:

3. Silt, moderate-yellowish-brown (10YR 5/4), gravelly, noncalcareous; contains subrounded to subangular sand-

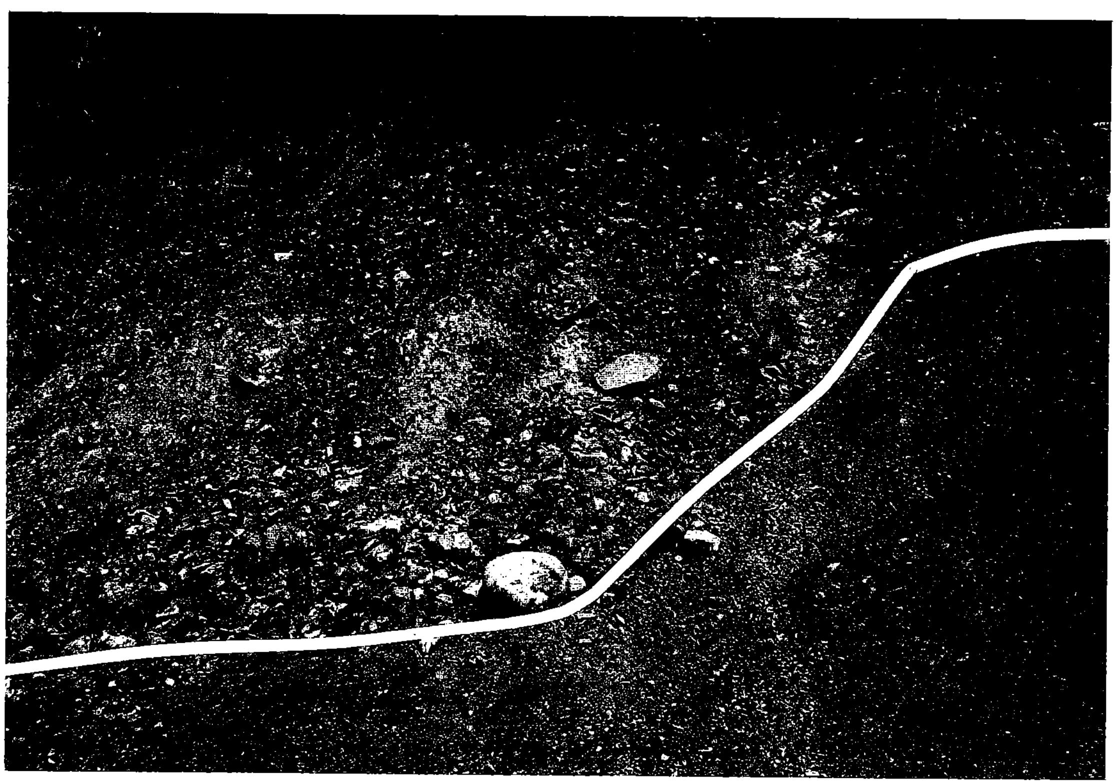

Figure 13. Angular unconformity between steeply dipping Atoka shales (below) and flat-lying Quaternary alluvial deposits (above). White line marks unconformity and defines the edge of an incised channel. (Stop 2.)

Figure 14. Black, slabby shales of the Atoka Formation dipping 23° north in lower part of spillway.

stone pebbles and small cobbles; base sharp 0.5

2. Sand, dark-yellowish-orange (10YR 6/6) with very light-gray (N 8), silt-filled desiccation cracks; very fine-grained, silty, noncalcareous; contains scattered, subrounded clasts of sandstone in the gravel- to pebble-size range; base sharp, with angular unconformity 5.5

ATOKA FORMATION:

1. Shale, grayish-black (N 2), weathers light-brown (5YR 5/6), noncalcareous, fissile, flaky; contains dark-reddish-brown (5YR 3/4) to dark-yellowish-orange (10YR 6/6) ironstone concretions up to 3 in. thick and 18 in. in diameter (to base of slope 12.0

Total thickness of section 18.0

Return to vehicle and drive due west across spillway channel to paved parking area east of discharge channel. Black shales of the Atoka Formation are exposed in the spillway channel (Fig. 14).

1.1 **STOP 3a**

Walk due southwest from parking lot to area of bedrock exposures (Figs. 15–17) south of riprap and observe rocks described in Measured Section 3, interpreted as low-energy, deltaic-marine outer fringe beds (see Fig. 6).

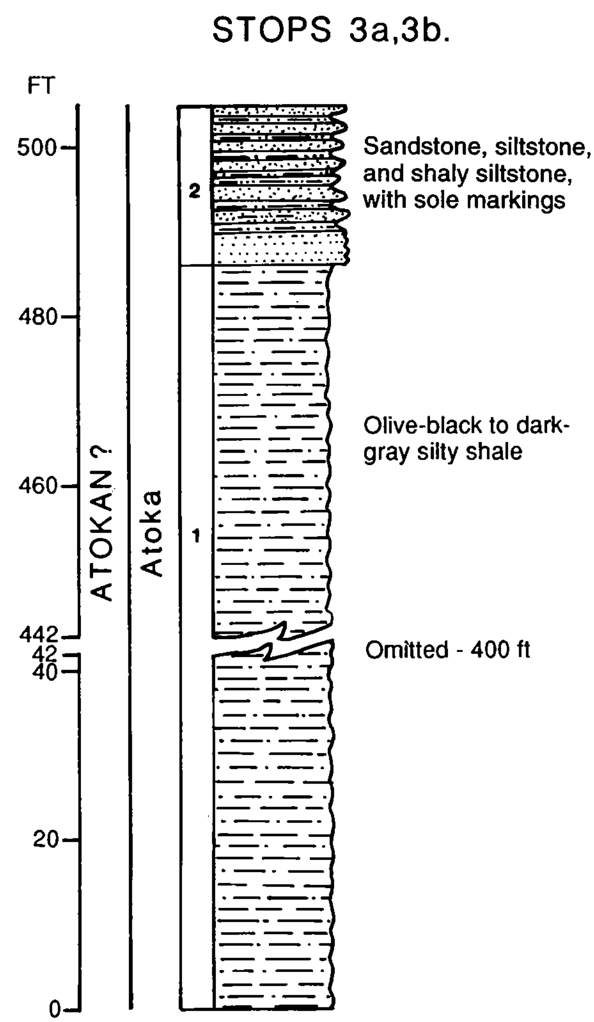

Figure 15. Graphic columnar section for Stops 3a and 3b.

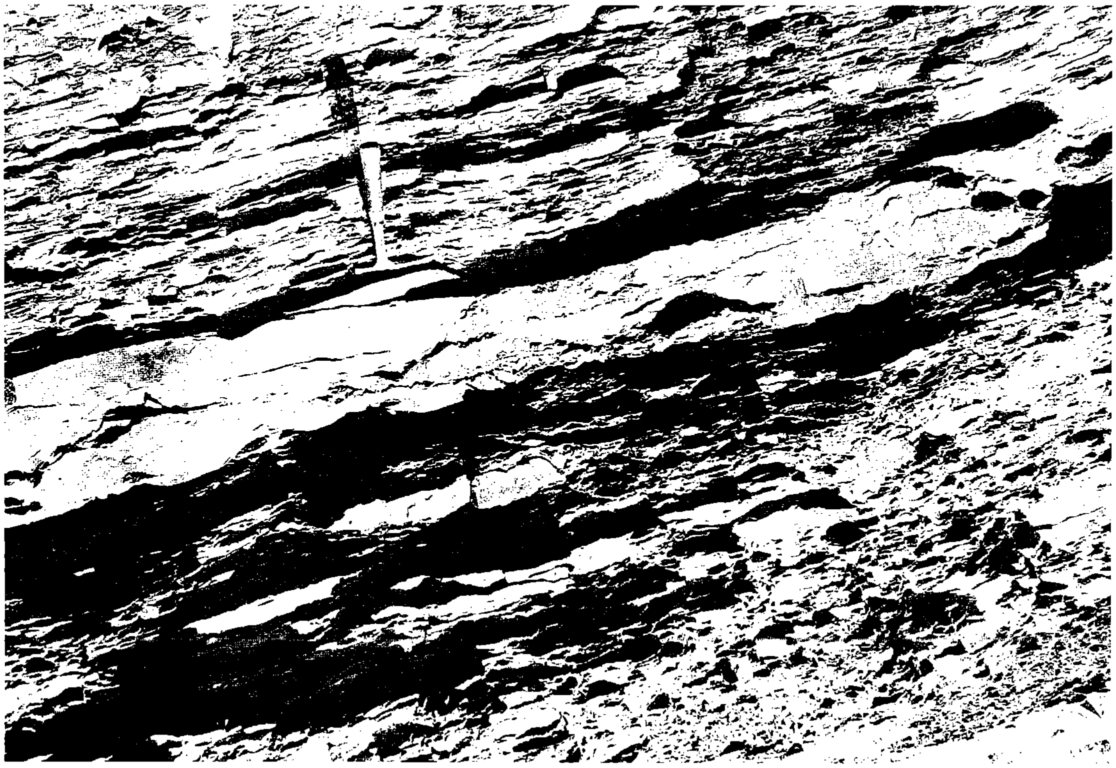

Figure 16. Close-up of wavy, thin-to medium-bedded sandstone interbedded with siltstone and shaly siltstone, with ripple-marked surfaces and abundant sole markings. (Stop 3a.)

Figure 17. Sole markings are common on Atoka Formation sandstones and siltstones. Bulbous load casts on bottom slab; load casts, prod marks, and organic markings on bottom of upper slab. Gar for scale. (Stop 3a.)

Measured Section 3

NW¼SW¼NW¼ sec. 6, T. 5 N., R. 25 E., Le Flore County. Measured from area covered by riprap just west of parking lot, southwest to east end of concrete discharge chute below dam.

	Thickness (ft)
ATOKA FORMATION:	
2. Sandstone, siltstone, and shaly siltstone, interbedded; light-olive-gray (5YR 5/2), to olive-gray (5YR 4/1), weathers dusky-red (5YR 3/4), to dusky-yellowish-brown (10YR 2/2); some sandstone and siltstone beds are very fine-grained, medium-bedded, and occur in layers ~1 ft thick that have abundant sole markings such as bulbous load casts, grooves, brush and prod marks, and trace fossils; unit is mostly thin-bedded, with wavy, parallel bedding; surface of beds ripple-marked, upper 3 ft weathers to small, blocky, angular fragments and is moderately bioturbated; lower part of unit is fissile, noncalcareous, and contains rare plant impressions ...	18.4
1. Shale, olive-black (5YR 2/1) to dark-gray (N 3), weathers moderate-brown (5YR 3/4, 5YR 4/4), silty, micaceous, noncalcareous, fissile, brittle; exhibits concretionary structure; monotonous sequence exposed on both sides of discharge channel ...	486.0
Total thickness of section ...	504.4

Return to vehicle and drive due south on blacktop road on west side of spillway cut. U.S. Army Corps of Engineers Project Office to the left.

1.5 Turn right at yield sign onto blacktop road and cross discharge outlet.

1.6 Turn right into Wister State Park campground and proceed to parking lot near restrooms.

1.8 **STOP 3b**

(Refer to Measured Section 3.)

Walk along guard rail toward dam and observe steeply dipping, monotonous sequence of dark marine shales of the Atoka Formation (Fig. 18) on both sides of the discharge channel. Note rapids just east of speed bump at entrance to parking lot (Fig. 19).

Return to vehicle and return to blacktop at foot of dam via road northwest of campground.

Drive due north along winding road on Quaternary alluvial deposits. Near sewage disposal ponds, rocks of the McCurtain Shale Member of

Figure 18. Thick, monotonous sequence of steeply dipping, olive-black to dark-gray silty shales of the Atoka Formation exposed at edge of discharge channel below Wister Dam. (Stop 3b.)

Figure 19. Rapids in discharge channel formed by more resistant beds in the Atoka Formation dark shale sequence. Beds dip north 27° (Stop 3b.)

the McAlester Formation are poorly exposed. At crest of small ridge just north of power lines, an
2.5 unnamed bed of sandstone in the McCurtain Shale Member is well exposed. Continue on blacktop road past Poteau Valley Improvement Authority building site, driving due northeast. Turn sharply left onto short stretch of blacktop road just past sewage lagoon. Park on grass at right of road if dry. If wet, remain on shoulder of blacktop.

2.8 **STOP 4**

Walk due north across U.S. Highway 270, using caution, as traffic may be heavy. Observe outcrops of McCurtain Shale in ditch west of U.S. Highway 270 and good exposures of the lower Warner Sandstone Member of the McAlester Formation at crest of ridge (Figs. 20–22). Good high-energy, deltaic-marine inner fringe sandstone overlying marine shales (see Fig. 6). Outcrop described in Measured Section 4.

Measured Section 4

NE¼NW¼NE¼SW¼ sec. 31, T. 6 N., R. 25 E., Le Flore County. Measured from top of sandstone outcrop just east of blacktop road, along east road ditch, to bottom of ditch on north side of U.S. Highway 270.

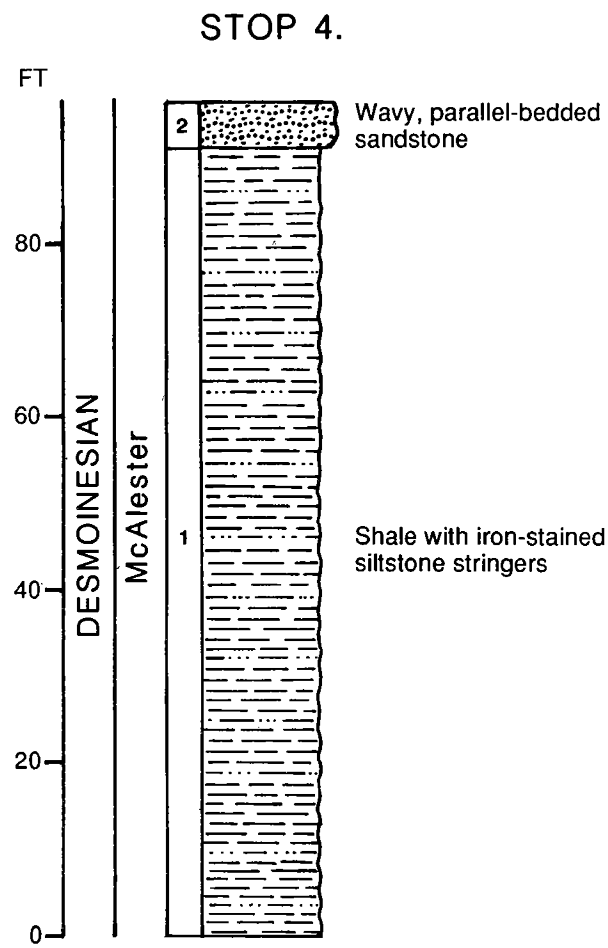

Figure 20. Graphic columnar section for Stop 4.

Figure 21. Lower unit of Warner Sandstone at crest of ridge. Note parallel bedding, characteristic of deltaic inner fringe sandstones. (Stop 4.)

Figure 22. Lower unit of Warner Sandstone a few yards east from exposure photographed in Figure 21. Note thin-bedded, rippled sandstone separating medium-bedded top and bottom layers, and sharp basal contact. (Stop 4.)

	Thickness (ft)
McALESTER FORMATION:	
Warner Sandstone Member:	
2. Sandstone, grayish-orange (10YR 7/4) to pale-reddish-brown (10YR 5/4), weathers dark-reddish-brown (10YR 3/4), 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 (lower unit of Warner Sandstone Member)	5.5
McCurtain Shale Member:	
1. Shale, medium-gray (N 5); weathers yellowish-gray (5Y 7/2), moderate-brown (5YR 4/4), and light-brown (5YR 5/6); noncalcareous; iron oxide-stained on joint surfaces; contains thin, ferruginous siltstone stringers that form resistant, broken bands on the outcrop; base covered	91.0
Total thickness of section	96.5

Return to vehicle, cross U.S. Highway 270, and drive due west along crest of Warner Sandstone ridge on blacktop road. To the right is Wister

3.6 State Park Utility Area. Continue west.

4.1 **STOP 5**

Park on south side of road at scenic overlook. Upper unit of the Warner Sandstone is exposed on the north side of the road (Figs. 23,24) just west of parking area. This is the youngest rock unit exposed in the park. Sandstone was deposited in a high-energy, deltaic-marine, inner fringe environment (see Fig. 6). Outcrop described in Measured Section 5.

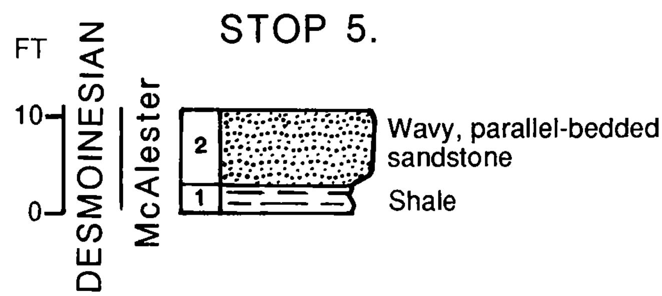

Figure 23. Graphic columnar section for Stop 5.

Figure 24. Upper Warner Sandstone. More blocky than lower Warner Sandstone observed at Stop 4, but otherwise has similar horizontal bedding characteristics. (Stop 5.)

Measured Section 5

NE¼SW¼SW¼NW¼ sec. 36, T. 6 N., R. 24 E., Le Flore County. Measured on low ridge just north of road ~100 ft west of scenic overlook.

	Thickness (ft)
MCALESTER FORMATION:	
Warner Sandstone Member:	
2. Sandstone, moderate-yellowish-brown (10YR 5/4), weathers grayish-red (10YR 4/6), very fine-grained, noncalcareous; thin- to medium-bedded; wavy, parallel-bedded; contains low-angle truncated trough cross-lamination; trace fossils on some bed soles and surfaces; interference ripple marks on some surfaces; base sharp (upper unit of Warner Sandstone Member)	7.7
1. Shale, medium-dark-gray (N 4) weathers light-brown (5YR 5/6), to grayish-orange (10YR 7/4), noncalcareous, fissile, flaky; contact with overlying sandstone exposed in road ditch ~50 ft west of culvert; base covered	3.0
Total thickness of section	10.7

Return to vehicle and follow blacktop road due west. Unnamed shale beds that separate the upper and lower Warner Sandstone beds are exposed in the road ditches.

An abandoned shale pit is on the right ~0.2 mi
past Stop 5. Just west of shale pit, at break in
4.3 slope, the lower unit of the Warner Sandstone
crosses the road.

4.6 McCurtain Shale well exposed on right side of
road just before curve.

Drive on McCurtain Shale for next 0.4 mi to just
beyond bridge where road curves sharply to the
southeast. Sandstone of the Hartshorne Forma-
5.0 tion crops out on the dip slope of Wister ridge
here in the right road ditch. The concealed contact between the Hartshorne Formation and the McAlester Formation is in the stream valley at the bridge.

Continue southeast on rocks of the Hartshorne
Formation to the entrance to Picnic Area 2, just
beyond hairpin turn in road. Rocks at crest of
ridge are the Hartshorne Sandstone. Contact be-
tween the Atoka Formation and the Hartshorne
5.6 Formation is at the base of the sandstone. Turn
east into picnic area and drive 0.1 mi to the vicinity of the picnic shelter. Park in "Road Ends" barricade area.

5.7 **STOP 6**

Walk ~100 ft past barricade, then follow trail left toward point where Wister ridge ends at water's edge. Observe rocks of the Atoka and Hartshorne Formations (Figs. 25–27), described in Measured Section 6. The depositional sequences at this stop are interpreted as marine shales overlain by pro-delta deposits, both units in the Atoka Formation. Above an erosional contact are distributary channel sequences of the Hartshorne Sandstone overlain by low-energy, shallow marine, outer fringe regressive beds (see Fig. 6).

A concealed tear fault with a left lateral sense of movement has been postulated as being present in the strait between Wister ridge and Quarry Isle, owing to the attitude of the rocks on the point of Wister ridge. If one sights along the strike of the beds here, it can be seen that they would project obliquely into the Warner Sand-

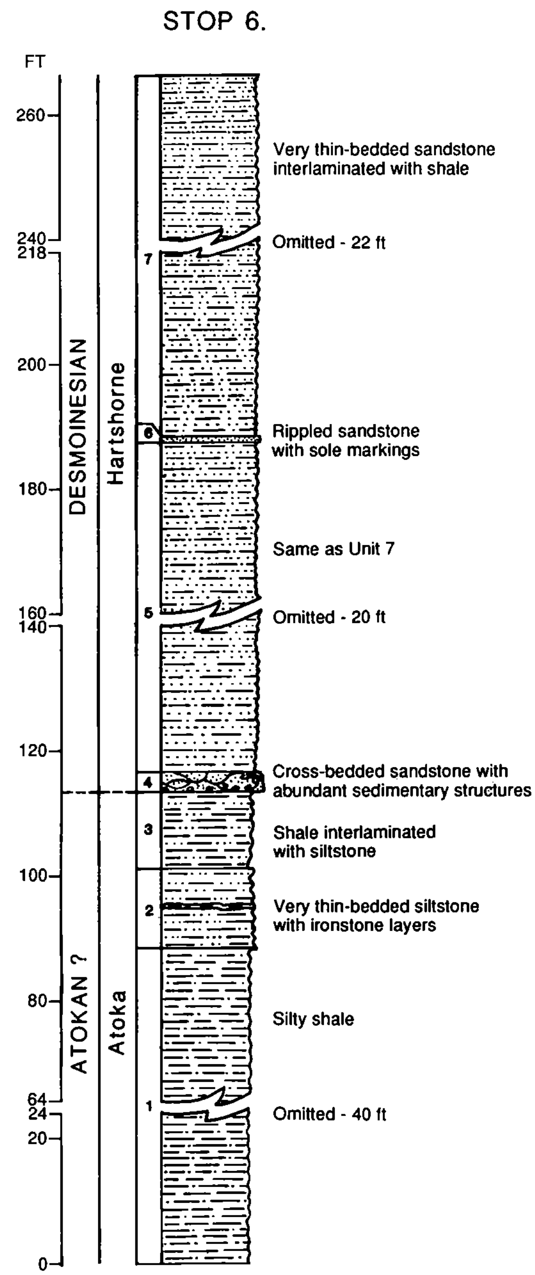

Figure 25. Graphic columnar section for Stop 6.

Figure 26. Pro-delta deposits of Atoka Formation overlain by stream-channel deposits of Hartshorne Sandstone. (Stop 6.)

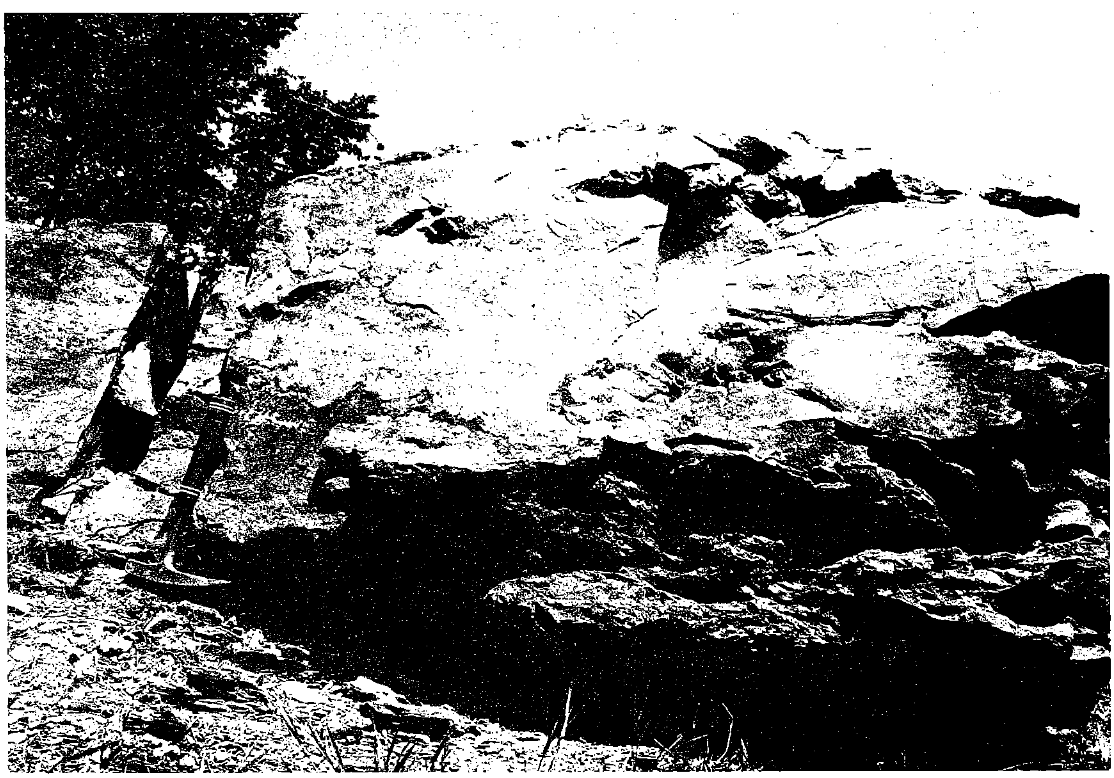

Figure 27. Close-up of block of Hartshorne Sandstone shown at upper right in Figure 26. Sandstone is mostly massive with obscure, thick, trough cross-bedding. Note pebble-lag conglomerate marking erosional contact. (Stop 6.)

stone ridge, indicating that they were dragged northward by movement along the tear fault.

Measured Section 6

NW¼SW¼SW¼ sec. 36, T. 6 N., R. 24 E., Le Flore County. Measured on east point of Wister ridge, just east of picnic area, starting ~250 ft north from resistant ridge of sandstone, and ending south of ridge at an east–west line extending through large boulder exposed offshore in Wister Lake.

	Thickness (ft)
HARTSHORNE FORMATION:	
7. Sandstone interlaminated with shale, light-olive-gray (5Y 5/2) to pale-yellowish-brown (10YR 6/2), weathers light-brown (5YR 5/6) to moderate-brown (5YR 3/4); sandstone is very fine-grained, very silty, very thin-bedded, wavy to flat, parallel-bedded, noncalcareous, micaceous, weakly bioturbated, fissile, iron oxide-stained; contact gradational	77.6
6. Sandstone, light-olive-gray (5Y 5/2) to pale-yellowish-brown (10YR 6/2), weathers light-brown (5YR 5/6) to moderate-brown (5YR 4/4), very fine-grained, noncalcareous, micaceous, thin- to medium-bedded; wavy, parallel-bedded; trace fossils on surfaces and soles of beds; includes large, bulbous load casts in places; surface marked by interference ripples; forms thin, resistant rib on slope; base sharp	1.2
5. Sandstone interlaminated with shale (same description as Unit 7)	70.6
4. Sandstone, light-gray (N 7) to very pale-orange (10YR 8/2), weathers light-brown (5YR 5/6) to moderate-brown (5YR 4/4); very fine- to fine-grained, but includes a ferruginous pebble-lag conglomerate of variable thickness (generally ~1 ft thick) at base; thick-bedded; curved, nonparallel-bedded; trough cross-bedded to massive in places; contains soft-sediment deformation features such as flow rolls and load casts; includes abundant fossil plant impressions in places, some surrounded by coalified zones; trace fossils common, especially on bedding surfaces; surface ripple marked in some places and honeycombed by weathering-out of pebbles in others; base sharp and disconformable; thickness of unit variable—increases westward to >20 ft ~160 ft northeast from picnic shelter house. Measurements on asymmetric ripples indicate depositing currents flowed S.20°W.	3.2
ATOKA FORMATION:	
3. Shale, medium-gray (N 5), weathers moderate-yellowish-brown (10YR 5/4) to moderate brown (5YR 4/4) and dusky-yellowish-brown (10YR 2/2), interlaminated with siltstone, fissile, wavy-bedded, weakly bioturbated, base gradational	12.3
2. Siltstone, light-olive-gray (5Y 5/2), weathers moderate-brown (5YR 3/4), shaly, laminated to very thin-bedded; slightly wavy to flat, parallel-bedded; includes some thin lenses of very fine sandstone; micaceous; contains some black (N 1), comminuted plant fragments on bedding planes; includes some resistant, 1-in.-thick ironstone layers; more resistant than underlying unit; contact gradational	13.0
1. Shale, olive-gray (5Y 4/1) to medium-dark-gray (N 4), weathers light-brown (5YR 5/6) to moderate-brown (5YR 4/4, 5YR 3/4), silty, noncalcareous, fissile, exhibits concretionary structure, iron oxide-stained, base of unit not exposed	88.2
Total thickness of section	266.1

Walk west along the base of the Hartshorne Sandstone ridge to vicinity of picnic shelter. Note the thickening of the unit westward into what is apparently the deepest part of a channel. Also observe the trough cross-bedding and large-scale soft-sediment deformation features (Fig. 28). Return to vehicle.

Return to blacktop road and turn left. Proceed west on rocks of the Atoka Formation. Large boulders that are scattered about are "float," or colluvium, and are derived from weathering of the Hartshorne Formation and the youngest sandstone unit in the Atoka Formation.

6.3 Entrance to Wards Campground Area. At the break in slope, just before the road again turns west, a low ridge of Atoka Formation sandstone crosses the road. Low ridges, capped by steeply dipping (45°) sandstones of the Atoka Formation parallel the road to the south. At times of high water owing to floods, they become isolated from the mainland and temporarily become islands.

7.9 Bridge across stream inlet and bay area of Wister Lake. A tear fault with a left-lateral sense of movement has been mapped here.

8.3 Entrance to Victor Campground Area. Turn left and follow blacktop road; cross two low ridges of Atoka Formation sandstone before descending onto terrace deposits associated with the Poteau River.

8.7 Turn right at playground and restroom area and follow winding blacktop road through campground to southwestern end of campsite.

Figure 28. Soft-sediment deformation and trough cross-bedding in channel sequence in Hartshorne Sandstone, just northeast of picnic shelter. (Stop 6.)

9.0 **STOP 7**

Park and walk below wave-cut bluffs as per directions in Measured Section 7. Appropriately, at this stop, which concludes the field trip, there is something of interest for everyone—whether it be in the field of geomorphology, petrology, stratigraphy, sedimentary geology, or structural geology (Figs. 29–32). The rocks are described in Measured Section 7. The entire bedrock sequence is interpreted as outer fringe, low-energy deltaic-marine (see Fig. 6).

Measured Section 7

SW¼SW¼SW¼NE¼ sec. 4, T. 5 N., R. 24 E., Le Flore County. Measured from top of terrace at edge of bay north from campsite 2 in a southerly direction along wave-cut beach to waters edge on south side of point, Victor Campground Area.

	Thickness (ft)
Quaternary terrace deposits:	
15. Clay, silt, sand, grayish-orange (10YR 7/4), unconsolidated; contains rounded and subrounded sandstone pebbles and cobbles; base sharp, with angular unconformity	10.0
Atoka Formation:	
14. Shale, medium-dark-gray (N 4), light-olive-gray (5Y 5/2), and light-brownish-gray (5YR 6/1), weathers grayish-orange (10YR 7/4) to dark-yellowish-orange (10YR 6/6), micaceous, fissile; includes some dark-yellowish-brown (10YR 4/2), shaly siltstone beds as well as a 2-in.-thick, light-olive-gray (5Y 6/1), very fine-grained sandstone bed with well-preserved trace fossils on both top and bottom surfaces; base gradational	131.0
13. Sandstone, light-olive-gray (5Y 6/1), weathers grayish-orange (10YR 7/4) and moderate-brown (5YR 4/4), very fine-grained, very shaly, weakly indurated, noncalcareous; thin, parallel-bedded; some beds have abundant trace fossils on soles; beds are deformed by soft-sediment slumping and contain lenses of rolled sandstone; base gradational	5.0
12. Shale, medium-dark-gray (N 4), weathers moderate-yellowish-brown (10YR 5/4), silty, noncalcareous; includes in upper part several 1- to 7-in.-thick, light-olive-gray (5Y 6/1), very fine-	

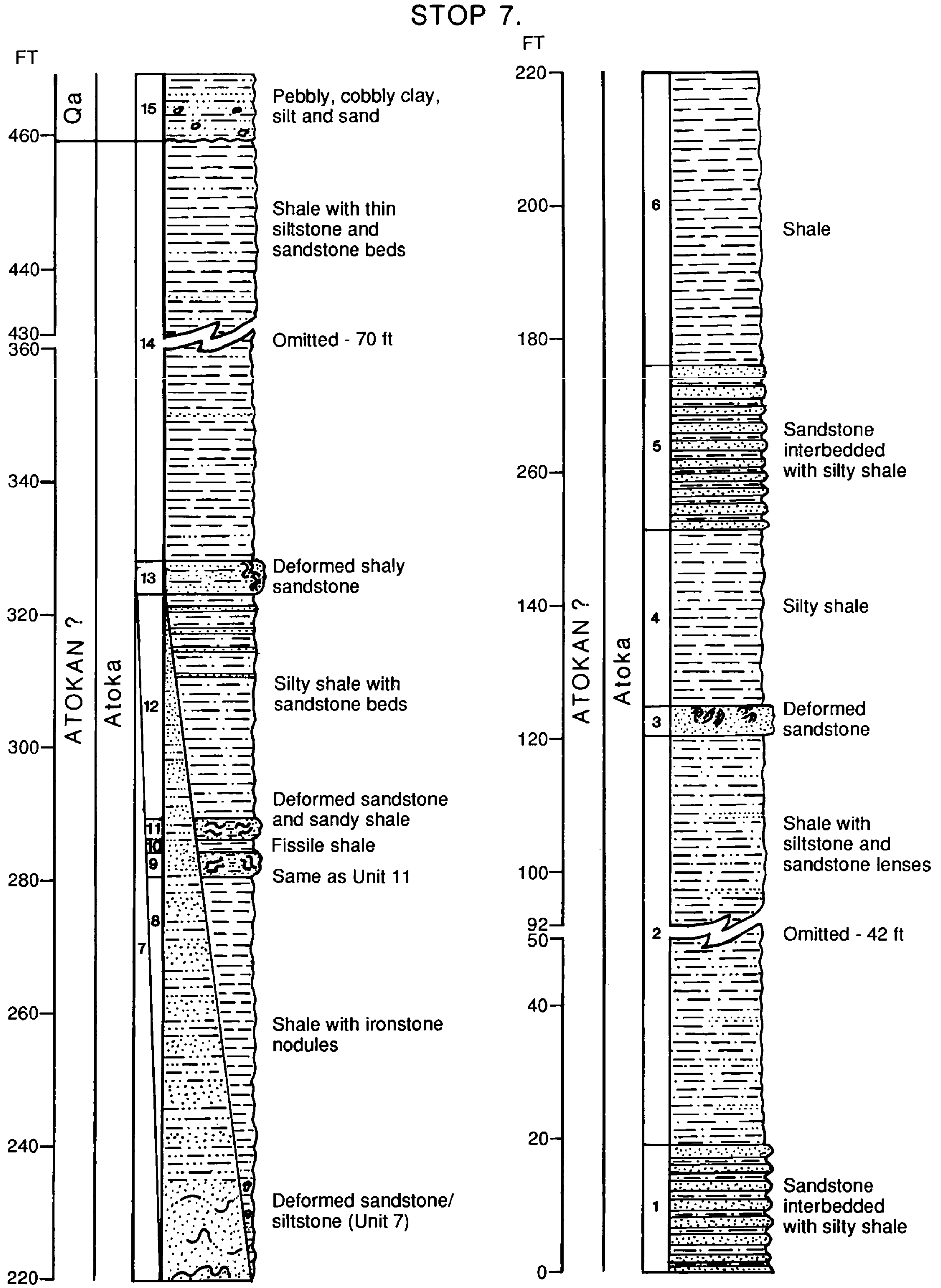

Figure 29. Graphic columnar section for Stop 7.

Figure 30. Steeply dipping, thin- to medium-bedded, deformed sandstone beds (Unit 3) in the Atoka Formation. Unit is truncated by a fault at base of alluvial terrace deposits (marked by white line) in upper right-center in photo. Two horizontal, parallel zones of sandstone rubble (upper left) are high-water storm deposits resulting from wave action and beach erosion. (Stop 7.)

Figure 31. Sandstone/siltstone beds (Unit 7) deformed by drag along a NW-trending tear fault. (Stop 7.)

Figure 32. Very thin- to medium-bedded, ripple-marked sandstone with abundant sole markings, interbedded with silty shale (Unit 1). Exposed just above water level at south side of section. (Stop 7.)

grained, thin, flat, parallel-bedded, micaceous sandstone beds that have excellent trace fossils and current ripples on soles; contact gradational 33.9

11. Sandstone and sandy shale, very pale-orange (10YR 8/2), to dark-yellowish-orange (10YR 6/6), very fine-grained, micaceous, noncalcareous; sandstone occurs as rolled lenses and pods; unit exhibits deformation caused by soft-sediment slumping; weakly indurated except for sandstone masses; base gradational 3.0
10. Shale, dark-yellowish-orange (10YR 6/6) and dark-gray (N 3), noncalcareous, fissile, base gradational 2.0
9. Sandstone and sandy shale (same description as Unit 11) 3.5
8. Shale, medium-dark-gray (N 4), weathers grayish-orange (10YR 7/4), noncalcareous, fissile. Unit merges southward with a very light-gray (N 8) to very pale-orange (10YR 8/2), highly disturbed, brecciated zone of silty, clayey shale(?) containing hackly nodules of ironstone as well as broken sandstone beds (interpreted to be a fault-gouge zone) 60.7
7. Sandstone/siltstone, olive-gray (5Y 4/4), laminated, noncalcareous. Beds are deformed (folded and faulted) and occur laterally along strike from Units 8–12 (toward the water). Bending of the rocks on the west side of the fault trace (described with Unit 8) to the northeast suggests drag folding along a NW-trending tear fault with a left-lateral sense of movement. Offset unknown. Thickness of Unit 7 excluded from cumulative thickness of measured section .... (103.0 ft)
6. Shale, medium-dark-gray (N 4), fissile (exposed on west side of fault zone) 44.0
5. Sandstone, light-gray (N 7), weathers light-brown (5YR 5/6), very fine-grained, micaceous; thin, wavy, parallel-bedded to thick, wavy, discontinuous-bedded; interbedded with moderate-yellowish-brown (10YR 5/4) silty shale; includes abundant trace fossils; unit is marked by numerous healed fractures, and is broken and dragged northeast along the fault trace described in Unit 8 .... 24.3
4. Shale, grayish-orange (10YR 7/4) to moderate-yellowish-brown (10YR 5/4), silty, noncalcareous 26.7
3. Sandstone, light-olive-gray (5Y 5/2), weathers moderate-yellowish-brown

(10YR 5/4) to light-brown (5YR 5/6), very fine-grained, micaceous; beds are thin and slightly curved, parallel in bottom part, and thin- to medium-bedded, wavy, and highly deformed (tightly folded) in upper part; base gradational 4.5

2. Shale, medium-light-gray (N 6), weathers olive-gray (5Y 4/1) to grayish-orange (10YR 7/4) to moderate-yellowish-brown (10YR 5/4), very silty, noncalcareous, fissile; grades into a shaly siltstone with very fine-grained sandstone lenses in places laterally; base gradational 100.8

1. Sandstone interbedded with silty shale, grayish-orange (10YR 7/4) to pale-yellowish-brown (10YR 6/2) to moderate-brown (5YR 3/4), sandstone is very fine-grained, noncalcareous, very thin- to medium-bedded; wavy, parallel-bedded to flat, parallel-bedded; contains low-angle cross-stratification with channels scouring into underlying shaly beds in places; some surfaces ripple-marked; soles have abundant, well-formed flutes, grooves, load casts, and trace fossils; base covered by waters of Wister Lake 19.6

Total thickness of section 469.0

Return to your embarkation point at your own leisure. Hopefully, the trip has enhanced your understanding of the geology in the park and furthered your appreciation of the beauty of nature.

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GLOSSARY OF GEOLOGICAL TERMS

alluvium—A general term for all fragmental deposits resulting from the operations of modern streams, thus including the sediments laid down in stream beds, flood plains, lakes, fans at the foot of mountain slopes, and estuaries.

angular unconformity—A surface of erosion at which the older strata dip at a different angle (generally steeper) than the younger strata.

anticline—An upfold of strata the center of which is the "axis." The strata dip away from the axis like the roof of a house. Opposite sides of an anticline (or syncline) are called flanks, or limbs. The core of the fold contains stratigraphically older rocks. The opposite of a syncline.

basin [structural geology]—A depressed, sediment-filled area of the Earth's crust which has been downwarped, usually for a considerable time, but with intermittent risings and sinkings.

bed—The smallest division of a stratified series, marked by a more or less well-defined divisional plane from its neighbors above and below.

bedding plane—A characteristic of sedimentary rocks. Bedding planes are subparallel planes along which individual beds may separate.

bedrock—Any solid rock exposed at the surface of the Earth or overlain by unconsolidated material.

bioturbation—The churning and stirring of sediments by organisms.

brush mark—A tool mark oriented parallel to the current and produced by an object that struck the bottom and rebounded, leaving a small crescentic ridge of mud pushed up. See also *sole marking.*

calcareous—Said of a substance containing calcium carbonate. A calcareous rock effervesces (bubbles and hisses) when acid is applied.

clastic rock—Sedimentary rock consisting of fragments derived from preexisting rocks that were broken down and then transported to another place of deposition.

colluvium—A general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity.

columnar section—A drawing or graphic representation showing in a vertical column the sequence of rock units found in a specific area.

comminuted—Said of disintegrated organic materials that have been fragmented by various chemical and physical processes and incorporated in sedimentary rocks.

cross section—A profile portraying an interpretation of a vertical section of the Earth explored by geological methods.

depositional environment—A geographically restricted setting where a sediment accumulates; for example, a lake, swamp, flood plain, or delta.

dip—The angle at which a rock stratum or fault surface is inclined from the horizontal. Dip is always at right angles (90°) to the strike of a stratum.

drag—Minor folding of strata along the walls of a fault in which the "drag" of displacement has produced flexures in the beds on either side.

epoch—Subdivision of a period of time. Rocks formed during an epoch constitute a series.

era—Greatest of all geologic time divisions. Consists of two or more geologic periods.

erosion—The natural process of weathering, disintegration, dissolution, and removal of rock and earth material, mainly by water and wind.

fault—A fracture or a zone of fractures in rock with displacement of the sides relative to one another either horizontally, vertically, or both.

ferruginous—Containing iron. Descriptive of rocks of red color, but not necessarily of abnormal iron content.

fissile—An adjective describing rocks that split along closely spaced parting planes. In sedimentary rocks such planes parallel the stratification.

float—Term used by geologists for pieces of rock found on the surface that have been separated from the parent strata by weathering and have fallen or moved downslope. See also *colluvium.*

flood plain—A relatively flat area close to a stream. It is made of sediment carried over the stream banks during times of flood.

flow roll—A rounded, pillow-like body or mass of sandstone occurring within the basal part of a sandstone overlying shale and presumed to form by deformation, such as mud flowage accompanied by subaqueous slump or foundering of sand channels.

flute cast—A tongue-shaped sole mark consisting of a subconical bulge on the underside of a siltstone or sandstone bed, characterized by a steep or blunt and rounded, bulbous, or beaked upcurrent (deeper) end from which the structure flattens or flares out in a downcurrent direction and merges with the bedding plane. See also *sole marking.*

fold—A curve or bend in rock strata, usually as a result of deformation.

formation—The fundamental stratigraphic unit used for geologic mapping. It may include several rock types. Formations sometimes are divided into members and beds.

fossil—The remains or traces of an animal or plant that have been preserved by natural causes in the

Earth's crustal rocks. The term does not include an organism that has been buried during historic time.

geologic time—History of the Earth divided into eras, periods, and epochs.

geomorphology—The branch of geology that deals with the form of the Earth, the general configuration of its surface, and the changes that take place in the evolution of land forms.

groove casts—Rounded or sharp-crested rectilinear ridges, fractions of an inch to inches high and many inches to many feet long, occurring on undersurfaces of sandstone layers lying on shale or mudstone. See also *sole markings.*

group—Two or more formations with similar characteristics or other affinities.

hackly—Said of a mineral or rock that has a hard, jagged surface.

hogback—A sharp-crested ridge formed by a resistant layer of rock that dips steeply downward.

imbricate structure—In general, refers to tabular masses that overlap one another as shingles on a roof. Used in structural geology for a series of thrust sheets dipping in the same direction.

ironstone—A heavy, compact, clayey rock containing a substantial portion of iron oxide; commonly in nodular or concretionary form.

joint—A fracture in rock along which no displacement has occurred.

lag—Coarse-grained material that is rolled or dragged along the bottom of a stream at a slower rate than the finer material. Also refers to the material that is left behind after currents have winnowed or washed away the finer materials.

load cast—Roll or other irregularity at the base of an overlying stratum, commonly sandstone, projecting into an underlying stratum, commonly clay or shale, produced by differential settling and compaction. See also *sole marking.*

marine—Of or belonging to the sea.

measured section—A description of the successive rock units found on an exposed surface.

member—See *formation.*

nonclastic rock—A sedimentary rock whose deposition was caused by chemical or biological action.

organic deposits—Deposits formed from the remains of living matter such as plants and animals.

orogeny—A movement or movements of the Earth's crust (folding and faulting) that cause mountains to form.

paleocurrent—An ancient current (generally of water) that existed in the geologic past; its direction is inferred from the sedimentary structures and textures of the rocks formed at that time.

Pennsylvanian Period—The span of geologic time between about 320 and 280 million years ago.

period—Subdivision of an era. Rocks formed during a period constitute a system.

petrology—A general term for the study by all available methods of the natural history of rocks, including their origins, present conditions, alterations, and decay.

platform—The area of thinner sediments in a stable cratonic-type setting adjoining a more rapidly subsiding, more mobile basin of sedimentation. Also called a tectonic shelf.

prod mark—A short tool mark oriented parallel to the current and produced by an object that plowed into and was then raised above the bottom; its longitudinal profile is asymmetric. The mark deepens downcurrent where it ends abruptly (unlike a flute). See also *flute cast* and *sole marking.*

riprap—Broken rock used for revetment, the protection for bluffs or structures exposed to wave action.

Quaternary Period—The span of geologic time thought to cover the last two or three million years.

saddle—A low point on the crest of a ridge.

sediment—Bits of rock, often the result of weathering, that accumulate in layers. Sand, gravel, silt, and mud are some examples of sediment, which can be transported or deposited by air, water, or ice.

sedimentary rock—Rock formed by the compaction and cementing of sediments deposited in water or from air. Sediments may consist of rock or mineral fragments of various sizes (mud, sand, gravel), the remains of animals or plants, the products of chemical action or evaporation, or mixtures of these materials. Sedimentary rocks typically have a layered structure known as bedding or stratification.

series—See *epoch.*

soft-sediment deformation—Deformation of rocks such as sandstone, generally caused by large-scale load casting, flowage, or subaqueous slump prior to lithification. Beds appear contorted, rolled, or squeezed. See also *flow roll.*

sole marking—A general and descriptive term applied to a directional structure or other irregularity found on the original underside of a bed of sandstone or siltstone along the contact, where it overlies a softer and finer grained layer (such as shale). The term refers to a filling of a primary structure formed on the upper surface of the underlying mud by agents such as currents, organisms, and unequal loading; the structure is preserved as a sole cast after the underlying material has weathered away. Examples: load casts, brush marks, prod marks, groove casts, flute casts, trace fossils.

stratigraphy—That branch of geology that deals with the formation, composition, sequence, and correlation of the layers of rocks as part of the Earth's crust.

stratum—A single sedimentary bed or layer. The plural form is strata.

strike—The direction or trend of a rock stratum or fault surface as it intersects the horizontal.

stringers—Thin sedimentary beds included in a rock mass of different material.

structural geology—Study of the structural features of rocks (folds and faults) and the causes of their deformation.

syncline—A fold in rock layers in which the strata dip inward from both sides toward the axis. A downfold. The core of the fold contains stratigraphically younger rocks. The opposite of an anticline.

tear fault—Strike-slip fault that trends transverse to the strike of deformed rocks. A strike-slip fault is a fault in which the actual movement is parallel to the direction of the fault strike.

tectonic—Of, pertaining to, or designating the rock structure and external forms resulting from deformation of the Earth's crust.

terrace—A relatively flat, horizontal, or gently inclined surface, typically bounded by a steeper ascending slope on one side and by a steeper descending slope on the opposite side. A terrace commonly occurs along the margin and above the level of a body of water, marking a former water level.

terrestrial—Consisting of or pertaining to land as distinct from water. Examples of terrestrial deposits are flood plains of streams and rivers. These clastic sediments are deposited by flood waters.

thrust fault—A reverse fault that is characterized by a low angle of inclination with reference to a horizontal plane. A reverse fault is a fault along which the upper wall has been moved upward relative to the lower wall.

topography—The physical features of a region; the shape of the land's surface.

trace fossils—Sedimentary structures consisting of fossilized tracks, trails, burrows, tubes, borings, or tunnels made by animals such as invertebrates in or on soft sediment at the time of its accumulation. Often preserved as raised or depressed forms in sedimentary rocks, commonly as sole markings.

trough cross-bedding—Cross-bedding in which the lower bounding surfaces are curved by erosion; it results from channeling and subsequent deposition.

valley fill—The unconsolidated sediment derived from the erosion of highlands that was deposited by an agent, such as a stream, so as to fill or partly fill a valley.

water gap—A pass in a ridge through which a stream flows.

weathering—The group of processes—such as the chemical action of water and air and of plants and bacteria, and the mechanical action of changes of temperature—whereby rocks exposed to the weather change in character, decay, and finally crumble into soil.

NOTES