GUIDEBOOK 86-4

STATE OF ARKANSAS
ARKANSAS GEOLOGICAL COMMISSION
Norman F. Williams, Director

THE TERTIARY AND QUATERNARY GEOLOGY OF CROWLEY'S RIDGE: A GUIDEBOOK

By
M.J. Guccione, W.L. Prior, and E.M. Rutledge

Prepared for Southeastern and South-Central Sections, of the Geological Society of America Memphis, Tennessee
April 5, 1986

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GEOMORPHOLOGY

Crowley's Ridge is an erosional remnant of unconsolidated Eocene clay, silt, sand, and lignite capped by Pliocene sand and gravel and middle to late Pleistocene loess (Haley, 1976). Located in eastern Arkansas (Fig. 1) and southeast Missouri, the Ridge is no more than 11 miles (18 km) wide and extends 186 miles (300 km) from Campbell, Missouri, to Helena, Arkansas. In striking contrast to the surrounding countryside, it stands 100 to 200 feet (30 to 60 m) higher than the adjoining lowlands.

Crowley's Ridge is a divide formed during the Pleistocene as ancestors of the Mississippi River to the west and the Ohio River to the east of the Ridge eroded Coastal Plain sediments (Call, 1891; Fisk, 1944) (Fig. 2). During the initial stage of the Mississippi River, its course was on the west side of the alluvial valley from Thebes Gap at the upper end of the valley to its delta. The Ohio River flowed along the east side of the alluvial valley and joined the Mississippi River near Simmesport, Louisiana, 404 miles (650 km) south of where it joins the Mississippi River today. Abundant glacial outwash and rising sea level contributed to the aggradation of the Mississippi and Ohio Rivers, causing a decrease in the rivers' gradients. Decrease in gradient and/or tectonic activity along the New Madrid seismic zone may have caused the eastward shifting of the Mississippi River, culminating in the cutting of the present channel through the divide at Thebes Gap. Today the Mississippi River joins the Ohio River near Cairo, Illinois, and flows on the east side of the Ridge. The Mississippi River's diversion to the east side of Crowley's Ridge is estimated to have occurred between 3,000 and 6,000 B.P. by Fisk (1944, Table 3). However, the source of the loesses which cap the Ridge (Saucier 1974 and West et al, 1985) and the loess-covered terrace west of Crowley's Ridge (Rutledge et al., 1985) suggests that the diversion may be older than Fisk's estimate.

GEOLOGIC SETTING AND STRATIGRAPHY

Crowley's Ridge is lo-

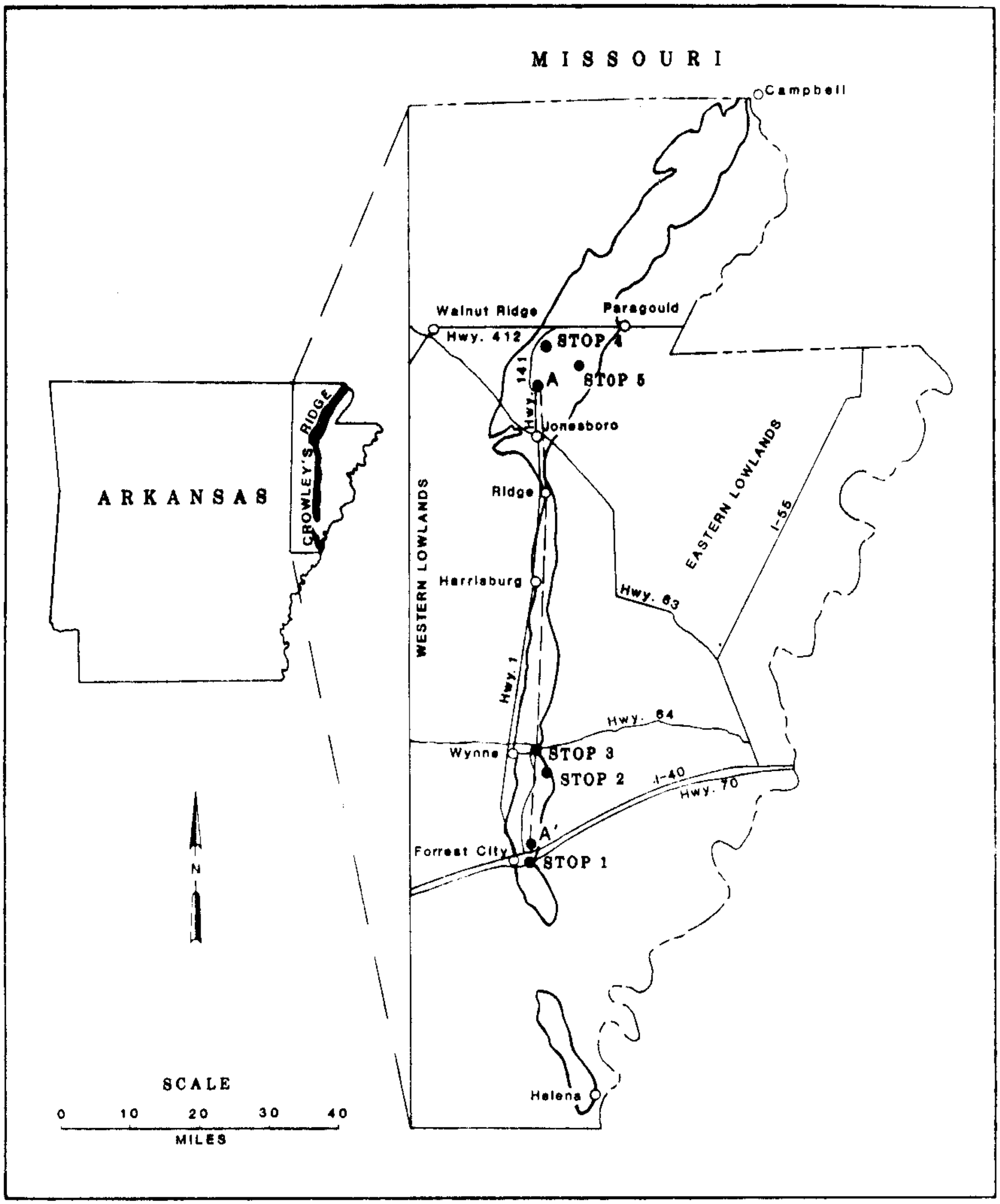


Figure 1. Location map of Crowley's Ridge and the stops and sections described in this field guide. Location of cross sections (Figs. 3 and 6) is also shown.

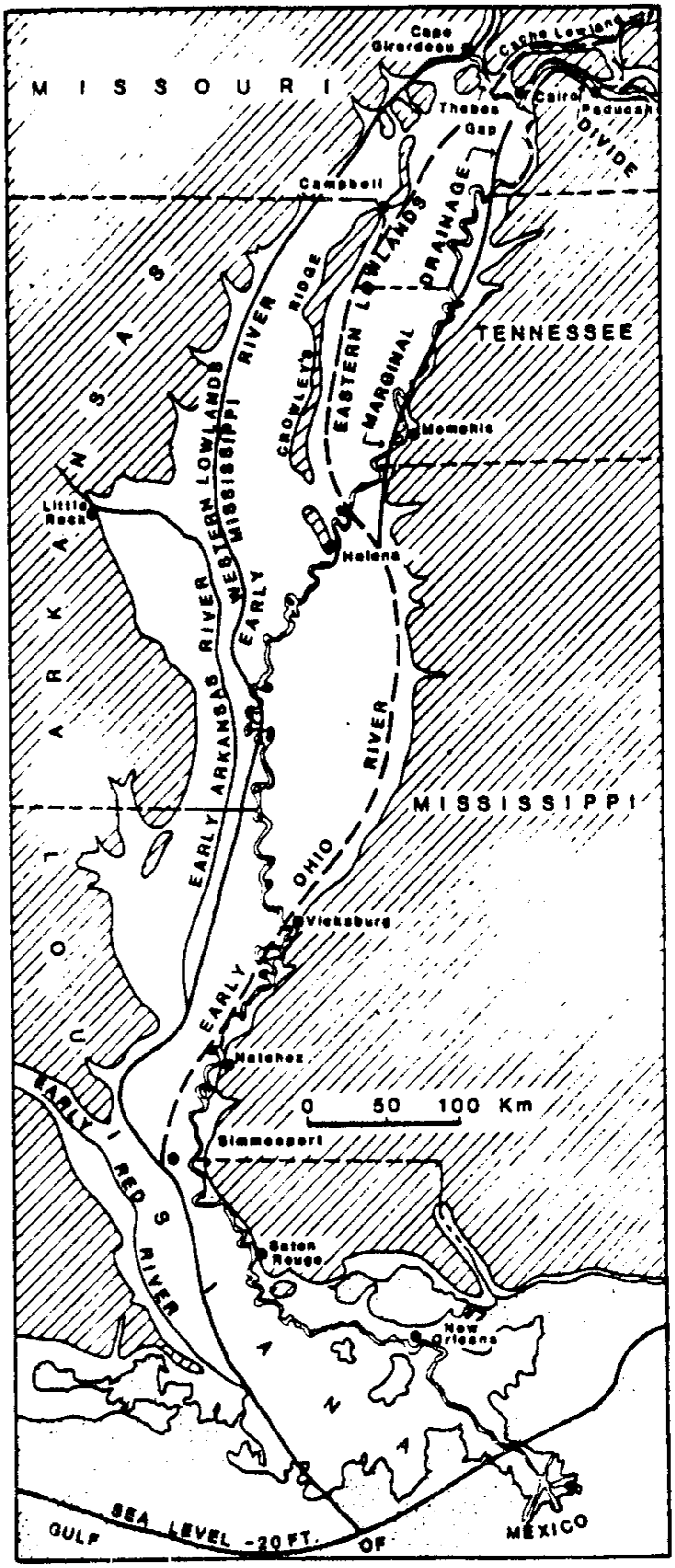


Figure 2. Early-stage relationships between the Mississippi and Ohio rivers (modified after Fisk, 1944, Fig. 42)

cated in the northwestern section of the Mississippi River Embayment (Meissner, 1984). The Embayment axis trends approximately parallel to the modern Mississippi River and plunges south toward the Gulf of Mexico. The Cretaceous and Tertiary sediments deposited in this basin dip 35 to 75 ft/mile (7 to 14 m/km) to the east-southeast toward the axis of the embayment (Meissner, 1984). The sediments also thicken toward the southeast due to greater deposition and less subsequent erosion in that direction.

Eocene Strata

Wilcox Group.--Three of the Tertiary basin-fill units, all Eocene (Table 1), crop out on Crowley's Ridge (Fig. 3). As marine waters transgressed over the area, the sediments change from dominantly fluvial to dominantly marine facies. The oldest unit, the Wilcox Group, is exposed along the flanks of the northern portion of the Ridge. Wells indicate that the Wilcox is approximately 775 feet (236 m) at the southern edge of the Ridge (Meissner, 1984). The sediments consist of interbedded sand, silt, clay, and some lignite, all deposited in a fluvial-deltaic environment.

Claiborne Group.--The Claiborne Group overlies the Wilcox Group and is exposed along flanks of the Ridge in the central portion of Crowley's Ridge (Fig. 3). The maximum thickness of the Claiborne Group is 690 feet (210 m) near the southern end of

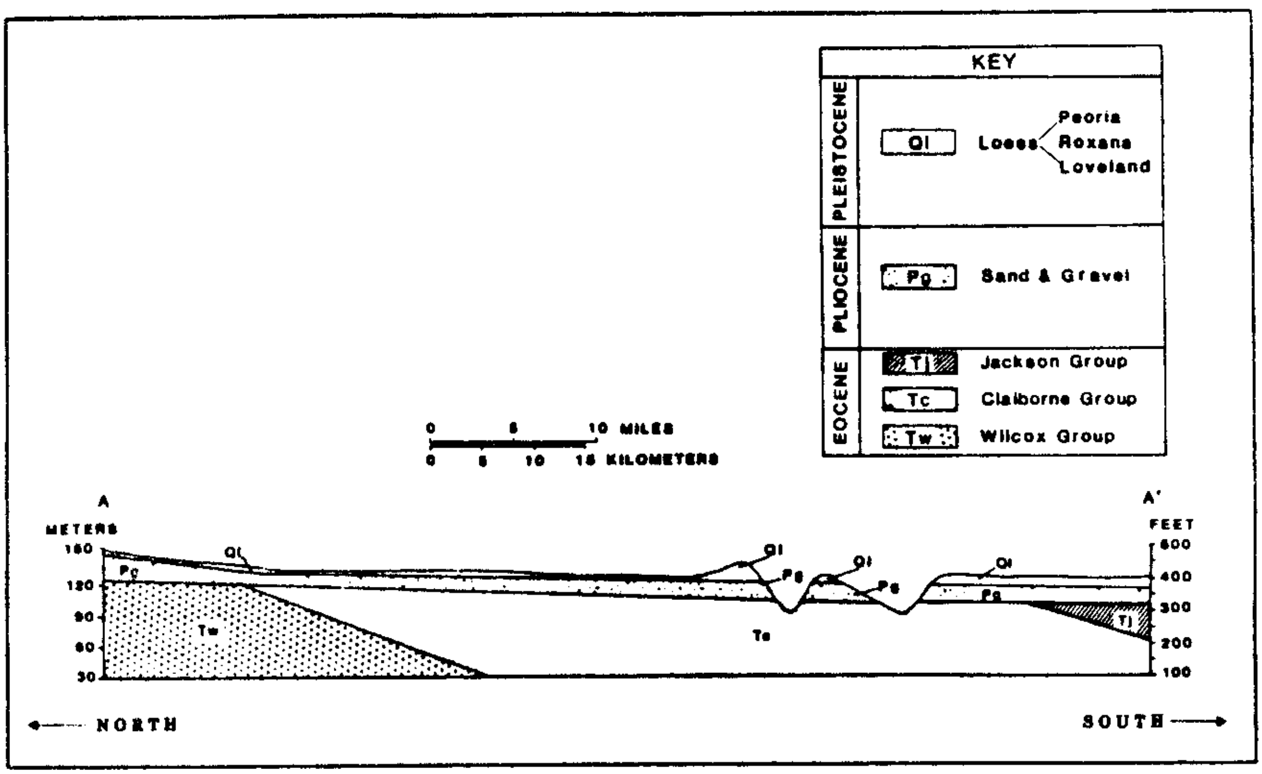


Figure 3. North-south cross section of Crowley's Ridge. Location is shown in Figure 1. Datum is mean sea level. Interpretation is by Guccione and Rutledge.

Table 1. Stratigraphic Units of Crowley's Ridge

Time Stratigraphic				Rock Stratigraphic	Soil Stratigraphic
		Stage	Substage		
Quaternary System	Holocene Series			unnamed terrace sand and gravel	Loring soil (ground soil)
	Pleistocene Series	Wisconsinan	Valderan		
			Two Creekan		
			Woodfordian	Peoria Loess	
			Farmdalian		Farmdale Soil
			Altonian	Roxana Silt	
		Sangamonian			Sangamon Soil
		Illinoian		Loveland Silt ?	
					unnamed soil
Tertiary System	Pliocene Series			sand and gravel (Lafayette Gravel ?)	
	Eocene Series			Jackson Group	
				Claiborne Group	
				Wilcox Group	

the Ridge (Meissner, 1984). The sediments consist of fine sand, silt, sandy clays, and some minor lignite, all de-

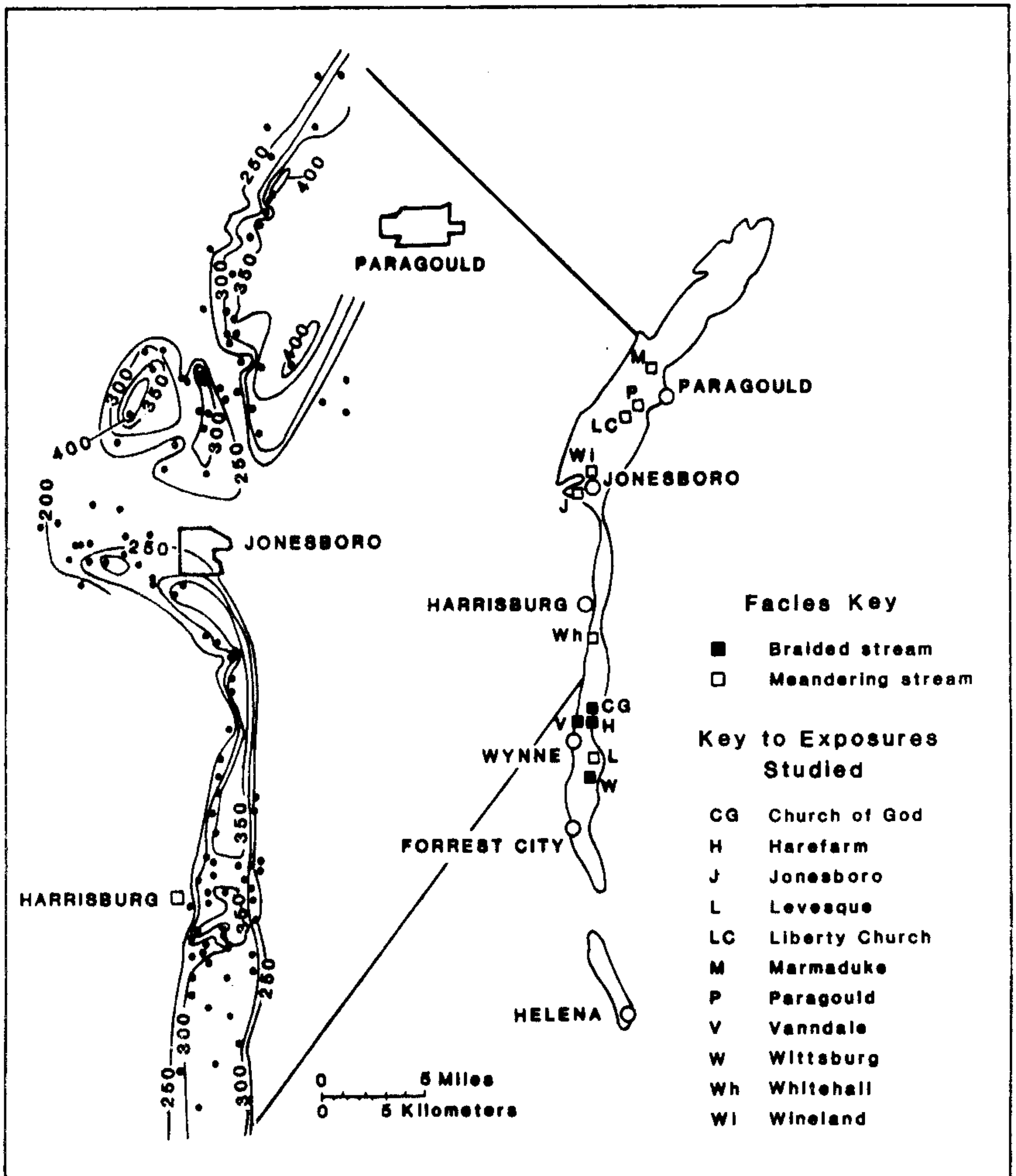


Figure 4. Elevation of the Eocene-gravel contact (in feet above mean sea level) on part of Crowley's Ridge. Elevations above 300 feet are the Eocene-Pliocene contact and those below 300 feet may be the Eocene-Quaternary contact. Location and interpreted facies of some Pliocene sand and gravel exposures are also shown. Small solid circles are drill hole sites.

posited in deltaic and nearshore marine environments.

Jackson Group.--The Jackson Group overlies the Claiborne Group and is exposed along the flanks of the southernmost portion of Crowley's Ridge (Fig. 3). Here the sediments are approximately 490 feet (150 m) thick and consist of sandy clay, silt, and glauconitic, fossiliferous sandy clay deposited in a nearshore marine environment. The Jackson Group was deposited during the last marine transgression into Arkansas. This transgression was centered over the Desha Basin, which is a structural low that trends east-west, south of Crowley's Ridge (Wilbert, 1953). An undetermined thickness of Tertiary strata has been lost by erosion since the Eocene.

PLIOCENE STRATA

Geometry.--Overlying the Tertiary units on Crowley's Ridge is a Pliocene sand and gravel unit. It varies from 0 to 125 feet (38 m) in thickness and averages 33 feet (10 m) (Holbrook, 1980). In outcrop the unit is continuous for hundreds of meters laterally, although individual beds are more local. Subsurface lithologic logs suggest a nearly continuous deposit that slopes 1.74 ft/mi (0.33 m/km) to the south (Fig. 4). Some deep channels within this broad sheet are incised into the bedrock. A larger anastomosing channel system is located just north of Jonesboro and is 9.9 mi (16 km) wide with a single channel being 2.8 mi (4.5 km) wide. The maximum thickness of the unit in this channel may have been 197 feet (60 m), if the gravels are the same age and if the channel was filled to the upper elevation of the gravel on the surrounding surfaces. This channel system has some surface expression in that the ground elevation is lower over the channel than it is on surrounding parts of the sheet. A smaller single channel east of Harrisburg is 1.4 mi (2.3 km) wide and may have been filled with a maximum of 79 feet (24 m) of gravel. Surface expression of this channel is minimal. Two small streams are aligned with this buried channel but the elevation of the divide between them is no lower than that of the surrounding gravel sheet.

Source.--The source area of the Pliocene sand and gravel unit included sedimentary and metamorphic rocks. The mid-continent Paleozoic craton and Appalachian Mountains in the eastern United States probably provided the materials. Chert is the dominant lithology in the pebble fraction but sandstone, quartz, and Tertiary clay pebbles are also present (Table 2). The heavy minerals in the sand fraction are dominantly zircon, rutile, and tourmaline. The high-rank metamorphic minerals sillmanite, kyanite, and staurolite are also present (Table 3). This limited lithologic suite without any igneous rocks and a mineral suite with a paucity of epidote, hornblende, augite, and garnet is unlike the lithologic and mineralogic suite in Quaternary glacial

Table 2. Lithology of the gravel (>2 mm) and sand (≤2 mm) fractions of Lafayette Gravel.

	Gravel, %	Sand, %	
	>2 mm (Potter, 1955)[1]	1-0.062 mm (Potter, 1955)[2]	0.5-0.088 mm (Wilkinson, 1982)
Chert	86	9	6
Quartz	14	81	81
Quartzite	included with quartz	7	9
Sandstone	present	0	0
Clay	1	0	0
Feldspar	0	2	4

[1] mean of eight samples from Crowley's Ridge, southern Illinois, and western Kentucky. Sandstone and nonmetamorphic quartzite are more abundant on Crowley's Ridge and in southern Illinois than in western Kentucky.

[2] mean of eight samples from Crowley's Ridge, southern Illinois, and western Kentucky.

[3] mean of six samples from Crowley's Ridge.

sediments in Missouri (Guccione, 1983) and Illinois (Willman and Frye, 1970, Table 4).

Age.--The gravel on Crowley's Ridge is tentatively correlated with the Lafayette Gravel from the northern margin of the Mississippi Embayment (Potter, 1955). Both units occur in a similar stratigraphic position: they overlie Paleocene and Eocene sediments and are overlain by Quaternary (Illinoian) loess (Table 1). Both units have a similar limited lithology and mineralogy that does not include glacial outwash sediments. Therefore the gravels on Crowley's Ridge and the Lafayette Gravel are both thought to be preglacial and probably Pliocene in age.

Texture and Sedimentary Structures.--The texture of the sand and gravel is coarse, not well sorted, and subrounded. In gravel beds the subrounded and imbricated clasts are granule to pebble in size, commonly with a medium to coarse sand matrix. Silt and clay are also present in the

TABLE 3. MINERALOGY OF HEAVY MINERAL SAND FRACTION (0.5-0.088 mm) FROM GRAVEL ON CROWLEY'S RIDGE.

	Potter (1955)[1]	Wilkinson (1982)[2]
Zircon	46	31
Staurolite	25	14
Tourmaline	11	18
Kyanite	8	7
Sillimanite	5	15
Rutile	4	6
Topaz	2	trace
Amphibole	0	1
Others	0	8

[1] mean of 8 samples from Crowley's Ridge

[2] mean of 6 samples from Crowley's Ridge

matrix of the upper part of the gravel unit at many localities. Much of the clay may be pedogenic. In sand beds the grains are medium to coarse in size. Some sand beds are well sorted but other beds contain gravel lenses or have gravel along bedding planes. Silt and clay beds, which may contain gravel lenses or be interbedded with gravel, occur in the upper part of the unit at some localities.

Bedding within the gravel and silty clay layers is indistinct but the sand layers are massive or cross-bedded. Thick gravel layers have weak bedding which is horizontal or parallel to the shape of the deposit. Very rarely does the gravel have planar cross bedding or trough cross-stratification. In contrast, the thick sand layers are generally cross bedded. The sets are horizontal beds with planar or broad trough cross-stratification. The cross beds have reactivation surfaces. No ripple marks or ripple surfaces have been identified. Thin gravel layers are horizontal beds or are low-angle epsilon-style cross beds (Allen, 1963). The thin sand layers are similar to and are associated with the thin gravel layers. They are also horizontal beds or are low-angle epsilon-style cross beds. The silt and clay units are massive. Original stratification within these fine-grained strata may have been destroyed by pedogenesis in many units.

The gravel and sand may have any position within the stratigraphic unit, but the silt and clay, where present, are in the upper part of the unit. Where horizontal, thick (16.5 feet or 5 m+) sand and thick gravel beds are present, the sand dominates in the lower part of the unit (for example Liberty Church quarry, Stop 5 and Wittsburg quarry, Stop 2). The contact with the overlying gravel may be erosional or gradational. If the contact is gradational, as at the Wittsburg quarry, the sand beds become thinner and contain more gravel in the upper part of the sand facies. They are overlain by successively more and thicker gravel beds which dominate in the upper gravel facies. Where horizontal, thin (<10 feet or 3 m) sand and gravel beds are present, the beds alternate, and there is no consistent vertical textural trend. Where low-angle dipping beds of sand and gravel occur, gravel is more commonly the upper unit. At some localities (Jonesboro quarry and Paragould quarry) these low-angle dipping beds slope toward deep scour channels which are filled with gravel.

Soils.--Buried soils are locally developed in lower beds of the Pliocene sand and gravel unit. These pedons are weakly developed with A or E and cambic or argillic horizons. Vertical root channels with gleyed halos are present in sandy parent materials. The thickness of the pedons is less than 2.6 feet (0.8 m).

A buried soil developed in the upper bed of the Pliocene gravel is present throughout Crowley's Ridge. Most of the pedons are well developed, oxidized soils. Where the pedon is developed in sand and gravel, yellowish-brown (10YR) E horizons are up to 1.5 feet (45 cm) thick and red (2.5YR) B horizons (argillic), up to 7.9 feet (240 cm) thick, have considerable clay accumulation and soil structure. Where the pedon is developed in a silt and clay, red colors are less dominant and gray mottles occur. These pedons are best developed and preserved on the Ridge south of Jonesboro, where the overlying loess is thick. North of Jonesboro the loess is thinner and has been removed by erosion at many sites. In these erosional sites the buried soil is exhumed, partially stripped, or entirely removed. At several sites north of Jonesboro, Arkansas, including the Liberty Church quarry, Stop 5, two gravel beds separated by a partly truncated, strongly developed red soil are exposed. This stratigraphy is different than that of most exposures of the Pliocene gravel with a soil in a lower bed of gravel for four reasons. First, the soil in a lower gravel is similar in its development to that in the upper bed of the gravel at most other localities on Crowley's Ridge. Second, the upper gravel at these few sites only has a thin brown ground soil developed in it, not a thick red soil similar to that present at most other localities. Third, the soil in the lower bed at these few sites is developed in a gravel, in contrast to the soils developed in lower beds of sand and silty clay at other sites on the Ridge. Finally, the overlying loess is not present at these sites but is present nearby. For these reasons we (Guccione and Rutledge) speculate that the lower gravel at Liberty Church quarry is the Pliocene gravel. The upper gravel may be reworked Pliocene gravel which was deposited prior to the loess or which has been deposited in erosional sites subsequent to loess deposition.

Depositional Environments.--The Pliocene gravels exposed on Crowley's Ridge were deposited dominantly in braided stream and coarse-grained meandering stream environments and, to a lesser extent, on floodplains. Textures, bedding, geometry, and sedimentary structures can be used to distinguish these environments.

Pliocene Braided Stream Facies.

The more laterally continuous coarse-grained sand and gravel bodies with nearly horizontal bedding on Crowley's Ridge were deposited in braided stream environments (Fig. 5A). Most of the gravels were deposited by vertical accretion as lateral, and mid-stream bars. The bars have a slightly scoured or concave lower surface and a flat or gently convex upper surface forming a large pod or sheet of gravel. The gravel is relatively well sorted and grain supported, but has sand trapped in the interstices. The pebbles are imbricated upstream and a crude bedding conforms to the geometry of the gravel body. The bars are stacked vertically and may accumulate to a thickness of 9-12 feet (3-4 m) and may be laterally continuous for 0.6 miles (1 km) (Wittsburg quarry, Stop 2). The orientation of the Pliocene bars has not been determined.

In contrast to gravel bodies in the braided stream facies, sand bodies were deposited by lateral accretion along slip faces (Fig. 5A). Sand bars accumulated as subaqueous dunes in the channels. The sand bodies have horizontal beds with broad trough to planar foreset cross-stratification (Wittsburg quarry, Stop 2 and Harefarm section). Reactivation surfaces occur within the beds and lag pebbles occur along the planes. The beds thin upward from 4 feet (1.2 m) at the base to 0.3 feet (0.1 m) at the upper contact as the water depth diminished. The sand bars are 9-13 feet (3 to 4 km) thick and may be laterally continuous for at least 0.7 km. The orientation of the Pliocene sand bars has not been determined.

The braided stream facies was dominantly an aggradational one. Horizontally bedded sand and gravel layers generally do not have scoured lower contacts and buried soils are preserved between units (Harefarm section). The boundaries between the gravel bars and the sand dunes or bars are commonly gradational with interfingering beds of sand and gravel. Beds of gravel become thicker and more abundant laterally or vertically toward the gravel bar. Conversely, beds of sand become thicker and more abundant laterally or vertically toward the sand dune (Wittsburg quarry, Stop 2 and Church of God quarry). The textures do not have a consistent vertical trend; they may coarsen or fine upward, though coarsening upward sequences are more common.

The braided stream facies is exposed in the southern section of the study area at the Wittsburg quarry, the Church of God quarry, the Vandale quarry, and the Harefarm section (Fig. 4). It is possible that these sections expose only medial bar environments of a wide channel system.

Both the braided stream and meandering stream facies have abandoned channel-fill, upper bar channel-fill, or floodplain sediments which overlie and are laterally adjacent to gravel bars and sand bars (Fig. 5A). The channel fill is dominantly massive, fine-grained sediment which may contain transported organic debris such as logs and

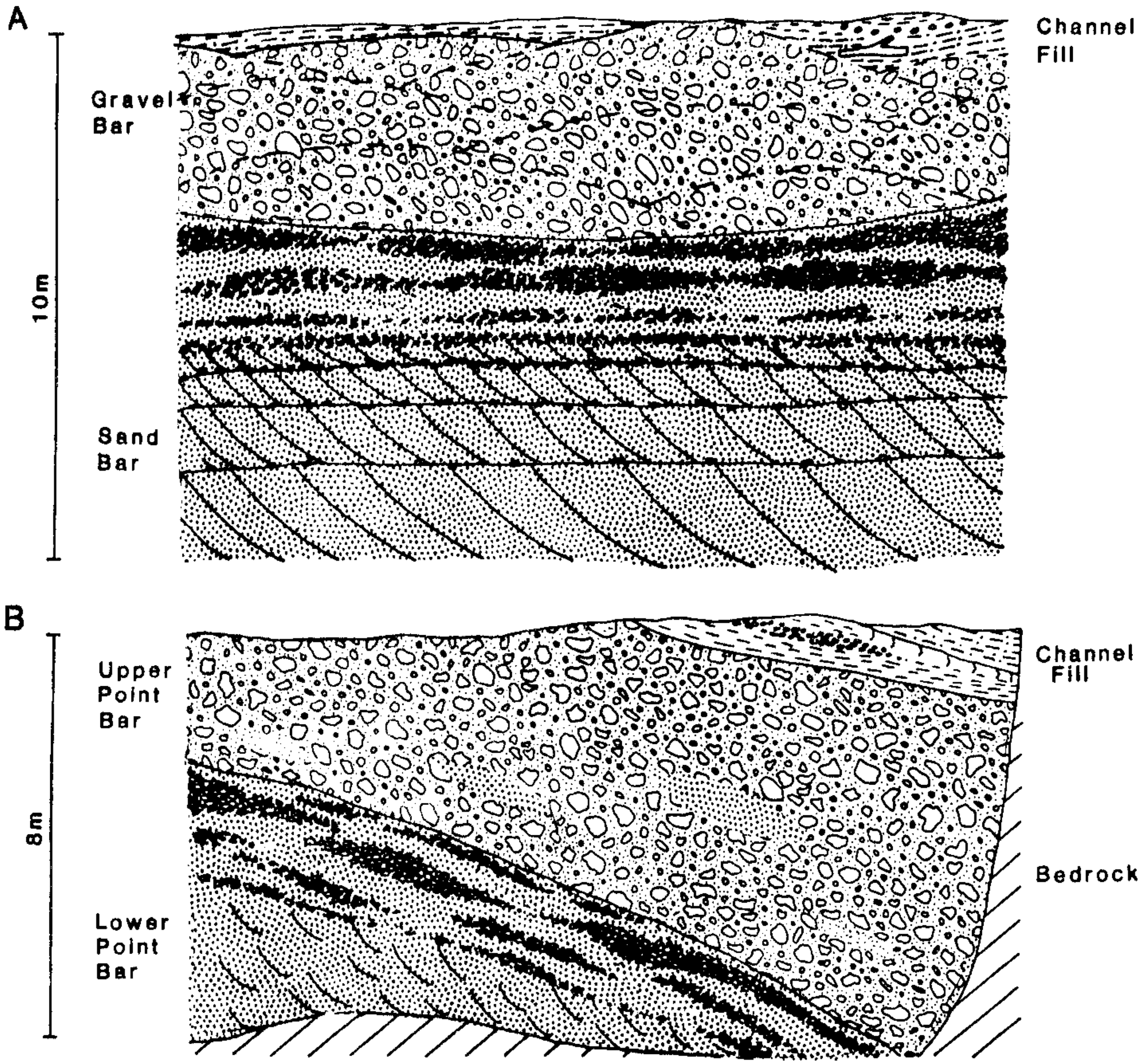


Figure 5. Diagramatic view of sediments and structures of (A) braided stream facies and (B) coarse-grained meandering stream facies exposed on Crowley's Ridge.

roots (Wittsburg quarry, Levesque quarry, and Whitehall quarry). Discontinuous lenses of coarse-grained material were deposited during occasional floods and temporary reoccupation of the channels. Buried soils within this package of sediment also indicate that the fill was episodic (Whitehall quarry). The silt, sand, and gravel beds have low-angle epsilon bedding and the soils developed in them formed on gently sloping surfaces at the margins of gravel bars. The sloping surfaces are due to lateral accretion at the channel-bar margins.

Pliocene Coarse-Grained Meandering Stream Facies.

Thin, gently dipping (20^{o}) interbedded sand and gravel layers were deposited in coarse-grained meandering stream environments (Fig. 5B). These epsilon-bedded units were deposited by lateral accretion without significant erosion along the convex channel margin. The beds dip toward the scour pool with sand beds dominating the lower point bar and gravel beds becoming more dominant on the upper point bar. The upper point bar thickens abruptly into the scour pool of the concave channel margin. The amalgamated gravel bars fill the scour pool to a thickness of 15 to 30 meters (Whitehall quarry, Jonesboro quarry, and Paragould quarry). The scour pool has been cut into bedrock which can have a nearly vertical contact with the gravel. The upper point bar gravels may be overlain by upper bar channel-fill, abandoned channel-fill, or floodplain deposits, similar to those in the braided stream facies.

The meandering stream facies is exposed throughout the study area at the Levesque quarry, the Whitehall quarry, the Jonesboro quarry, the Paragould quarry, and the Marmaduke quarry (Fig. 4). At the Jonesboro and Paragould quarries nearly vertical contacts of the bedrock and the Pliocene gravels are preserved. At the other sites epsilon bedding suggests that the channel was sinuous and lateral accretion dominated. These sections may preserve point bar environments at the margin of a wide channel system. The meandering stream facies at the channel system margins may be laterally continuous with the braided stream facies located in the center of the channel system.

Climate.--Numerous lines of evidence to support a humid Pliocene climate with forested vegetation have been found. First, logs are preserved in the gravels. Second, buried soils, developed between depositional episodes and subsequent to the deposition of the entire unit, have E horizons with root channels and roots preserved. Third, no carbonate pebbles have been identified in the gravels, despite the fact that the gravel deposit is surrounded by and partly derived from Paleozoic carbonates. The absence of the carbonate pebbles supports a humid climate. Fourth, a relative abundance of coarse-grained meandering stream deposits suggests bank stabilization by dense vegetation (McGowen and Garner, 1970). Finally, the absence of abundant cut and fill features and the dominance of laterally continuous bedding suggests a more constant stream flow in a humid climate (Ore, 1964).

Pleistocene Strata

Previous Investigations of Loess Stratigraphy.--Crowley's Ridge and the Pleistocene loesses capping it have been the subject of numerous investigations. Many of these have centered in the area of Wynne, Arkansas, perhaps because of its accessibility to both Memphis and Little Rock. Call (1891) published one of the earlier, and to this date, one of the more extensive investigations of the entire Ridge within Arkansas. He (Call, 1891) and Salisbury (1891) were among the first to discuss the loesses on Crowley's Ridge. Call recognized two loess deposits and a buried soil in the lower deposit. In addition, he suggested the possibility of a third loess on the southern half of the Ridge. Salisbury (1891) also recognized two loesses and the presence of a buried soil with variable degree of development in the lower loess.

More recent workers have identified three loesses: an upper thick loess, a middle thin loess, and a lower thick loess with a buried soil in its upper portion. Most workers have also recognized the loesses to be thicker on the southern portion of the Ridge. Wascher, Humbert, and Cady (1947), though they mainly investigated loesses east of the Mississippi River, identified three loess sheets on Crowley's Ridge. The "Peorian" Loess, the upper unit, they identified as greater than 15 feet (5 m) thick on the southern portion of the Ridge and 10 to 15 feet (3 to 5 m) thick on the northern portion of the Ridge. The middle loess they identified as the "Late Sangamon" and the lowest unit they termed the "Third" loess. They noted that the buried soil developed in the "Third" loess was best expressed east of Wynne, Arkansas. Leighton and Willman (1950) also identified three loesses which they identified (from the upper to the lower unit) as "Peorian", "Farmdale", and "Loveland".

Similar to previous workers, West et al. (1980) recognized an upper thick brownish loess containing the modern soil, a middle thin dark brownish loess, and a lower thick reddish or brownish loess containing a buried soil (Appendix II). They noted the absence of any dates in the loesses of the Ridge and continued the previous correlations but updated them to the terminology in use in the upper Mississippian Valley (Willman and Frye, 1970). They correlated the upper unit with the Peoria Loess, the middle unit with the Roxana Silt, and the lower unit with the Loveland Silt. West et al. (1980) noted that the surface of the buried soil in the Loveland was absent at essentially all locations, thus placing the thin Roxana deposit in the normal surface soil position. They used degree of weathering, as expressed by total Ca and K contents in the coarse silt fraction, with other lines of evidence to show that the Roxana was a separate deposit and not simply the upper part of the buried soil in the Loveland.

Table 4 is a composite description by West et al. (1980) of the deeper loess sites in the Wynne area. It is noteworthy that West et al. (1980) also observed two silty deposits, each containing well developed buried soils, below the Loveland Silt at one location on Crowley's Ridge. Although these deposits are likely loesses, the authors have not dated them or attempted correlations.

Saucier's (1974) report on the lower Mississippi Valley recognizes the loesses of Crowley's Ridge as do the state geology (Haley, 1976) and state soil (Soil Conservation Service and University of Arkansas Agricultural Experiment Station, 1982) maps of Arkansas. However, the state geologic map (Haley, 1976) does not recognize loess on the northern portion of the Ridge (Fig. 6).

Source of Loesses.--A study of the geographic distribution of loess particle size is critical to the identification of the source. Smith (1942) in his classical work in Illinois, reported that the particle size of unweathered loess decreased with the log of distance from the source area. Rutledge et al. (1975) showed that weathered loess exhibited the same relationship if the particle sizes were expressed on a clay-free basis to reduce the effects of weathering and soil formation. They showed that the content of clay-free medium and fine silt increased and the content of clay-free silt decreased with log of distance from a source area.

West et al. (1980) noted that the Mississippi River had flowed on both the east and west sides of Crowley's Ridge during parts of the Pleistocene, and thus presented possible loess sources on both sides of the Ridge. An east-west transect of the Ridge in the Wynne area was used to determine the source area and the corresponding wind direction for each unit. Figure 7 (West et al., 1980) shows clay-free particle size contents of the Peoria Loess and Roxana Silt in the Wynne area as a function of log distance from the flood plain east of Crowley's Ridge. In both loesses the clay-free fine and medium silt contents increase and the clay-free coarse silts decrease with log distance from the flood plain east of the Ridge. These data clearly indicate that the Peoria Loess and Roxana Silt came from the flood plain east of the Ridge and were deposited by winds blowing generally east to west. This does not indicate that this wind direction was the prevailing or dominant one. The more extensive loess deposits in Tennessee east of the Mississippi River flood plains were evidently deposited by the prevailing westerly winds. Later research (Rutledge et al., 1985) has shown by means of particle size and loess thickness that the Peoria Loess of Crowley's Ridge extends over the Ridge and onto the terrace west of the Ridge in the Wynne area. The Roxana is too thin to be traced onto the terraces.

The clay-free silt content of the Loveland as a function of log distance from proposed source areas (Fig. 7) suggests source areas for this

Table 4. Composite description of sites sampled by West et al. 1980 (Revised 1986) Depths given are those of deeper sites sampled.

	Peoria Loess
Ap	0 - 0.3 ft. (0 to 0.1 m); brown (10YR 4/3) silt loam; weak medium granular structure; very friable. (0.32 to 0.33 ft. or .10 to 0.13 m thick)
Bt	0.3 - 1.5 ft. (0.1 to 0.5 m); brown (7.5YR 4/4) silt loam; moderate medium subangular blocky structure; firm; medium discontinuous clay films. (0.49 to 1.57 ft. or 0.15 to 0.48 m thick)
Btx	1.5 - 5.8 ft. (0.5 to 1.9 m); brown (7.5YR 4/4) silt loam; weak medium prisms parting to moderate medium subangular blocky structure; firm and brittle; medium discontinuous clay films. (1.6 to 7.41 ft. or 0.51 to 2.26 m thick)
BC	5.8 - 8.5 ft. (1.9 to 2.8 m); brown to yellowish brown (7.5YR 4/4 to 10YR 5/6) silt loam; weak medium prismatic structure; firm. (2.00 to 3.74 ft. or 0.61 to 1.14 m thick)
C	8.5 - 20.7 ft. (2.8 to 6.8 m); yellowish brown (10YR 5/4) silt loam; massive; friable; weak effervescence with 10% HCl. (2.33 to 14.24 ft. or 0.71 - 4.34 m thick)
	Roxana Silt
2Ab	20.7 - 23.5 ft. (6.8 to 7.7 m); dark brown (7.5YR 4/4, 3/2) silt loam; massive; friable to very firm. (0.92 to 2.76 ft. or 0.76 to 0.97 m thick)
2BAtb	23.5 - 25.9 ft. (7.7 to 8.5 m); reddish brown to dark brown (5YR 4/4 to 7/5YR 4/4) silt loam; weak medium prisms parting to weak medium subangular blocky structure; firm; thin patchy clay films and clay lining some pores. (0.92 to 2.76 ft. or 0.28 to 0.84 m thick)
	Loveland Silt
3Btb	25.9 - 29.9 ft. (8.5 to 9.8 m); reddish brown (5YR 4/4) silt loam-silty clay loam; moderate medium prisms parting to moderate medium to fine angular blocky structure; firm; thick continuous clay films. (1.84 to 4.66 ft. or 0.55 to 1.42 m thick)
3BCtb	29.9 - 31.7 ft. (9.8 to 10.4 m); strong brown (7.5YR 5/6) silt loam; moderate medium prisms parting to moderate medium subangular blocky structure; firm; medium patchy clay films. (1.25 to 5.84 ft. or 0.38 to 1.78 m thick)
3C	31.7 - 49.7 ft. (10.4 to 16.3 m); yellowish brown (10YR 5/6, 5/4) silt loam; massive; friable; no effervescence with 10% HCl. (0 to 21 ft. or 0 to 6.40 m thick)

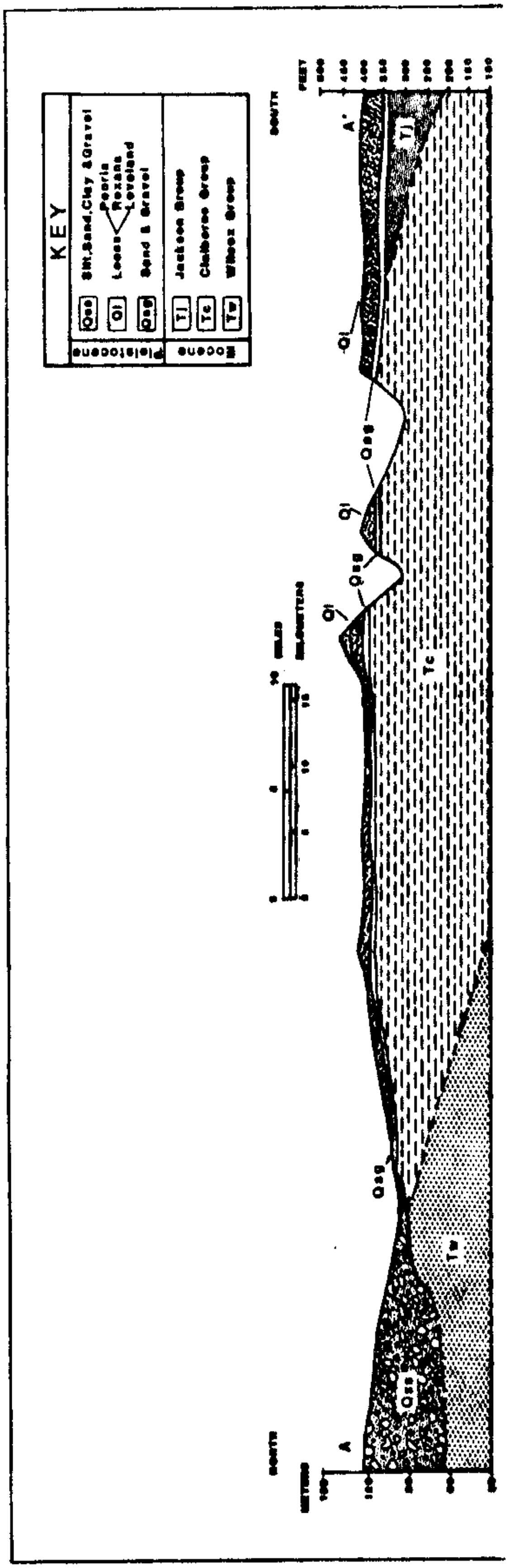


Figure 6. North-south cross section of Crowley's Ridge. Location is shown in Figure 1. Interpretation is by Haley (personal commun., 1984). Datum (for elevations) is mean sea level.

deposit on both the east and west sides of Crowley's Ridge. In contrast to the relationships of particle size and log of distance from a source area for the Peoria and Roxana deposits, neither Figure 7C with a source area on the east nor Figure 7D with a source area on the west show the expected relationships. The high coarse silt contents throughout the transect imply that all sites are relatively close to source areas. The coarse silt content tends to decrease and the medium silt content tends to increase toward the center of the Ridge. These data were interpreted (West et al., 1980) to indicate that the Loveland Silt was deposited from source areas on both sides of Crowley's Ridge.

<u>Distribution of Loess</u>.--The total thickness of the three loesses on Crowley's Ridge ranges markedly. Present information, although more limited than desired, indicates the thickness of the loesses commonly varies together; where one loess is thick, the other two are also likely to be thick. Variable source areas cause some deviation from this general trend. The thickness of the three loesses varies from south to north on the Ridge, with the thicker deposits on the southern portion of the Ridge and the thinner deposits on the northern portion. Call (1891) reports total loess thicknesses of up to 140 feet (43 m) on the southern portion of the Ridge. Deeper deposits on the east side of the Ridge in the Wynne area are 50 feet (16 m) or more thick (Appendix II). The loesses are noticeably thin on the northern portions

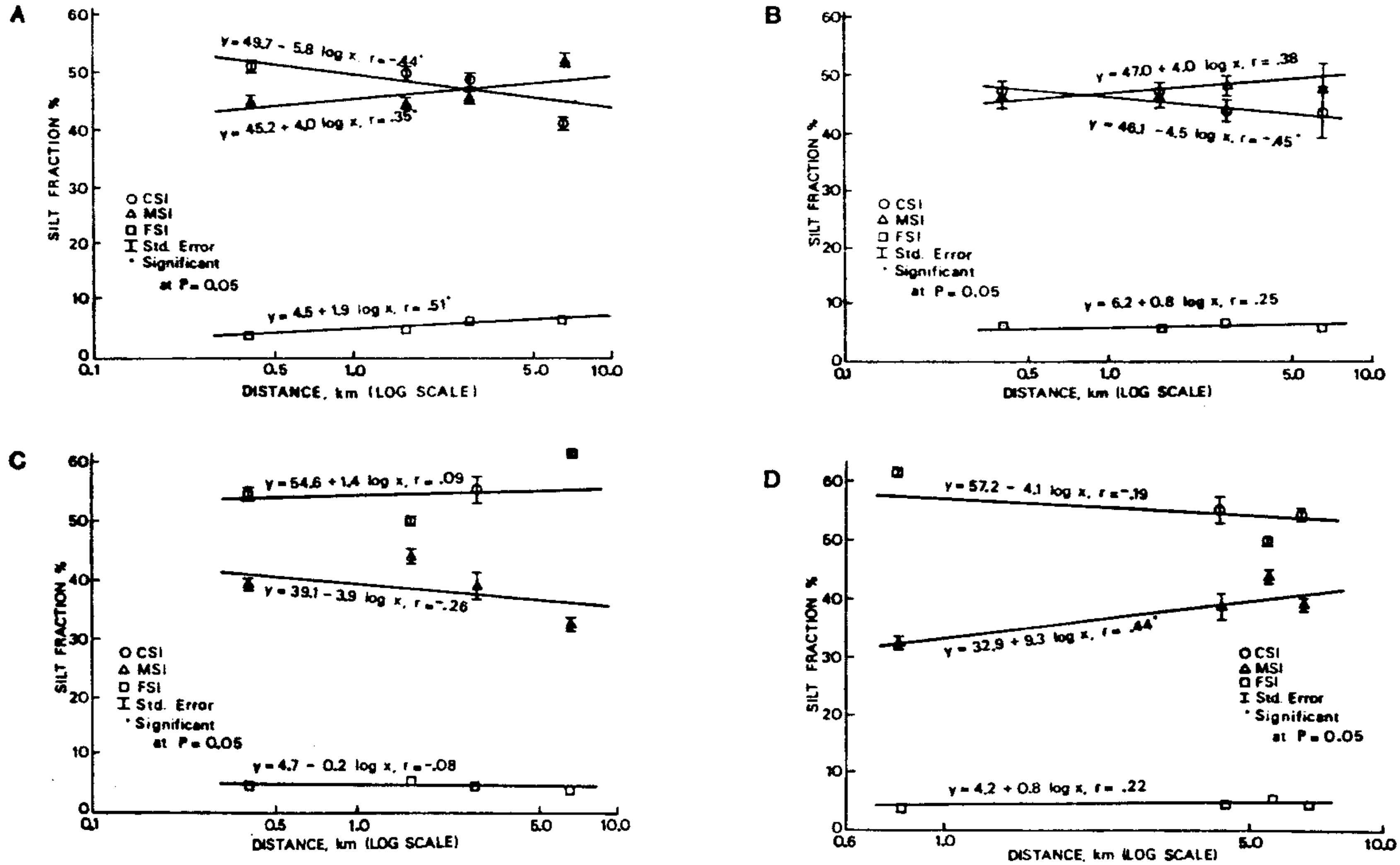


Figure 7. Means of coarse (CSI), medium (MSI), and fine silt (FSI) in Pleistocene loesses in relation to distance from the proposed flood plain source. Proposed source east of Crowley's Ridge: A. Peoria Loess, B. Roxana Silt, C. Loveland Silt. Proposed source west of Crowley's Ridge: D. Loveland Silt.

of the Ridge. Many locations have 2 to 4 feet (about 1 m) of loess and many locations, especially side slopes, do not have a detectable loess deposit. The thickness of the loesses is quite variable over short distances throughout the Ridge. Most of the Ridge is highly dissected and the amount of loess present at a given location is a function of geomorphic stability. Thus the thicker loess deposits are on the more stable landscape positions.

Age of Loess.--West et al. (1980), noting the absence of any dates and the nomenclature of previous workers (Leighton and Willman, 1950), correlated the loess on Crowley's Ridge with the Peoria Loess, the Roxana Silt, and the Loveland Silt (Table 1) of the upper Mississippi Valley (Willman and Frye, 1970). However recent work by Miller et al. (1985) suggests that the Loveland Silt (Illinoian) of Crowley's Ridge correlates with the "Pre-Peoria" loess previously reported in Louisiana and Mississippi. Using thermoluminescence (TL) dating and other parameters Miller et al. (1985) consider the "Pre-Peoria" loess to be Early Wisconsinan.

Canfield (1985) has determined TL dates for the Peoria Loess, Roxana Silt, and Loveland Silt at the Whittsburg section on Crowley's Ridge. His TL date at the base of the Peoria is 19,200 ± 2,650 years. This is stratigraphically above a radiocarbon date of 25,700 ± 710 years (Illinois State Geological Survey) obtained for the upper part of the Roxana deposit (Donald E. McKay, personal commun., 1986). Canfield obtained a TL date of 45,600 ± 9,000 years for the lower part of the Roxana Silt. A sample of Loveland Silt "below the leached zone" produced a regeneration TL date of 85,300 ± 7,200 years which Canfield noted "...may be too young though no sensitivity change was noted, suggesting that the date should be reasonable." Canfield (1985) noted that, "...the total bleach method yielded a date of 111,550 ± 11,600 years (for the same sample) which may be too old...". These TL dates (Canfield, 1985) of 85,300 ± 7,200 and 111,550 ± 11,600 years for the Loveland deposit on Crowley's Ridge compare to a TL date (Norton and Bradford, 1985) for the Loveland Silt near the type location in Iowa of 89,200 ± 9,230 years. Canfield sampled the Loveland Silt in Nebraska and obtained a TL regeneration date of 82,700 ± 7,260 years and a TL total bleach method date of 121,000 ± 15,400 years. Johnson et al. (1984), as reported by Miller et al. (1985), obtained dates of 75,000 to 95,000 years for the "Pre-Peoria" loess at Vicksburg and 120,000 to 135,000 years for the Loveland deposit also at Vicksburg. We (Guccione and Rutledge) would like to see more TL dates and a stabilization of TL methods before attempting a correlation.

ROAD LOG

Drive on I-40 west from Memphis, TN to Arkansas Hwy 1 at Forrest City.

Drive 2 miles (3.2 km) south on Hwy 1.

Turn east on U.S. Hwy 70 and continue 2.9 miles (4.7 km) to Crow Creek Bridge.

STOP 1-Crow Creek section is the west valley wall of Crow Creek, just north of Hwy 70.

Return to I-40.

Drive 1 mile (1.6 km) east on I-40.

Exit north on Arkansas Hwy 284.

Drive 13.8 miles (22.2 km) north on Hwy 284.

Turn east on a gravel road at Harris Chapel Baptist Church. This is 2.2 miles (3.5 km) north of the entrance to Village Creek State Park.

Drive 2.5 miles (4.0 km) on the main gravel road to a series of gravel pits and a road cut.

STOP 2-Wittsburg section is a road cut in this quarry. Additional exposures are available along the quarry faces and in gullies.

Continue east on gravel road 0.4 miles (0.6 km) to the intersection of Arkansas Hwy 163 (gravel road) at east edge of Crowley's Ridge.

Turn north on Hwy 163 and drive 3.8 miles (6.1 km) to the Copperas Creek Bridge.

STOP 3-Copperas Creek section is the south valley wall of Copperas Creek, just east of the bridge.

Continue north 0.4 miles (0.6 km) on Hwy 163 to Levesque, AR.

Turn west on Arkansas Hwy 64 and drive 4.7 miles (7.6 km) to Arkansas Hwy 1 in Wynne, AR.

Turn north on Hwy 1 and drive approximately 50 miles (80 km) to Jonesboro, AR. At the southeast edge of Jonesboro Hwy 1 becomes U.S. Hwy 49. Continue driving north 3.3 miles (5.3 km) on Hwy 49 to Business Route 49.

Turn west on B.R. 49 and drive 2.3 miles into Jonesboro.

At Arkansas Hwy 141 turn north and drive 14 miles (22.5 km) to Zion Church.

Turn east on gravel road and drive 0.7 miles (1.1 km) to Mt. Zion Baptist Church.

Turn south onto a gravel road and drive 0.4 miles (0.6 km) to a low water bridge.

Walk 0.2 miles (0.3 km) upstream (east).

STOP 4-Poplar Creek section is exposed along the north valley wall. The landowner requests that visitors stay within the creek bed.

Continue south on gravel road for 0.9 miles (1.4 km) to Arkansas Hwy 358.

Turn east on Hwy 358 and drive 3.6 miles (5.8 km) to Arkansas Hwy 351.

Turn south on Hwy 351 and drive 1.5 miles (2.4 km) to a road cut which is 0.7 miles (1.1 km) south of Liberty Church and 0.1 mile (0.1 km) south of a gravel road intersection.

STOP 5A-Liberty Church road cut is an exposure on the west side of the road.

Return north 0.1 mile (0.1 km) to gravel road intersection with Hwy 351.

Turn east on gravel road and drive 1.9 miles (3.1 km) to quarry entrance on north side of road. Walk into quarry.

STOP 5B-Liberty Church quarry.

Continue east on gravel road to Arkansas Hwy 1 just south of Paragould.

Return to Memphis, TN.

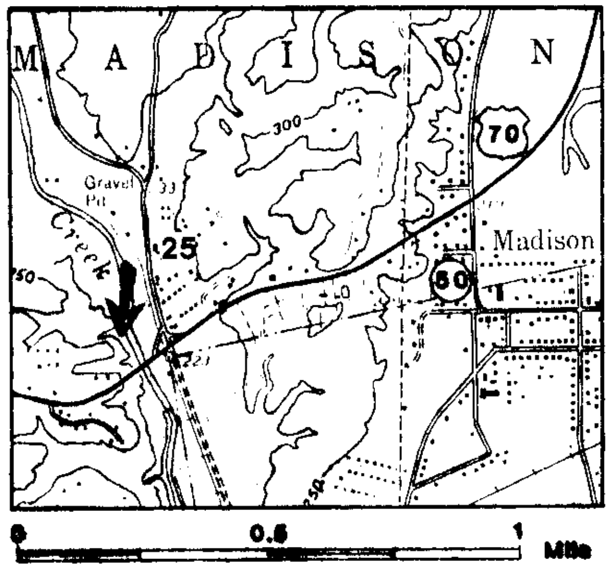


Figure 8. Map showing location of Crow Creek section, T5N, R3E (from Madison 7½ minute quadrangle).

DESCRIBED SECTIONS

Crow Creek Section

SE 1/4, NE 1/4, SW 1/4, Sec 25, T5N, R3E, St. Francis County Arkansas (Madison 7 1/2 minute quadrangle) (Fig. 8).

Exit I-40 on Arkansas Hwy 1 at Forrest City Arkansas. Drive 2 miles (3.2 km) south on Hwy 1. Turn east on Arkansas Hwy 70 and continue 2.9 miles (4.7 km) to Crow Creek bridge. The outcrop is the west valley wall of Crow Creek, just north of Hwy 70.

The section exposes both marine fossiliferous sandy marl and nonmarine sediments of the Jackson Group.

About 14 feet (4 m) of the Jackson Group are exposed at the base of the stream cut and along the stream bed. These sediments are of two types. The lower marine unit is 5 to 8 feet (2 to 3 m) of gray marl with fine sand, mica, and numerous fossils. The invertebrate fossils include pelecypod and gastropod shells and shell fragments. Diverse vertebrate fossils include sharks' teeth and washed-in land mammals (Westgate, 1982). The marl was deposited in a lagoon or bay formed by the last marine transgression within Arkansas (Wilbert, 1953).

The upper nonmarine unit of the Jackson Group at this outcrop is 4 to 7 feet (1 to 2 m) thick and ranges from brown, very fine, sandy silt to gray clay. It may be a deltaic crevasse splay or a sheet deposit filling the bay or lagoon. This rapid sediment influx buried and killed the oyster beds.

The gravels within the stream bed are reworked Pliocene gravels which overlie the Tertiary units on Crowley's Ridge.

Wittsburg Section

NE 1/4, Sec 32, T7N, R4E, Cross County, Arkansas (Wittsburg 7 1/2 minute quadrangle) (Fig. 9).

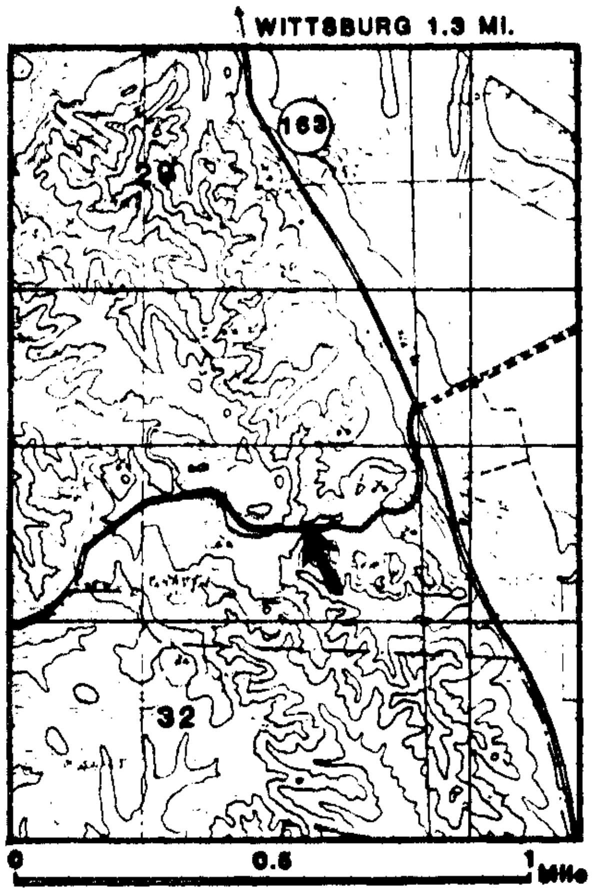


Figure 9. Map showing location of Wittsburg section, T7N, R4E (from Wittsburg 7½ minute quadrangle).

Drive north of Forrest City, Arkansas or south of Wynne, Arkansas on Arkansas Hwy 284. At Harris Chapel Baptist Church (2.2 miles or 3.5 km north of the entrance to Village Creek State Park) turn east on a gravel road. Continue 2.5 miles (4.0 km) on the main gravel road. The described exposure (Fig. 10) is a road cut but additional quarry and gully exposures are also available for examination.

This series of gravel pits, road cuts, and gullies is one of the larger and most complete exposures of Tertiary and Quaternary sediments on Crowley's Ridge. The great lateral and vertical extent of the exposures provides a three dimensional view of the deposits and the buried soils developed within them.

At the base of the section the Eocene Claiborne Group is exposed along the east edge of the exposure (Fig. 10). This unit includes fine sand, clay, silt, and lignite. The fine sand contains thin continuous horizontal laminae of gray clay. Overlying the fine sand is a massive gray silty clay. The contact between the two layers is undulating or hummocky because the silty clay fills in wedge-shaped depressions within the underlying sand. Adjacent to these depressions the laminations of clay are displaced by normal micro faults with the central "graben" being in-filled with silty clay. The infilled material may have a rounded lower margin but the displacement and blurring of the laminations continues to a greater depth becoming narrower and eventually undetectable at a maximum depth of 6 feet (2 m) below the top of the wedge. The origin of these wedges is unknown. Our present interpretation is that they are root casts, but we are open to

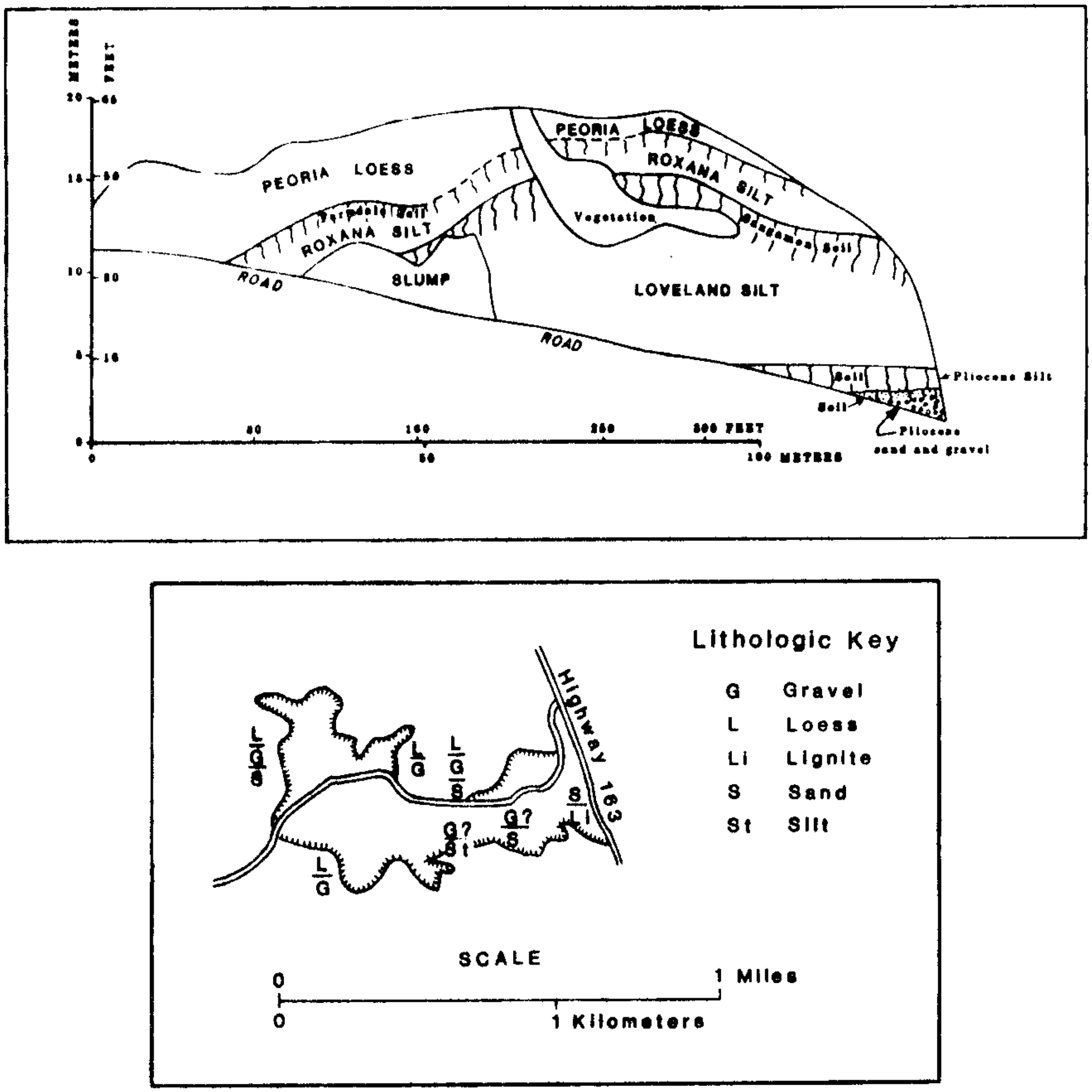


Figure 10. Sketch of section exposed on north side of gravel road in the Wittsburg quarry and sketch map of quarry showing sequences exposed at various points. Vertical exaggeration of section, 2.5X.

suggestions. Near the base of the gray silty clay is a thin lignite. Its surface is depressed and it thickens above some of the larger wedges but is horizontal and is unaffected by the presence of other wedges underlying it.

Overlying the Eocene silty clay at the Wittsburg section is a braided stream facies sand bar deposit Pliocene sand and gravel (Fig. 5A). There is no apparent channel scouring of the Eocene clay and the unconformity is approximately a horizontal planar surface. The medium to coarse graded sands have tabular to broad trough cross-stratification. The cross-bedded sets thin upward from 4 feet (1.2 m) at the base to 0.3 feet (0.1 m) at the top of the unit. The total thickness is estimated to be 80 feet (24 m) but considerably less than that (15 feet or 4.6 m) is exposed at any single vertical section. The sand is exposed on the east and north portions of the exposure (Fig. 10).

Lateral to the sand bar facies is a channel fill or floodplain facies. This is a massive silt with lenses of sand and gravel. The unit also contains wood fragments including logs. Amino acid dating of some wood from this site indicates that the amino acid content is very low and the wood is "very old" (N. W. Rutter, personal commun., 1986). The thickness of the silt is in excess of 10 feet (3 m). The silt is exposed in a gully approximately in the center of the exposure (Fig. 10). It may also underlie the gravel in the southwest portion of the exposure.

Above the sand bar facies and the channel fill or floodplain facies is a gravel bar facies. This is a massive to crudely bedded gravel with a few lenses of sand. The gravel layers become less abundant and the sand layers become more abundant near the gradational contact with the sand below and toward the northwest portion of the exposure. The gravel is 23 feet (7 m) thick and was probably a continuous deposit across the entire exposure prior to mining.

A soil developed on the gravel is truncated at the road cut exposure (Fig. 10). It has not been eroded in the gravel pits to the south and the west of the road cut.

The three Pleistocene loesses of Crowley's Ridge are well exhibited at this site. The lower unit, Loveland Silt, is overlain by the relatively thin Roxana Silt, which is overlain by the Peoria Loess. As shown in Figure 10, the thickness of the units varies along the face of the exposure. The data of West et al. (1980) from a site 2 1/2 miles north (Appendix II) are assumed to apply reasonably well to this section.

The base of the Loveland Silt is a brownish, massive silt loam with about 10% clay. It contains fragments of snail shells and is weakly calcareous in some locations but not in others. It contains carbonate concretions which are noticeable on the face. The upper part of the Loveland contains the subsoil (Bt horizon and argillic horizon) of the buried soil. The Bt horizon is a brownish to reddish silty clay loam (clay content approximately 28%) with prismatic structures, and evident clay films on about 70% of the ped surfaces. It is noncalcareous.

The Roxana Silt section shows some layering. It is a brownish to dark brownish silt loam with clay contents increasing with depth, from about 12% to about 22%. It is noncalcareous.

The base of the Peoria Loess is a brownish, massive silt loam with about 10% clay. It is noncalcareous in most parts but contains some carbonate concretions and an occasional snail shell fragment. The similarity between the base of the Peoria Loess and the base of the Loveland Silt is noteworthy. The surface of the Peoria section, including the modern soil, has been removed by mining equipment.

As discussed earlier in this guide, all three of these loesses came from source areas in the flood plain to the east. The Loveland evidently also had a source in the flood plain west of Crowley's Ridge.

Copperas Creek Section

NE 1/4, SE 1/4, SE 1/4, Survey No. 498, Cross County, Arkansas (Wittsburg 7 1/2 minute quadrangle) (Fig. 11).

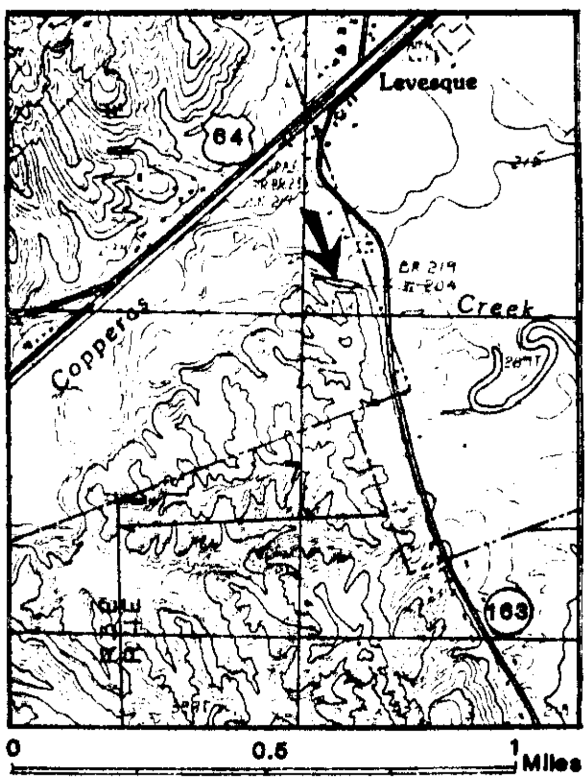


Figure 11. Map showing location of Copperas Creek section, Survey no. 498 (from Wittsburg 7½ minute quadrangle).

Drive 3.8 miles (6.1 km) north of the Wittsburg section or 0.4 miles (0.6 km) south of Levesque, Arkansas on gravel highway 163 to the Copperas Creek bridge. The outcrop is the south valley wall of Copperas Creek, just east of the bridge.

The section exposes approximately 80 feet (25 m) of Claiborne Group sands and clays at the base, 7 feet (2 m) of overlying Pliocene gravel, and 13 feet (4 m) of Pleistocene loess above the gravel (Fig. 12). The Claiborne Group consists of coastal sediments which have been divided into six zones in ascending order.

Zone 1 is interlaminated clay and sand. The clay laminae contain fossil leaves and twigs. The sand laminae contain fossil root casts and burrows. These bedding features and trace fossils suggest that the environment of deposition was a delta or a coastal marsh. The clayey horizons supported vegetation and were buried by the sandy strata during recurrent flooding.

Zone 2 is approximately 4 feet (1 m) of mottled sandy clay with abundant burrows (?) and lignite fragments. This zone may have been deposited during a larger flood event when abundant clastics and transported pieces of wood (lignite) filled in the marsh.

Zone 3 is approximately 2 feet (0.6 m) of iron-cemented, cross-bedded sands with rip-up clay clasts and layers. This zone may have been deposited in a distributary channel.

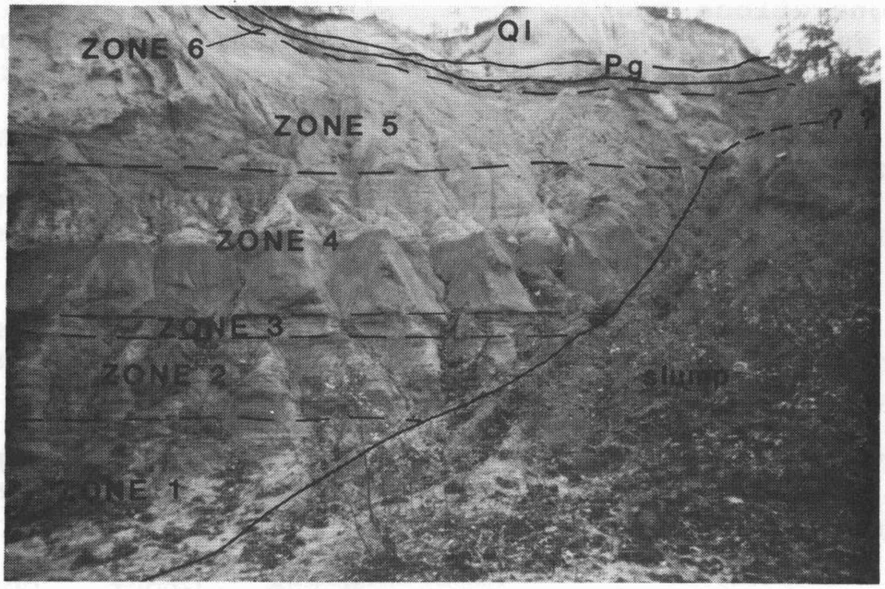


Figure 12. Photograph of Copperas Creek section looking south. Zones 1-6 are the Claiborne Group. Pliocene sand and gravel (Pg), and Quaternary loess (Ql).

Zone 4 is approximately 20 feet (6 m) of sand. The lower portion of the zone is sandy clay which is gradational with the underlying sand and contains selenite crystals. This sandy clay may have been deposited in a brackish water lagoon. The upper portion of zone 4 is fine sand. It may have been deposited where a distributary channel or a bar prograded over the underlying lagoon or bay deposits.

Zone 5, the thickest layer, is approximately 25 feet (8 m) of mottled sandy clay and sand with some iron-cemented layers. These materials are the youngest unweathered Claiborne sediments and may have been deposited in a lagoon or bay environment which formed during a marine transgression.

Zone 6 is a weathering zone about 6 feet (2 m) thick developed in the lagoonal sand and clay of zone 5. It is heavily iron-cemented.

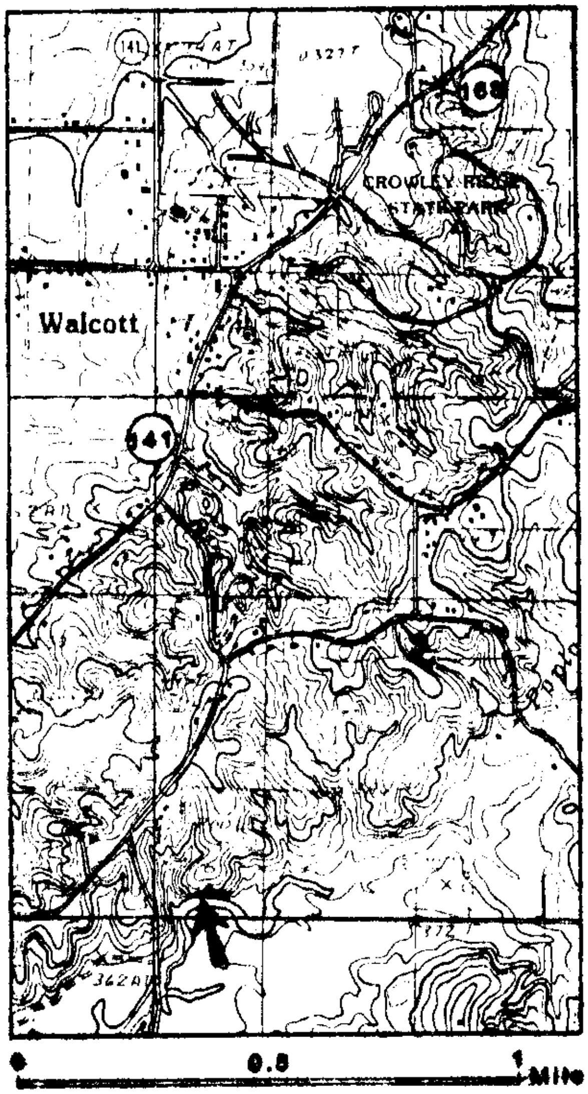
Overlying the Claiborne Group are approximately 7 feet (2 m) of fluvial Pliocene gravel. The dominantly chert cobbles and boulders have a red, silty clay matrix.

Approximately 13 feet (4 m) of undifferentiated Pleistocene loess caps the exposure. The unit is a massive brown silt.

Poplar Creek Section

SE 1/4, SW 1/4, SW 1/4, Sec 9, T16N, R4E, Greene County, Arkansas (Walcott 7 1/2 minute quadrangle) (Fig. 13).

Drive 1 mile (1.6 km) south of Walcott, Arkansas on Arkansas Hwy 141 to Mt. Zion Church. Turn east on gravel



Figu.e 13. Map showing location of Poplar Creek section, T6N, R4E (from Walcott 7½ minute quadrangle).

road and continue 0.7 miles (1.1 km) to Mt. Zion Baptist Camp. Turn south onto gravel road and drive 0.4 miles (0.6 km) to low water bridge. Walk 0.2 miles (0.3 km) upstream (east) to outcrop on north valley wall. The landowner requests that visitors stay within the creek bed.

This stream cut exposes 41 feet (12 m) of Wilcox Group sands and clays. Overlying the Wilcox Group is 6 feet (2 m) of Pliocene sand and gravel capped by 13 feet (4 m) of undifferentiated Pleistocene loess (Fig. 14).

The Wilcox Group consists of alternating beds of fluvial sands and clays. The sand beds, 0.5 to 1.0 feet (0.2 to 0.3 m) thick, are medium-grained, subrounded, and planar or cross-stratified point bar deposits (Fig. 15). The cross-stratified layers contain carbonaceous material and ripup clasts of the underlying clay. The clay beds, 0.1 to 0.5 feet (0.1 m) thick, are white to maroon, sandy, and kaolinitic slack water deposits. The sand units thin and the clay units become thicker and more abundant in the upper part of the section.

Overlying the Wilcox Group is approximately 4 feet (1 m) of fluvial Pliocene gravel and sand (Fig. 14). At the base is a weakly-bedded and imbricated gravel which contains chert cobbles and boulders and a reddish-brown to orange, coarse-grained, sand matrix. The gravel grades upward to a weakly-bedded, medium-grained sand which is approximately 2 feet (1 m) thick. The sand laterally fines and thickens.

The upper unit at this section is approximately 13 feet (4 m) of undifferentiated Pleistocene loess which forms a vertical bluff. At the bas is brown noncalcareous silt containing disseminated pebbles and sand. The coarser materials are absent in the middle and upper part of the unit. We (Guccione and Rutledge) correlate this sequence of sand and gravel and overlying silt with similar Pliocene

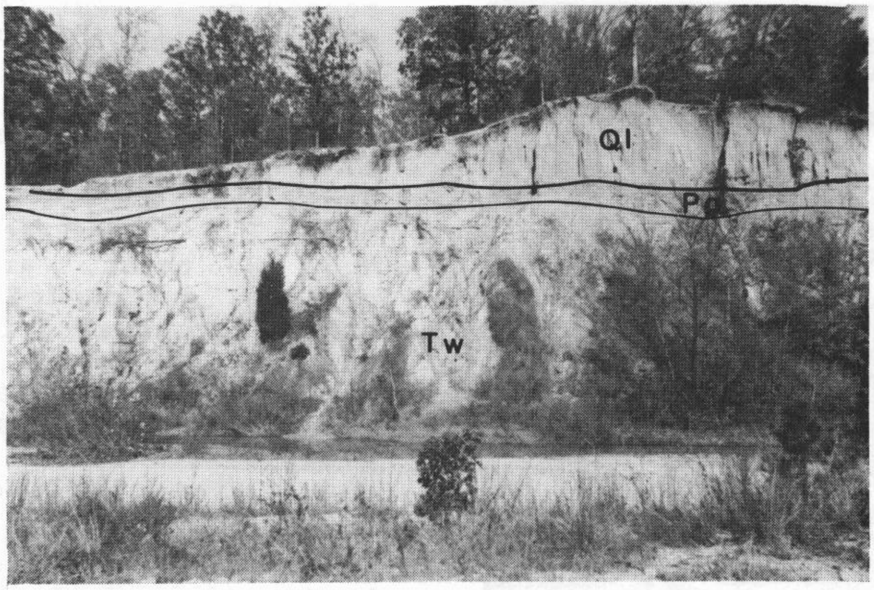


Figure 14. Photograph of Poplar Creek section looking north. Units exposed are Wilcox Group (TW), Pliocene sand and gravel (Pg), and Quaternary loess (Ql).

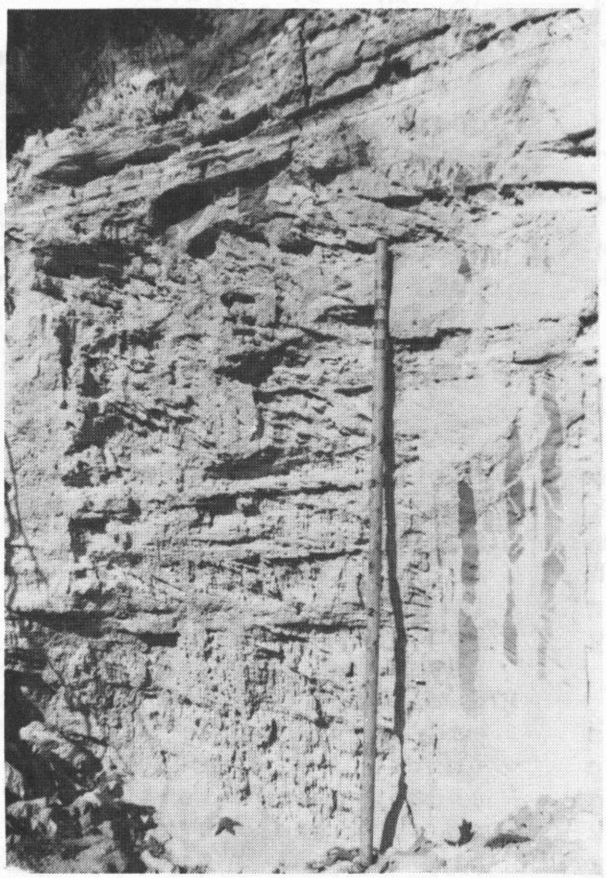


Figure 15. Photograph of cross-bedded sand and interbedded kaolinitic clay in Wilcox Group at Poplar Creek. Staff is 5 feet (1.5 m) long.

sand and gravel and Pleistocene loess found on the southern portion of the Ridge. In contrast, Haley (personal commun.) interprets these units to be younger than all the Pleistocene strata south of the town of Ridge, Arkansas.

Holocene deposits are exposed upstream (east) along the south bank. These gravels, sands, and silts with a weak soil form a 16.7-foot (15.1 m) high terrace which is presently being eroded. The exposure consists of four units. The basal unit is sand and gravel 3 feet (1 m) thick. It is composed of chert pebbles and cobbles with medium to coarse sand lenses which are reddish brown, stratified, and noncalcareous. Above the gravel is 2.9 feet (0.9 m) of massive yellowish-brown to gray silt. Overlying the massive silt is 3-6 feet (1-2 m) of trough cross-stratified coarse sand and granule-to pebble-sized gravel. The upper portion of this exposure is 6.9 feet (2.1 m) of massive light brown silt which is sandy at its base. The ground soil, with a cambic horizon, is developed in the silt.

Liberty Church Road Section

NW 1/4, SE 1/4, NW 1/4, Sec 25, T16N, R4E, Greene County, Arkansas (Brookland 7 1/2 minute quadrangle) (Fig. 16).

Drive on Arkansas Hwy 351 1.5 miles (2.4 km) south of the intersection of Arkansas Hwys 358 and 351 between Paragould and Walcott, Arkansas. The road cut is on the west side of the road, 0.7 miles (1.1 km) south of Liberty Church and 0.1 miles (0.1 km) south of a gravel road and Hwy 351 intersection.

This is one of the thicker loess sections (about 3 m or 10 feet exposed and base not identified) on this portion of Crowley's Ridge. Its presence here is the result of less dissection along the divide and perhaps of a more productive source area.

The base of the cut exposes the lower part of the buried soil (BCtb) in the Loveland Silt. It is brownish silt loam with about 16% clay, and weak soil structure, and a few prominant clay films. Above this is the maximum Bt horizon of the buried soil. It is a brownish to reddish silty clay loam with evident angular blocky structure, about 90% of which is covered with prominant clay film. Clay content is about 37%. This buried Bt horizon is the strongest evidence of multiple loesses at this site. It is assumed to be too deep to have developed in association with the modern soil. It also does not follow the topography of the present surface, rather it is more level.

Above the buried Bt horizon are more Bt horizons (reddish and brownish with about 25% clay) which are overlain by the surface horizon, a brownish silt with about 10% clay. These horizons may consist of one or more loesses. They have been altered by soil development to the extent that soil properties dominate the horizons.

Liberty Church Quarry Section

NW 1/4, SE 1/4, Sec 19, T16N, R5E, Greene County, Arkansas (Paragould West and Brookland 7 1/2 minute quadrangles) (Fig. 16).

Turn around and drive 0.2 miles (0.3 km) north from the Liberty Church road cut section on Arkansas Hwy 351 to the gravel road intersection. Turn east and drive 1.9 miles (3.0 km). The entrance to the gravel pit is on the north side of the road.

At this section two Pliocene sand and gravel units are exposed. The lower red gravel is 9.0 feet (2.7 m) thick and the upper brown gravel is 10 feet (3 m) thick. The Pleistocene loess, which presumably was deposited throughout the area and is exposed 2.0 miles (3.0 km) to the west, is not preserved at this site.

In the lower portion of the exposure is a red sand and gravel unit. A cross-bedded medium-to coarse-grained sand containing Wilcox Group clay balls is exposed at the base of the quarry. The presence of these poorly lithified balls indicates that bedrock is probably just below the quarry floor. The upper portion of the sand is interbedded with lenses of the overlying red gravel. The sand is thickest at the south end of the quarry and the overlying gravel beds dip northwest at a low angle of about 12°. The gravel has a pedogenic red clayey sand matrix. The upper part of the buried soil has been partly truncated by the overlying brown gravel. A

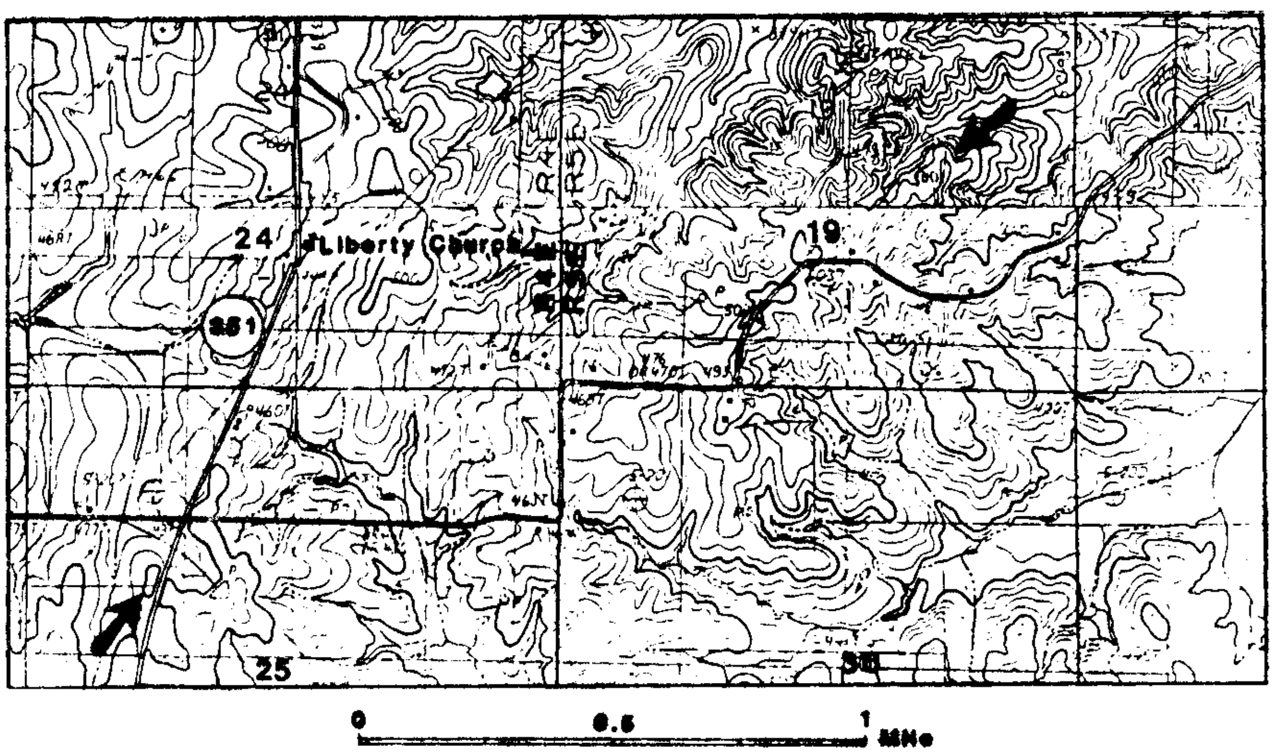


Figure 16. Map showing locations of Liberty Church Road, T16N, R4E, and Liberty Church quarry sections, T16N, R5E (from Brookland and Paragould West 7½ minute quadrangles).

discontinuous white "glossic" horizon at the contact of the two gravels may be a ground water feature at the lithologic boundary.

Overlying the red gravel is 10 feet (3 m) of brown gravel. It has a 1-foot (0.3 m) thick, planar cross-stratified sand and granule bed at the base. The overlying gravel is coarser-grained and horizontally bedded. The reddish-brown ground soil is developed in a thin silt (reworked loess?) in the upper gravel.

The age of the two gravel units at this site is debatable. We (Guccione and Rutledge) correlate the lower sand and gravel with the Pliocene sand and gravel exposed in the southern portion of the Ridge at, for example, the Wittsburg section, Stop 2. This correlation is based on the similar lithology, stratigraphic position, (topographically below and presumably stratigraphically below the loesses at the Liberty Church road cut section 2 miles (3 km) east), and the weathered condition of the gravel at the Liberty Church quarry, at the Wittsburg quarry, and at numerous localities along the Ridge. The age of the upper gravel is more problematic. We have seen two gravel units separated by a soil at only two sites on Crowley's Ridge. This upper gravel has a brown matrix suggesting that it is less weathered than the underlying red gravel, which is widely exposed on the Ridge. At both erosional sites only a thin silt overlies the gravel and is presumably not loess in place. Therefore, the stratigraphic position of the gravel with respect to the loess is uncertain. It may be a Pliocene gravel older than the loess or it may be a reworked Pliocene gravel either older or younger than the loess. We (Guccione and Rutledge) tentatively support the interpretation of a reworked gravel because of the less intense weathering and oxidation in the brown or tan gravel, compared to that in the underlying red Pliocene gravel.

The lower Pliocene gravel at the Liberty Church quarry section is interpreted to be a coarse-grained meandering stream point bar deposit. The units have the epsilon bedding characteristic of lateral deposition. The sand, a lower point bar, grades upward to a gravel, an upper point bar.

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Appendix I
Some Pliocene Sand and Gravel Locations

Section	Location	7½ minute Quadrangle
Church of God	SE¼, NW¼, NE¼ Sec. 7 T8N, R4E, Cross Co, AR	Princedale
Harefarm	Center NW¼, SE¼, Sec 30, T8N, R4E, Cross Co, AR	Princedale
Jonesboro Quarry	Center S½, Sec 15, and Center N½, Sec 22, T14N, R3E, Craighead Co, AR	Jonesboro
Levesque	NW¼, NW¼, SE¼, Sec 18, T7N, R4E, Cross Co., AR	Wittsburg
Liberty Church Gravel Pit	NW¼, SE¼, Sec 19, T16N, R5E, Greene Co, AR	Paragould West and Brookland
Liberty Church Road Cut	NW¼, SE¼, NW¼, Sec 25, T16N, R4E, Greene Co, AR	Brookland
Marmaduke	NW¼, NE¼, SW¼, Sec 16, T18N, R6E, Greene Co, AR	Marmaduke
Paragould	SW¼, SW¼, SEP, Sec 10, T16N, R5E, Greene Co, AR	Paragould West
Vanndale	NW¼, SW¼, SE¼, Sec 23, T8N, R3E, Cross Co., AR	Princedale
Wittsburg	NE¼, Sec 32, T7N, R4E Cross Co., AR	Wittsburg
Whitehall	Center W½, Sec. 18, T10N R4E, Pointsett Co., AR	Harrisburg and Cherry Valley East
Wineland	NW¼, NE¼, SE¼, Sec 19, T15N, R4E, Craighead Co, AR	Lorado

Appendix 2

Grain size distribution and elemental composition of site 73CS01 of West et al. (1980) located on the east side of Crowley's Ridge east of Wynne, Arkansas.

Deposit	Horizon	Depth Inches	Depth cm	Particle size distribution in percent: USDA fine earth basis: Sand (mm) VFS 0.1–0.05	Sand (mm) TS 2–0.05	Silt (µm) CSI 50–20	Silt (µm) MSI 20–5	Silt (µm) FSI 5–2	Silt (µm) TSI 50–2	Clay <2 µm	Clay-free basis: Silt (µm) CSI 50–20	Silt (µm) MSI 20–5	Silt (µm) FSI 5–2	Elemental Composition: % of CSI fraction Ca	K
								Site 73CS01							
Peoria Loess	BE	0– 9	0– 23	0.7	0.9	43.8	34.8	2.4	81.0	18.1	53.5	42.5	2.9	0.60	1.79
	Bt	9– 15	23– 38	0.5	0.7	44.4	34.3	3.8	82.5	16.8	53.4	41.2	4.6	0.54	1.76
	Bx1	15– 24	38– 61	0.5	0.6	46.0	34.1	3.9	84.0	15.4	54.4	40.3	4.6	0.64	1.76
	Bx2	24– 35	61– 89	0.6	0.8	47.1	35.1	2.3	84.5	14.7	55.2	41.1	2.7	0.65	1.81
	BC1	35– 47	89–119	0.7	0.8	49.7	33.6	2.6	85.9	13.3	57.3	38.8	3.0	0.67	1.82
	BC2	47– 59	119–150	0.6	0.7	45.4	36.6	3.5	85.5	13.8	52.7	42.5	4.1	0.70	1.78
	BC2	59– 72	150–183	0.4	0.5	41.5	38.1	4.0	83.6	15.9	49.3	45.3	4.8	0.76	1.79
	C1	72– 84	183–213	0.4	0.6	38.9	39.3	5.7	83.9	15.5	46.0	46.5	6.7	0.76	1.76
	C1	84– 95	213–241	0.5	0.6	40.2	42.1	2.5	84.8	14.6	47.1	49.3	2.9	0.75	1.81
	C2	95–107	241–272	0.6	0.6	44.6	36.2	4.9	85.7	13.7	51.7	41.9	5.7	0.79	1.77
	C2	107–119	272–302	0.6	0.6	46.4	37.7	3.5	87.6	11.8	52.6	42.7	4.0	0.82	1.75
	C3	119–131	302–333	0.5	0.5	49.4	35.0	4.9	89.3	10.2	55.0	39.0	5.5	0.81	1.75
	C4	131–143	333–363	0.5	0.7	51.6	34.4	3.8	89.8	9.5	57.0	38.0	4.2	0.80	1.74
	C4	143–155	363–394	0.4	0.4	48.6	39.9	1.9	90.4	9.2	53.5	43.9	2.1	0.77	1.66
	C4	155–167	394–424	0.3	0.3	41.7	45.6	2.9	90.2	9.5	46.1	50.4	3.2	0.83	1.74
	C4	167–179	424–455	0.5	0.5	48.7	39.4	1.6	89.7	9.8	54.0	43.7	1.8	0.80	1.74
	C4	179–191	455–485	0.3	0.3	47.9	38.6	3.0	89.5	10.2	53.3	43.0	3.3	0.78	1.75
	C4	191–203	485–516	0.3	0.3	41.7	43.8	3.0	88.5	11.2	47.0	49.3	3.4	0.79	1.78
	C4	203–215	516–546	0.5	0.6	44.9	40.4	2.4	87.7	11.7	50.9	45.8	2.7	0.80	1.77
	C4	215–227	546–577	0.2	0.3	38.3	45.2	4.5	88.0	11.7	43.4	51.2	5.1	0.88	1.69
	C5	227–236	577–599	0.2	0.3	34.0	49.0	3.7	86.7	13.0	39.1	56.3	4.3	0.90	1.68
	C5	236–243	599–617	0.3	0.4	39.0	42.8	3.5	85.3	14.3	45.5	49.9	4.1	0.91	1.68
Roxana Silt	2Ab1	243–250	617–635	0.3	0.6	35.6	42.6	4.3	82.5	16.9	42.8	51.3	5.2	0.83	1.77
	2Ab2	250–257	635–653	0.4	0.7	34.1	41.6	4.0	79.7	19.6	42.4	51.7	5.0	0.67	1.78
	2Ab3	257–265	653–673	0.3	0.7	33.5	40.0	3.6	77.1	22.2	43.1	51.4	4.6	0.58	1.74
	2Ab3	265–273	673–693	0.4	0.7	36.2	36.8	5.5	78.5	20.8	45.7	46.5	6.9	0.57	1.73
	2ABtb	273–282	693–716	0.4	0.7	40.0	34.1	6.7	80.8	18.5	49.1	41.8	8.2	0.65	1.77
	2BAtb1	282–289	716–734	0.4	0.6	41.3	33.3	6.0	80.6	18.8	50.9	41.0	7.4	0.61	1.80
	2BAtb2	289–298	734–757	0.4	0.7	43.3	31.1	5.1	79.5	19.8	54.0	38.8	6.4	0.61	1.87
	2ABtb2	298–306	757–777	0.3	0.6	39.5	36.0	4.0	79.5	19.9	49.3	44.9	5.0	0.57	1.83
Loveland Silt	3Btb1	306–313	777–795	0.4	0.8	43.7	29.5	4.6	77.8	21.4	55.6	37.5	5.9	0.47	1.75
	3Btb1	313–320	795–813	0.4	1.0	38.9	33.7	3.9	76.5	22.5	50.2	43.5	5.0	0.34	1.58
	3Btb2	320–329	813–836	0.4	1.0	37.9	31.9	3.8	73.6	25.4	50.8	42.8	5.1	0.26	1.45
	3Btb3	329–340	836–864	0.2	0.7	36.1	31.2	4.3	71.6	27.7	49.9	43.2	5.9	0.15	1.43

Appendix 2
Continued

				Particle size distribution in percent										Elemental Composition	
				USDA fine earth basis*							Clay-free basis+				
				Sand (mm)		Silt (µm)				Clay	Silt (µm)			% of CSI fraction	
Deposit	Horizon	Depth Inches	Depth cm	VFS 0.1-0.05	TS 2-0.05	CSI 50-20	MSI 20-5	FSI 5-2	TSI 50-2	Clay <2 µm	CSI 50-20	MSI 20-5	FSI 5-2	Ca	K
	3Btb3	340-351	864-892	0.2	0.3	35.2	29.9	3.5	68.6	31.1	51.1	43.4	5.1	0.20	1.37
	3Btb3	351-362	892-919	0.2	0.3	37.3	30.7	4.0	72.0	27.7	51.6	42.5	5.5	0.21	1.51
	3Btb4	362-371	919-942	0.4	0.6	39.6	30.2	3.2	73.0	26.4	53.8	41.0	4.3	0.25	1.64
	3Btb4	371-379	942-963	0.4	0.5	41.0	32.5	3.5	77.0	22.5	52.9	41.9	4.5	0.27	1.66
	3BCtb	379-392	963-996	0.4	0.7	45.9	34.4	2.4	82.7	16.6	55.0	41.2	2.9	0.30	1.65
	3C1	392-410	996-1041	0.5	0.6	45.2	36.0	3.3	84.5	14.9	53.1	42.3	3.9	0.31	1.64
	3C2	410-428	1041-1087	0.4	0.6	41.4	42.2	3.4	87.0	12.4	47.3	48.2	3.9	0.35	1.68
	3C2	428-446	1087-1133	0.6	0.7	42.5	41.0	3.3	86.8	12.5	48.6	46.9	3.8	0.39	1.75
	3C2	446-464	1133-1179	0.6	0.7	43.1	41.8	3.5	88.4	10.9	48.4	46.9	3.9	0.45	1.79
	3C2	464-482	1179-1224	0.6	0.8	44.9	40.3	4.1	89.3	9.9	49.8	44.7	4.6	0.54	1.88
	3C2	482-500	1224-1270	0.6	0.8	46.8	37.4	5.5	89.7	9.5	51.7	41.3	6.1	0.58	1.80
	3C2	500-518	1270-1316	0.6	0.9	50.5	33.4	4.1	88.0	11.1	56.8	37.6	4.6	0.63	1.90
	3C2	518-536	1316-1361	0.8	1.0	53.0	30.9	2.9	86.8	12.2	60.4	35.2	3.3	0.67	1.88
	3C2	536-554	1361-1407	1.5	1.6	56.4	25.4	3.8	85.6	12.8	64.7	29.1	4.4	0.67	1.94
	3C2	554-572	1407-1453	1.9	2.0	57.8	23.0	3.5	84.3	13.7	67.0	26.7	4.1	0.69	1.91
	3C2	572-590	1453-1499	1.7	1.8	58.1	22.3	5.1	85.5	12.7	66.6	25.5	5.8	0.70	1.81
	3C2	590-608	1499-1544	1.7	1.9	52.3	29.6	4.0	85.9	12.2	59.6	33.7	4.6	0.77	1.87
	3C2	608-626	1544-1590	1.4	1.7	49.2	31.6	3.5	84.3	14.0	57.2	36.7	4.1	0.76	1.84
	3C2	626-644	1590-1636	1.5	2.9	52.3	27.8	3.7	83.8	13.3	60.3	32.1	4.3	0.76	1.84
Unidentified	4C3IVC3	644-660	1636-1676	1.6	6.9	45.1	29.3	4.1	78.5	14.6	52.8	34.3	4.8	0.65	1.56
	4C3IVC3	660-669	1676-1699	2.3	17.3	35.9	25.2	2.1	63.2	19.5	44.6	31.3	2.6	0.25	0.96
	4C3IVC3	669-672	1699-1707	2.5	15.0	35.1	20.1	4.0	59.2	25.8	47.3	27.1	5.4	0.14	0.70

APPENDIX 3

Editor's Note: In the rush to assemble this guidebook in the time available, the editor (somewhat arbitrarily) excised the following pages from the original manuscript. However in accordance with the authors' wishes the pages were re-inserted at the last moment here in the appendices. This discussion of modern braided and meandering streams is part of the section (p. 10) entitled "Depositional Environments."

Braided Streams

Braided streams, in which bed loads dominate, aggrade by vertical and lateral accretion within the channel (Allen, 1965, p. 144). During flood stage channel scour occurs and relatively coarse-grained sediment is transported. As the flood dissipates and stream velocities decrease, deposition occurs in the deeper areas where diverging flow lines decrease the flow velocity. Coarse-grained bed loads are deposited initially and finer sediments are trapped in the interstitial areas. Deposition results in even horizontal bedding or bedding parallel to the geometry of the deposit. The interstream and lateral bars can build downstream during submergence by lateral accretion as sediment moves across the bar surface. Where the bar front is not steep, as is common in gravel bars, the bedding is nearly horizontal and the deposit is lense-shaped. Where the bar front is steep, as is common in sand bars, the sediment cascades down a slip face. This type of lateral accretion results in high-angle foreset cross bedding and a wedge-shaped deposit. The thickness of the cross-bedded unit is less than or equal to the water depth at the time of deposition. As the water level drops, the bars may become emergent and vegetated. Water flows around the margins of the bars and can modify the bar edges. Gravel bars are commonly oriented longitudinally or parallel to the channel and stream flow and sand bars are commonly oriented transversely or perpendicular to the channel and stream flow (Ore, 1964 and Smith, 1971). Vertical accretion may also occur beyond the channel on adjacent flood plains or in abandoned channels. These deposits are laminated or horizontally bedded if sedimentation is rapid. The deposits are massive if pedogenesis and mixing proceeds faster than the rate of sedimentation.

Modern Meandering Streams

In contrast to braided streams, meandering streams aggrade by lateral accretion of point bars at the convex margin of the channel and within-channel deposits are minor in extent (Allen, 1965, p. 138). the thickness of the point bar deposits is equal to the depth of the channels in which they were deposited. The beds parallel the gentle sloping point bar surface. Within these low-angle, epsilon cross-stratified beds a variety of cross-bedding may occur. Floodplain and channel-fill environments, similar to those described for braided streams, also occur beyond the channel and may overlie point bar deposits.

Meandering streams in which bed load dominates have similarities to both braided and fine-grained meandering streams (McGowen and Garner, 1970). During low water flow the stream has the properties and sinuous channel pattern of a meandering stream though little erosion of deposition occurs because a coarse-textured bed load dominates (Fig. 5). An erosional bank forms the concave margin and a depositional bank or point bar forms the convex margin of the channel. During high water flow the stream has the properties of a braided stream where the channel is nearly straight. Flow lines diverge around the lower point bar and a portion of the water flows through the scour pool on the concave side of the stream and a portion of the water flows through chutes on the upper point bar along convex side of the stream. Deposition of coarse-grained point bars occurs during the high and falling water stages. Coarse-

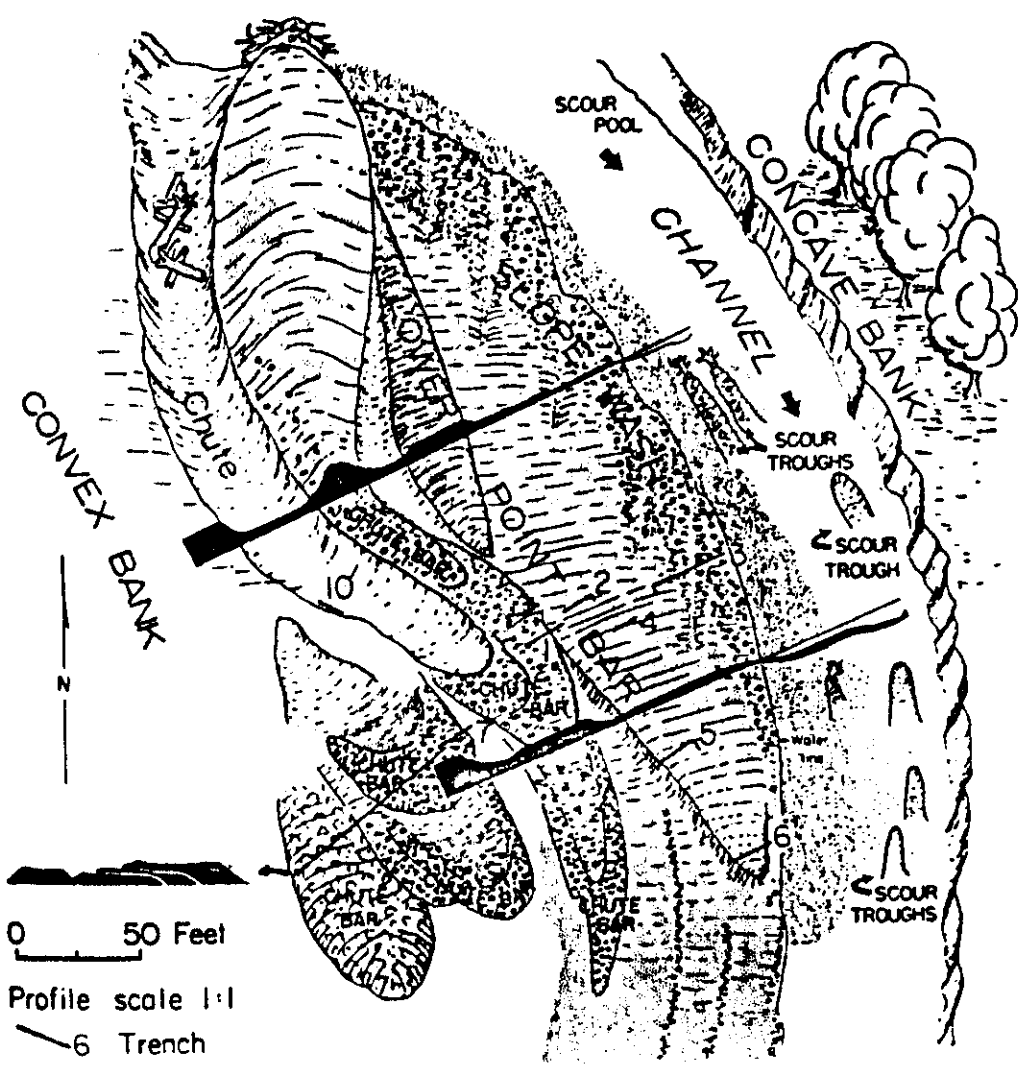

Figure 5. Plan view and profiles of a coarse-grained point bar near Magnolia, Louisiana (McGowen and Garner, 1970, Fig. 3).

grained sediment moves through the chutes during flood stage and is deposited by vertical and lateral accretion downstream of the chute as the flow lines diverge and the velocity slows. Falling water allows deposition of fine-grained sediment within the chutes and on the lower point bars.

Coarse-grained meandering stream deposits have some similarities to both braided stream deposits and fine-grained meandering stream deposits. Similar to braided stream deposits, the upper point bar deposits are coarse-grained, bed-load sediments and the sedimentary structures are commonly large-scale trough and foreset cross beds. Similar to fine-grained meandering stream deposit is asymmetrical with a dominantly erosional scour pool on the concave margin and a dominantly depositional point bar on the convex margin. The major bedding is low-angle, epsilon-style bedding. The preservation of the bar-channel wall scour contact may be the only way to definitively identify a coarse-grained point-bar deposited in a sinuous stream (Miall, 1977). Unlike both braided stream deposits and fine-grained meandering stream deposits, the coarse-grained meandering stream deposits have textures that coarsen upward. Coarser grained chute and chute bar sediments overlie finer grained lower point bar sediments as the stream migrates toward the concave bank.