STATE OF ARKANSAS

ARKANSAS GEOLOGICAL COMMISSION

Norman F. Williams, State Geologist

FIELD GUIDE TO THE PALEOZOIC ROCKS OF THE OUACHITA MOUNTAINS AND ARKANSAS VALLEY PROVINCES, ARKANSAS

By

Charles G. Stone and John D. McFarland, III
with the cooperation of Boyd R. Haley

Little Rock, Arkansas
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A special debt of gratitude is expressed to Loretta S. Chase, April Brewer, L.P. Kelone and others for their assistance during the preparation of this Guidebook.

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PREFACE

This guidebook has been prepared to provide geologic information on the Paleozoic rocks of the Arkansas Valley and the Ouachita Mountains. The route of the field trip crosses representative sections in these Provinces of Arkansas. Stops were selected to show the lithology of the various rock units, the respective depositional environments, and the various styles of structural deformation. On the first day, the trip is centered in the eastern Ouachita Mountains and southeastern Arkansas Valley; on the second day it extends from the southeastern Arkansas Valley through the frontal and into the central or "core" area of the Ouachita Mountains; and, on the third day it covers the central through the southeastern Ouachita Mountains.

Most of the detailed geologic maps presented in this guidebook were prepared by Boyd R. Haley and Charles G. Stone during the years 1968 to 1974 for the Arkansas State Geologic Map project. In the back of this field guide is a portion of the Geologic Map of Arkansas (Haley, et al., 1976) showing the general geology of the area covered on this trip. Additionally, there is a geologic cross-section from Arkansas Geological Commission Guidebook 77–1 (Bush, et al., 1977) paralleling that field trip route (Arkansas Hwy. 27) from Russellville, Arkansas southward through the Ouachita Mountains to Murfreesboro, Arkansas.

We wish to offer our sincerest appreciation to the many people who have so graciously given their time and ideas in assisting us on the many problems and studies that have arisen during investigations of this area. We owe a special debt of gratitude to Rufus J. LeBlanc, Alan Thomson, Gil Flanagan, and others of Shell Development Company for their contributions to the sedimentology of both deep and shallow water Carboniferous rocks of the Arkansas Valley and the Ouachita Mountains of Arkansas and Oklahoma.

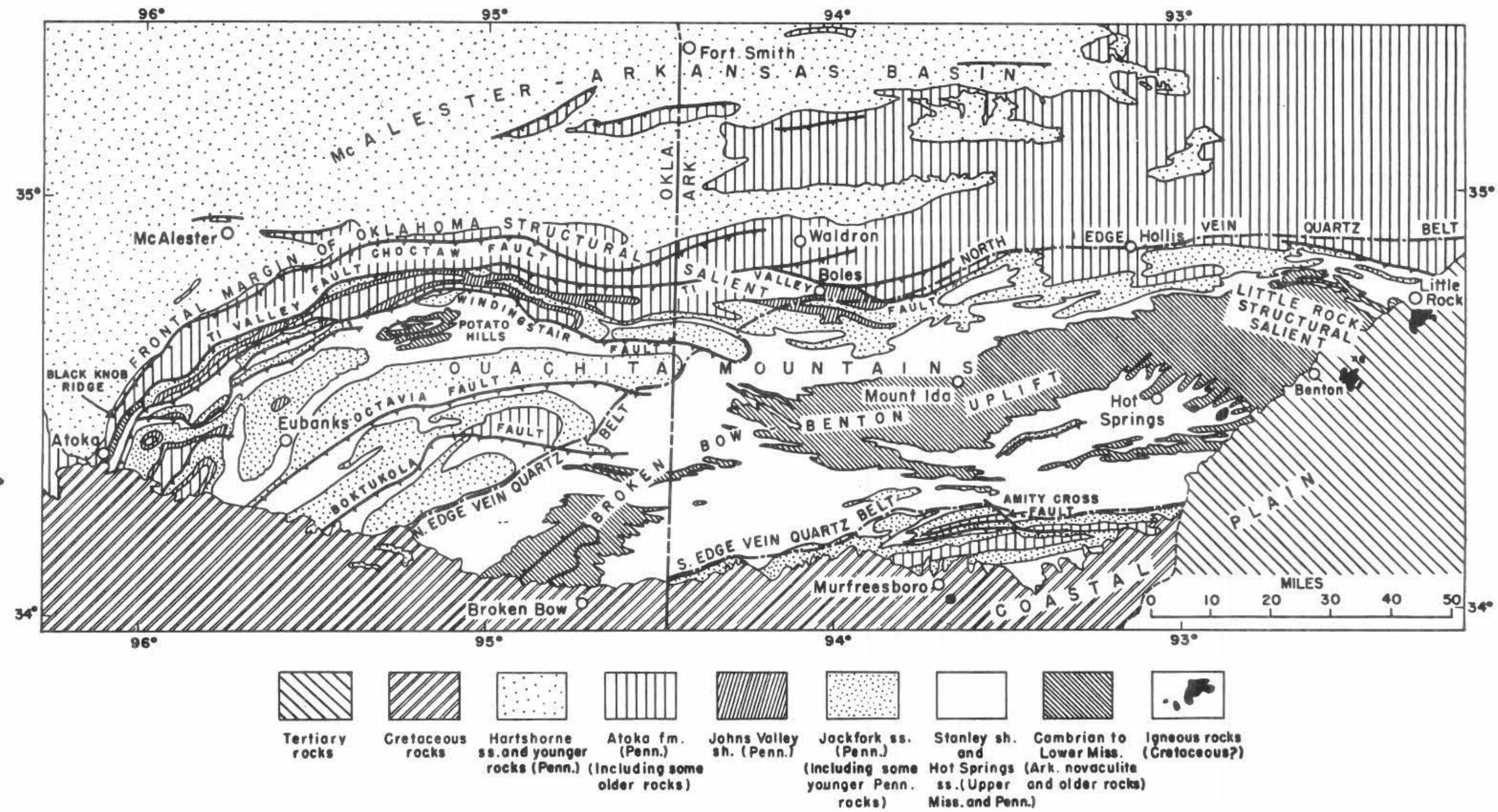


PLATE 1 GENERAL GEOLOGIC MAP OF OUACHITA MOUNTAINS SHOWING AREA OF OCCURRENCE OF VEIN QUARTZ

CORRELATION OF PALEOZOIC ROCKS IN THE OZARK, ARKANSAS VALLEY, AND OUACHITA MOUNTAIN REGIONS, ARK.

		Age	Ozark – Arkansas Valley Section		Map Sym.	Ouachita Mtn. Section		Map Sym.
Carboniferous System	Pennsylvanian	Des Moines	Boggy Fm.		IPby	Missing		
			Savanna Fm.		IPsv			
			McAlester Fm.		IPma			
			Hartshorne Sandstone		IPhs			
		Atoka	Atoka Fm.		IPa	Atoka Fm.		IPa
		Morrow	Bloyd Shale	Kessler Ls Mbr.	IPbh / IPbk	Johns Valley Shale		IPjv
				Woolsey Mbr.	IPbw			
				Brentwood Ls. Mbr.	IPbb	Jackfork Fm.		IPj
			Hale Fm.	Prairie Grove Mbr.	IPhp			
				Cane Hill Mbr.	IPhc			
	Mississippian	Upper	Pitkin Limestone		Mpfb / Mp	Stanley Shale	Chickasaw Creek Mbr.	Ms
			Fayetteville Shale	Wedington SS Mbr.	Mf			
			Batesville Sandstone	Hindsville Ls. Mbr.	Mbh			
			Ruddell Shale		Mr			
			Moorefield Fm.		Mm		Hatton Tuff	
			Boone Fm.	Short Creek Oolite Mbr.	Mb		Hot Springs SS Mbr.	
		Lower		St. Joe Ls. Mbr.		Arkansas Novaculite	Upper Div.	MDa
Devonian		Upper	Chattanooga Shale	Sylamore SS	MDcp		Middle Div.	
		Middle	Clifty Limestone				Lower Div.	
		Lower	Penters Chert					
Silurian		Upper	Missing			Missouri Mountain Shale		Sm Opc / Smb
			Lafferty Limestone		Slsb	Blaylock Sandstone		
			St. Clair Limestone					
		Lower	Brassfield Limestone					
Ordovician		Upper	Cason Shale		Ocj	Polk Creek Shale		Opc
			Fernvale Limestone		Of	Bigfork Chert		Obf
		Middle	Kimmswick Limestone					
			Plattin Limestone			Womble Shale		Ow
			Joachim Dolomite					
			St. Peter Sandstone		Ose			
			Everton Fm.	Jasper Ls. Mbr.				
				Newton SS Mbr.		Blakely Sandstone		Ob
				King River SS Mbr.				
		Lower	Powell Dolomite		Op			
			Cotter Dolomite		Ocjc	Mazarn Shale		Om
			Jefferson City Dolomite			Crystal Mountain Sandstone		Ocm
			Roubidoux Fm.		Not exposed	Collier Shale		Oc
			Gasconade-VanBuren Fm.	Gunter Mbr.				
Cambrian		Upper	Eminence Dolomite			Older rocks not exposed		
			Potosi Dolomite					
			Derby-Doerun-Davis Fm.					
			Bonneterre Dolomite					
			Lamotte Sandstone					
Pre-C			Igneous Rocks					

PLATE 2 —

GENERAL LITHOLOGIC DESCRIPTION OF UNITS TRAVERSED ON TRIP

Quaternary	
Alluvium -- clay, silt, sand, and gravel	90′
Terrace Deposits — gravel, sand, clay	40′
Cretaceous System	
Tokio Formation — gravel, sand, clay	300′
Brownstown Marl — gravel, sand, marl, and clay	250′
Igneous Rocks — peridotite, kimberlite, and tuff	---
Trinity Group — gravel, sand, clay, gypsum, and minor limestone	150-1,000
Pennsylvanian System	
Des Moinesian Series	
Savanna Formation - sandstone and sandy shale	850
McAlester Formation - shale, sandstone, and coal	1,000
Hartshorne Sandstone - massive sandstone	325
Atokan Series	
Atoka Formation - shale and sandstone	27,500+
Morrowan Series	
Johns Valley Shale - shale, minor sandstone and limestone, and erratic boulders	1,500+
Jackfork Sandstone - sandstone and shale	6,000
Mississippian System	
Stanley Shale - shale, sandstone, and some chert	8,500
Devonian and Mississippian Systems	
Arkansas Novaculite - novaculite, shale, and conglomerate	950
Silurian System	
Missouri Mountain Shale - shale with minor sandstone	250
Blaylock Sandstone - sandstone, siltstone, and shale	1,500
Ordovician System	
Polk Creek Shale - shale	175
Bigfork Chert - chert, limestone, and shale	800
Womble Shale - shale with some thin limestone and sandstone	3,500
Blakely Sandstone - shale and sandstone	450
Mazarn Shale - shale with some sandstone and limestone	3,000
Crystal Mountain Sandstone - sandstone	850
Collier Shale - shale and limestone	1,000

PLATE 3 —

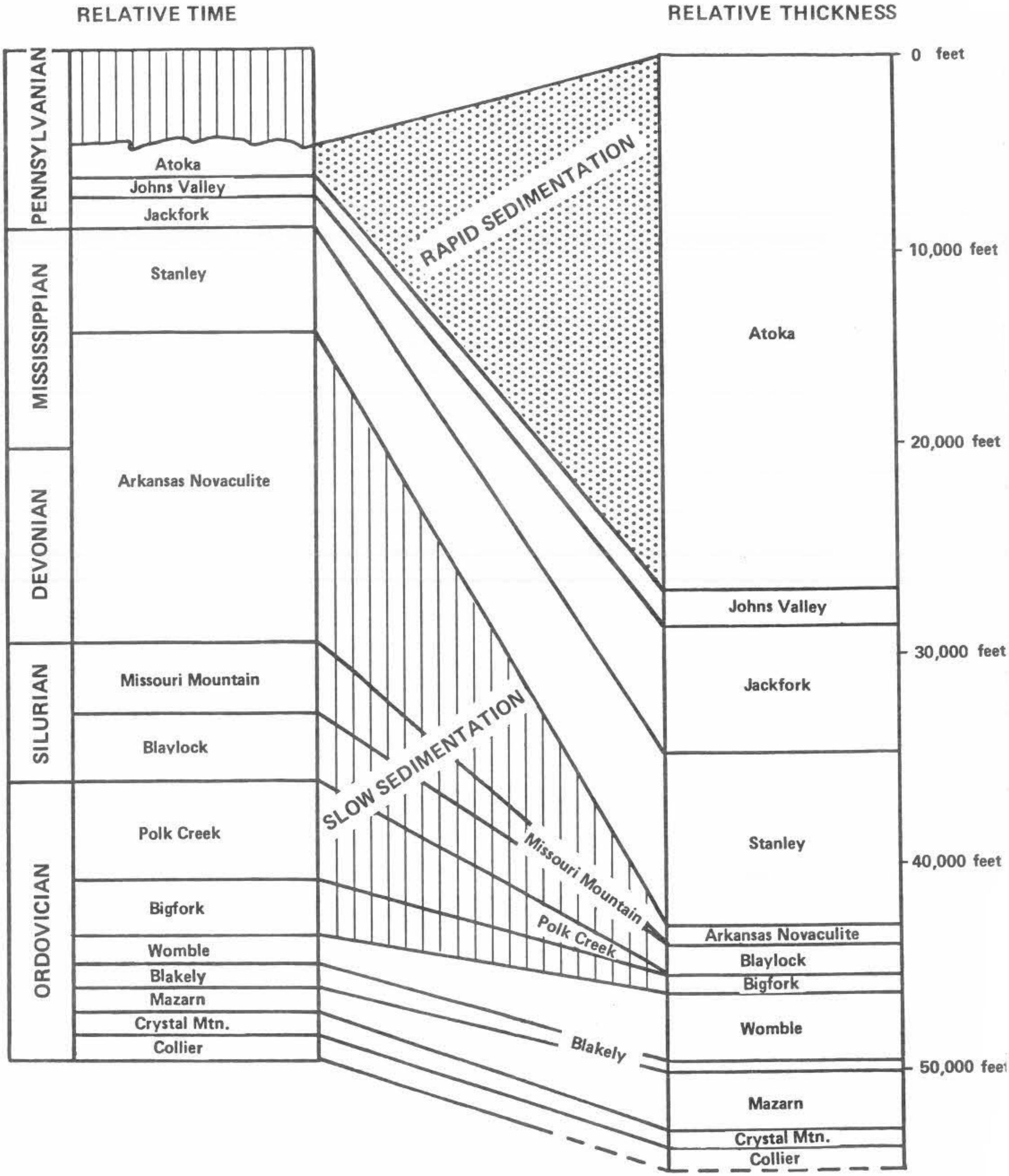


PLATE 4 — CHART SHOWING SEDIMENTATION RATES OF THE PALEOZOIC ROCKS IN THE OUACHITA MOUNTAINS, ARKANSAS.

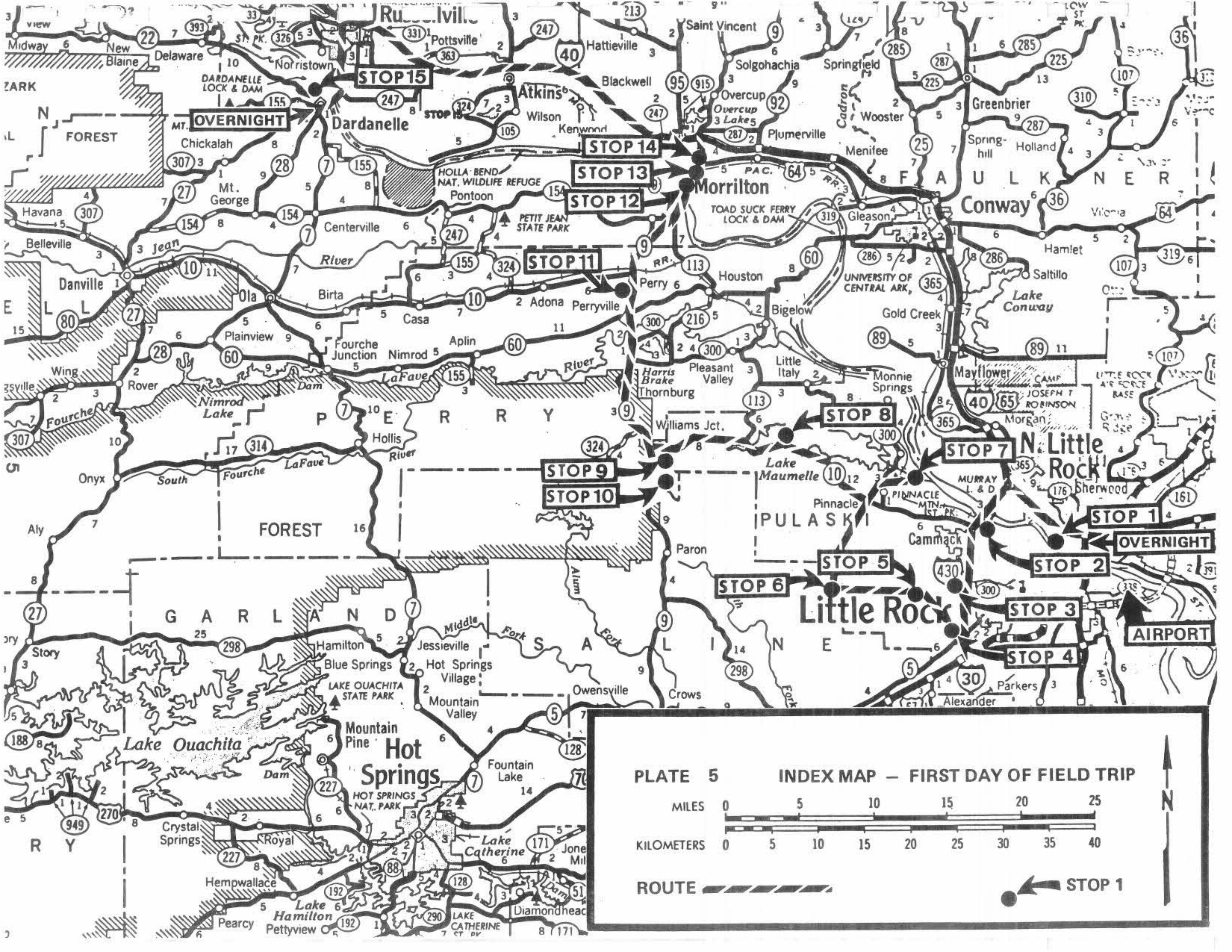


PLATE 5 INDEX MAP — FIRST DAY OF FIELD TRIP

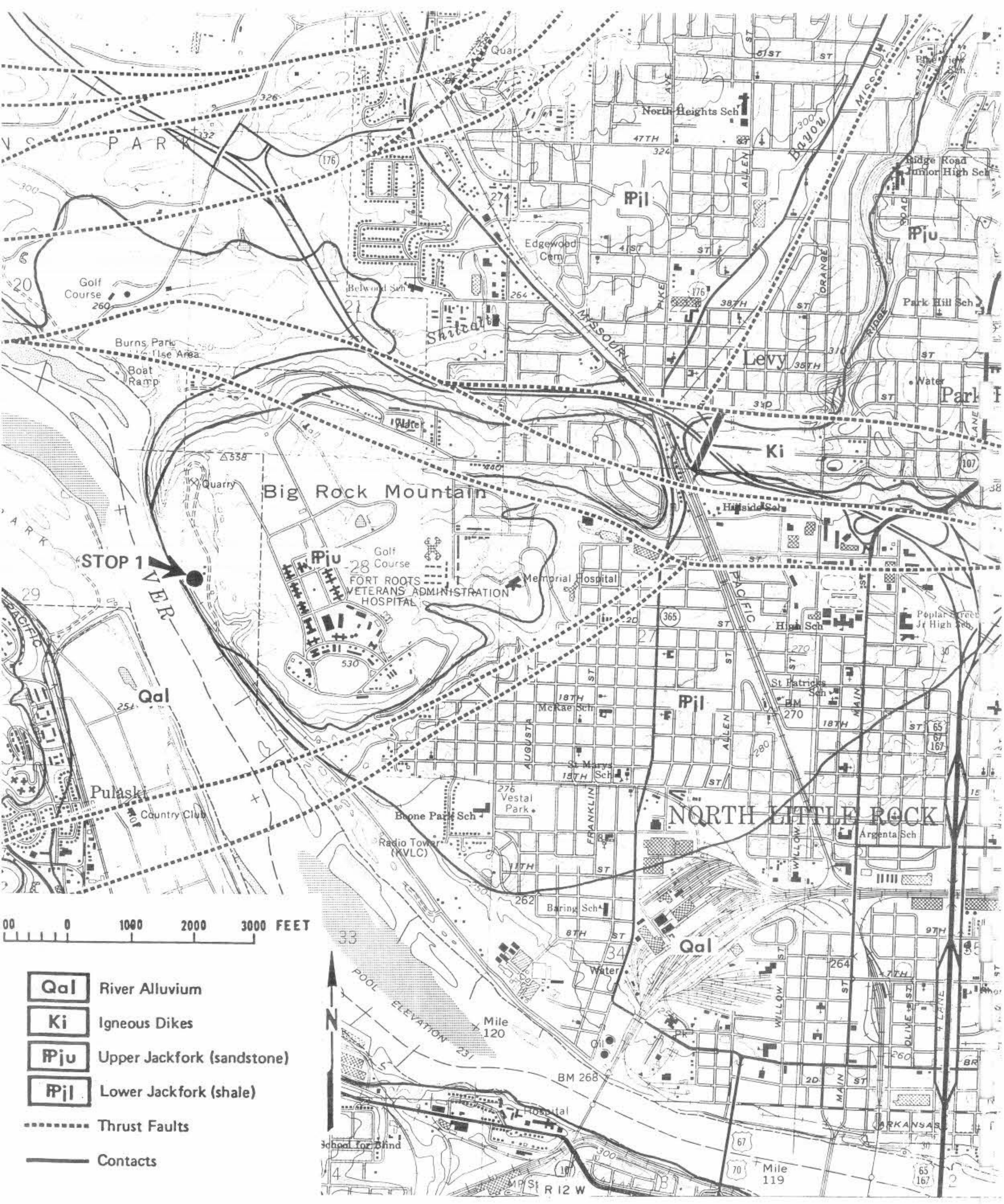


PLATE 6 GEOLOGIC MAP OF ABANDONED BIG ROCK QUARRY IN NORTH LITTLE ROCK – STOP 1

ROAD LOG – FIRST DAY

EASTERN OUACHITA MOUNTAINS AND SOUTHEASTERN ARKANSAS VALLEY

North Little Rock, Little Rock, Ferndale, Perryville, Morrilton, Russellville, Dardanelle (Plate 5).

MILEAGE	DESCRIPTION
0.0	Holiday Inn in North Little Rock. Turn west on Pershing Boulevard.
0.7	Turn south on Percy Machem Drive.
0.8	Turn west on 24th Street.
1.0	Turn south on Pike Avenue.
1.5	Turn west on Long 17th Street.
2.8	Turn northwest on Riverside Drive (Old River Road).
3.5	**STOP 1 – ABANDONED BIG ROCK QUARRY IN UPPER PART OF JACKFORK SANDSTONE (Plate 6 and Figures 1, 2, 3, 4, 5).**

–– DANGER –– The walls are subject to spalling – please stay away from the base!!! We wish to express our sincerest thanks to Charles B. Germer and members of his staff of the Arkansas Sand Company for permission to enter this site.

At the present time this pit is being used as a storage area for sand dredged from the bed of the Arkansas River. During the 1950's the sandstone was extensively quarried for rock aggregate.

More than 200 feet of quartzose sandstone, siltstone, conglomerate, and shale are exposed along the walls of the pit. The base of this unit is about 2600 feet below the top of the Jackfork. These rocks are representative of channel deposits in the upper part of a submarine fan and at least 14 channels are exposed. The dimensions of this submarine fan are not known, except it pinches out about 2½ miles north of here. Bottom marks and channel alignment indicate a paleocurrent from the northeast and east. Load casts, ball and pillow structures, and slump features are present in some intervals. Intraformational conglomerate composed mostly of sandstone and shale clasts are present at the base and flanks of some channels and can be examined in the blocks left in the floor of the pit. Fragments of plant and invertebrate fossils of early Pennsylvanian age are present in some of the siltstone and sandstone. Gordon and Stone (1977, p. 81–82) reported a "grit" bed near the base of this sequence across the Arkansas River in Little Rock.

Bedding-plane and tear faults are present and quartz veins containing chlorite and other minerals fill small fractures in or near these faults.

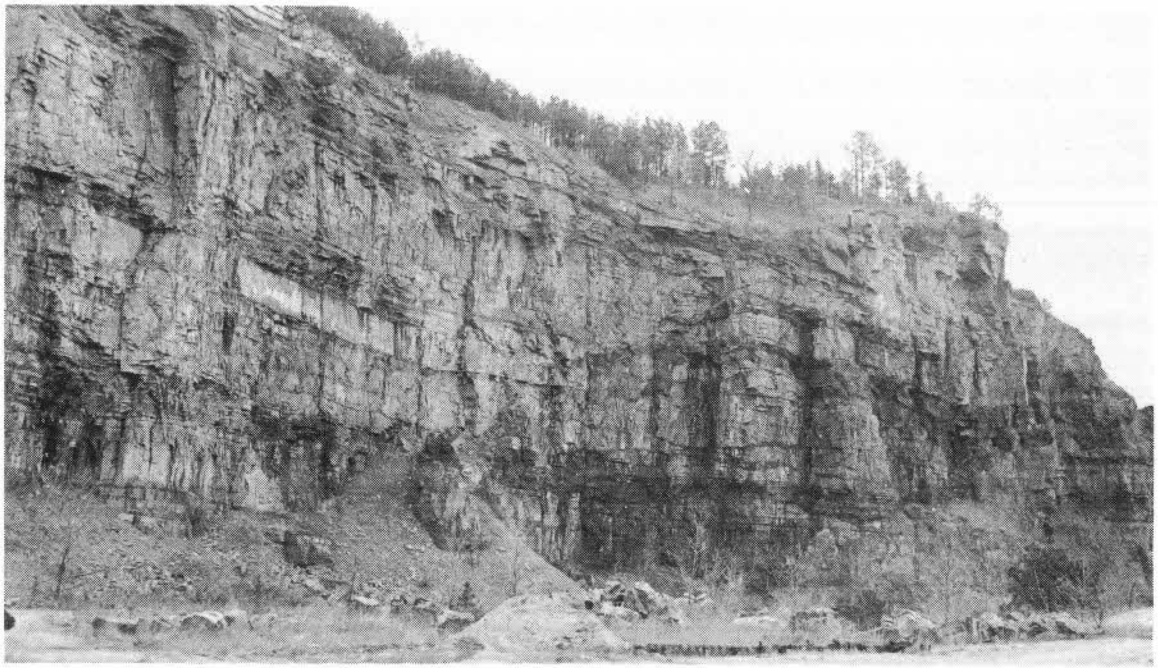


Figure 1 - Stop 1. Interbedded quartzitic sandstone and black shale in several submarine fan channel sequences in the basal upper Jackfork Sandstone at the abandoned Big Rock quarry in North Little Rock.

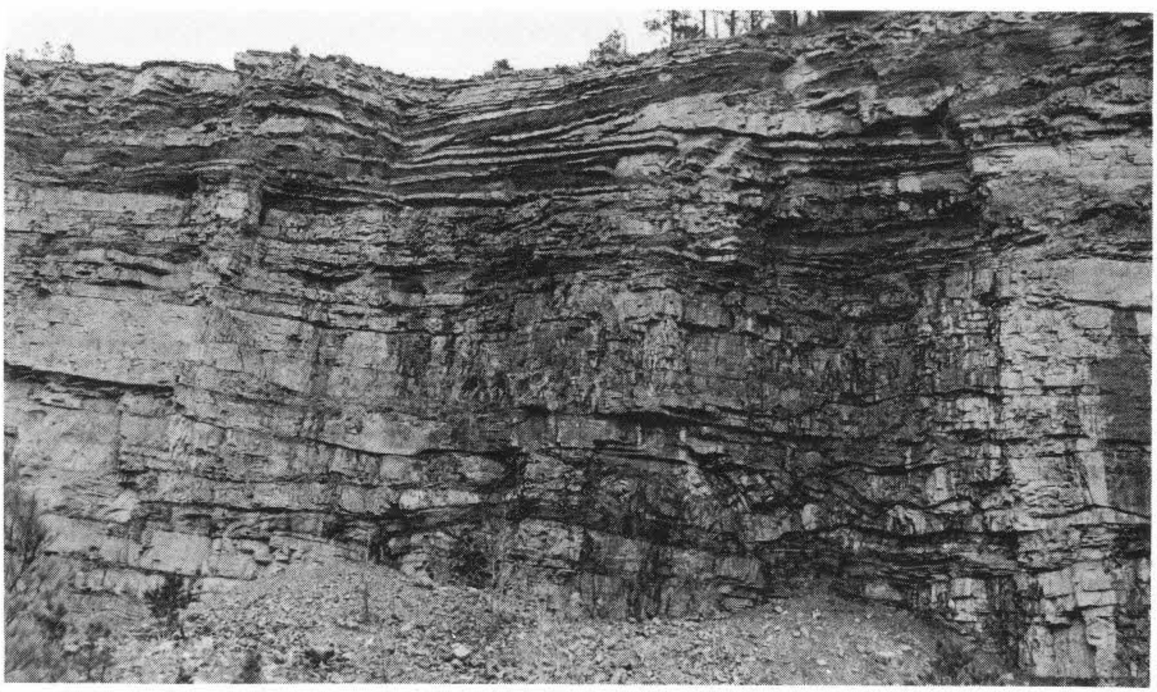


Figure 2 - Stop 1. Closeup of several submarine fan channel sequences in the basal upper Jackfork Sandstone at the north end of the abandoned Big Rock quarry in North Little Rock.

In recent years, rocks exposed at this quarry and other sites in Arkansas are Stops for several of the oil companies sandstone depositional training programs. A depositional model for the Jackfork here and elsewhere in Arkansas and Oklahoma has been proposed by Thomson and LeBlanc in the following abstract:

> Thomson, Alan, and Le Blanc, R. J., 1975, CARBONIFEROUS DEEP–SEA FAN FACIES OF ARKANSAS AND OKLAHOMA: Geological Society of America Abs. with Programs, v. 7, p.1298–1299.
>
> The Carboniferous flysch facies in the Ouachita Mountains of Arkansas and Oklahoma consists of over 20,000 feet of turbidites and related sediments. The section in Oklahoma is mainly shaly flysch, but Morris recently described several sections in Arkansas which contain thicker-bedded and coarser-grained rocks than those encountered in Oklahoma. More recently Graham, et al., suggested that the Ouachita flysch originated as a submarine fan system, similar to the Bengal fan.
>
> The writers recently studied exposures of Stanley, Jackfork, Johns Valley, and Atoka strata in Arkansas and Oklahoma in an attempt to classify these strata according to the submarine fan-channel model of Mutti and Ricci-Lucchi.
>
> Sequences in which sandstones thin upward and thicken upward, indicative of channel and fan-lobe, respectively, are common in all units studied. Sequences in which sands thicken upward and then reverse themselves to continue thinning upward are thought to represent lobes which are gradually abandoned.
>
> Examples which best fit the submarine fan-channel model occur in the Jackfork. The section in Big Rock Quarry at North Little Rock consists of at least eleven distinct channel-fill sequences. Along Route I-30 between Arkadelphia and Malvern five distinct channel-fill sequences can be seen. Deposits at both of these localities are interpreted as inner fan, with the former being most proximal. Midfan deposits are present farther to the west in the vicinity of DeGray Dam, and outer fan deposits occur in eastern Oklahoma. The submarine canyon which fed this deep-sea fan complex was located to the east near Memphis.

We would currently suggest that a major source area also existed northeast of the Big Rock site in the Searcy–Batesville area where sediments were likely derived from the Illinois Basin. Some of our additional concepts on the Jackfork deposition are shown on Plate 41.

A faunal assemblage was collected from the Jackfork in Little Rock and was studied by Girty who concluded that they were of Pottsville age (in Miser, 1934). The assemblage was reexamined by Gordon who reported more than 35 species of invertebrates including the Morrowan brachiopods *Chonetes arkansanus* Mather and *Hustedia miseri* Mather and the bivalve

Figure 3 - Stop 1. Slurried interval of intraformational breccia or conglomerate composed for the most part of sandstone, siltstone and shale clasts and lenses generally in a shale matrix associated with the upper submarine fan channels in the basal upper Jackfork Sandstone at the abandoned Big Rock quarry in North Little Rock.

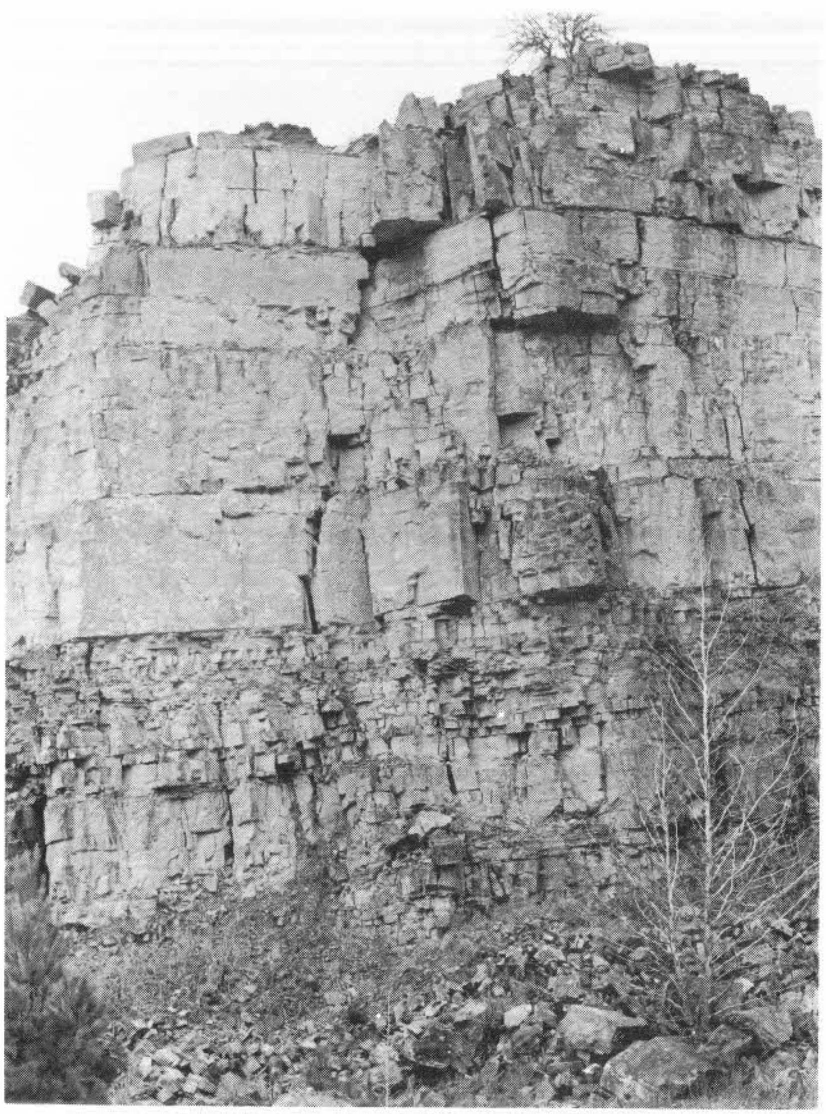


Figure 4 - Stop 1. Several submarine fan channel sequences that are exposed parallel to the depositional dip and thus show less entrenchment of the channels. The interval is the basal upper Jackfork Sandstone at the north end of the abandoned Big Rock quarry in North Little Rock.

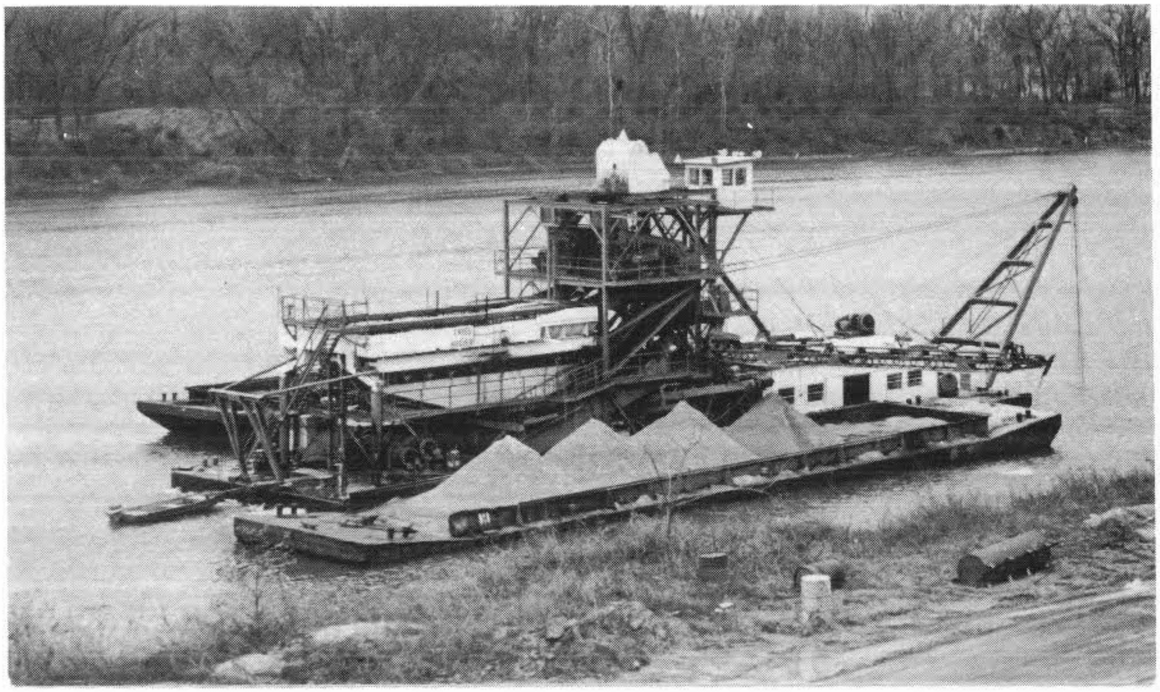
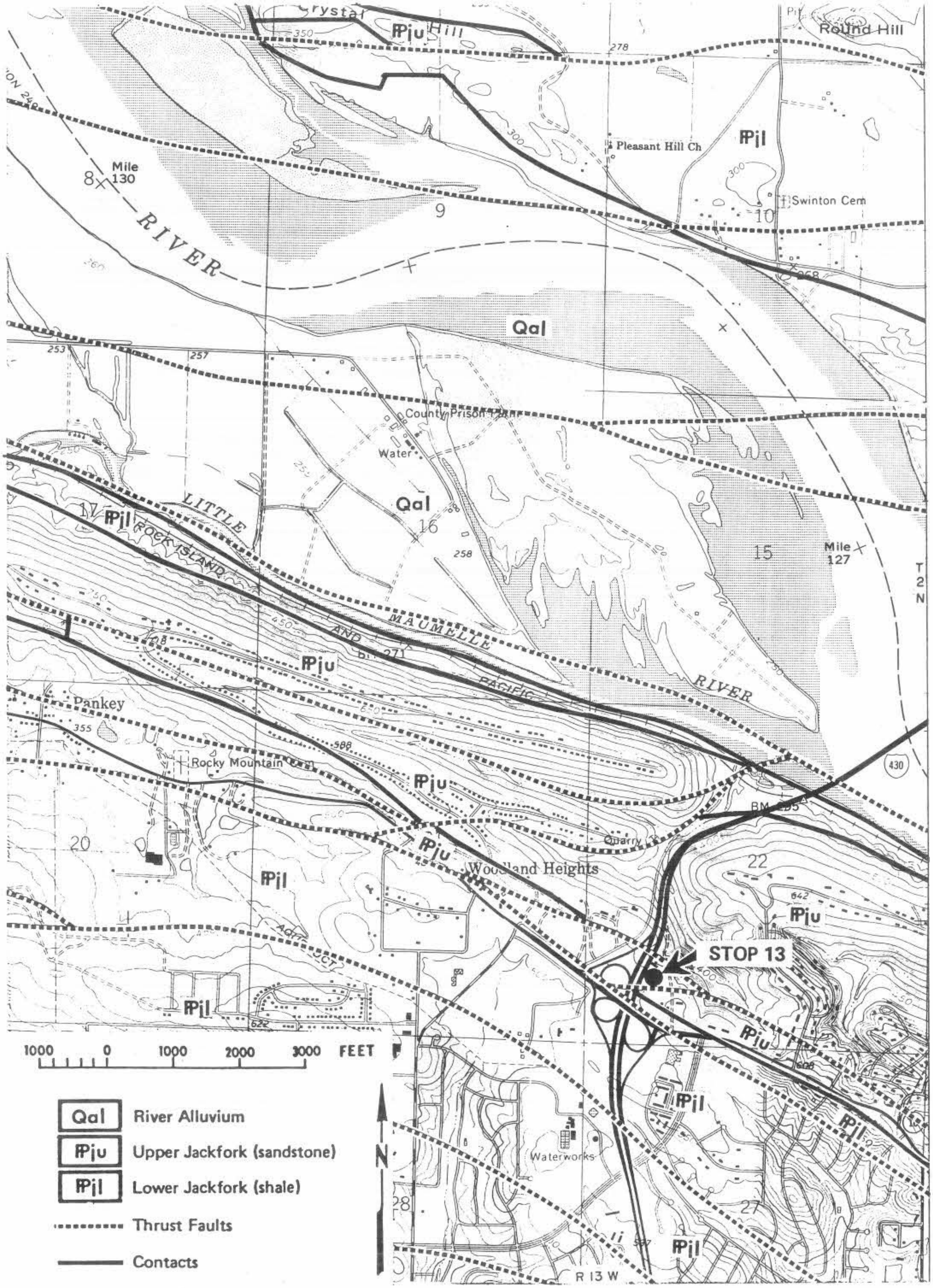


Figure 5 - Stop 1. Sand dredge and barge operated by the Arkansas Sand Company on the Arkansas River at the abandoned Big Rock quarry in North Little Rock.

Figure 6 - Mileage 6.3. Sandstone of the basal upper Jackfork Sandstone in fault contact with shale of the middle Jackfork Sandstone - note the numerous refracting hydrothermal milky quartz veins in roadcut south of Levy in North Little Rock.



GEOLOGIC MAP ALONG INTERSTATE HIGHWAY 430
IN WESTERN LITTLE ROCK STOP 2

Girtyana honessi Elias. Althought the paleontological evidence establishes a Pennsylvanian age for these rocks, it is not diagnostic enough to establish age correlation with the rocks in either the Bloyd or Hale Formations. Lithologic evidence strongly suggests that these rocks in the Jackfork are equivalent to the rocks in the Hale Formation.

Return to Pike Avenue via Long 17th Street.

5.5 Turn north on Pike Avenue.

6.3 The rocks in the exposure to the west are at the base of the upper Jackfork Sandstone exposed at Stop 1. A faulted and sheared interval occurs in the shales below the sandstone and is thought to represent a decollement zone between the sandstone and the underlying shale.

6.6 Turn west onto Interstate Hwy. 40.

10.2 Near the skyline to the north is the abandoned Jeffrey Stone Quarry in the upper Jackfork Sandstone. Rock was taken from this quarry during the 1950's and 60's for aggregate. Miser and Milton (1964) reported on the hydrothermal quartz veins containing needle quartz crystals, rectorite, cookeite, ankerite, siderite, and other minerals at this site. Stone and Milton (1976) indicate that similar quartz veins are present in the frontal Ouachita Mountains through most of Arkansas. Konig and Stone (1977) show that at the abandoned Kellogg silver mine some six miles to the northeast there are two generations of quartz veins; the earlier, more prominent set with dickite contains most of the lead, zinc, copper, and silver minerals and the later set with pyrophyllite and cookeite contains minor ore minerals. It is thought that these rectorite–cookeite-bearing quartz veins occurred during very late episodes of Ouachita tectonism.

10.6 Turn right at Exit 147 and proceed south on Interstate Hwy. 430.

13.3 North side of Arkansas River. View of Murray Lock and Dam to the east and Pinnacle Mountains formed by the upper Jackfork Sandstone to the west.

14.7 Turn right onto Exit 9 (access road to Arkansas Hwy. 10 Junction).

14.9 **STOP 2 – JACKFORK SANDSTONE AT JUNCTION OF INTERSTATE HWY. 430 AND ARKANSAS HWY. 10 (Plate 7 and Figures 7, 8).**

This large roadcut is in black shale of the middle Jackfork Sandstone and massively bedded, gray, quartzitic sandstone of the basal upper Jackfork Sandstone. These rather intensely sheared and, in part, thrust faulted sequences are on the south flank of the Big Rock syncline. Submarine fan channels are present in the sandstone sequences but these rocks were probably deposited a little farther down the slope of the fan as evidenced by the lack of deep-cutting channels and the less abundant intraformational conglomerates.

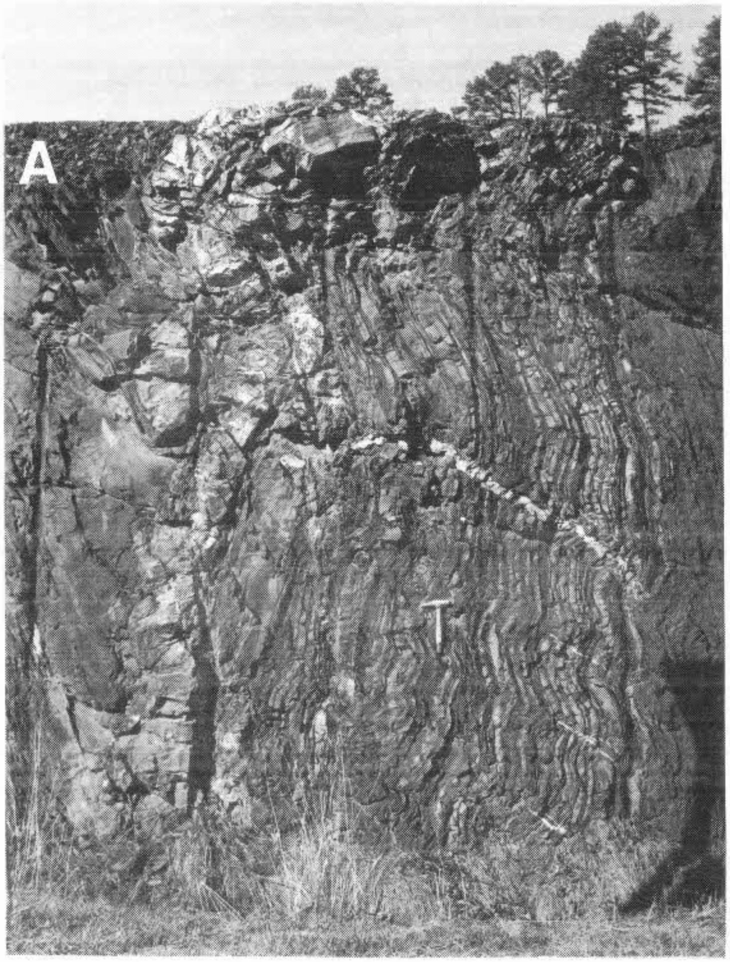
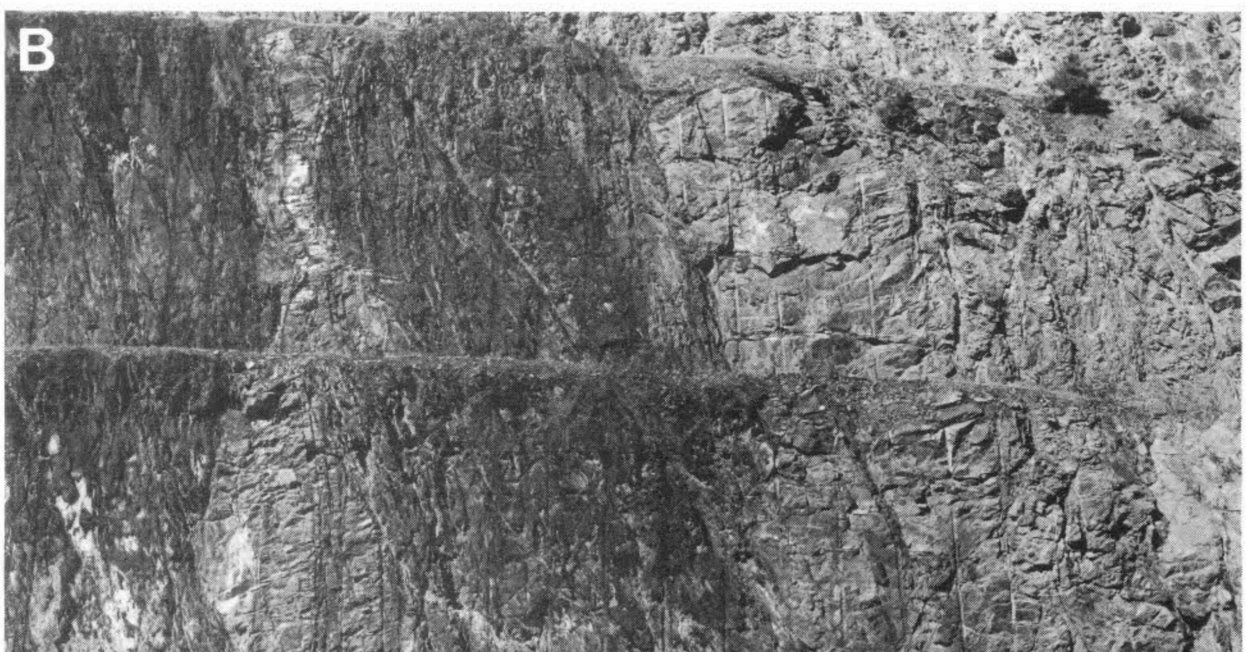


Figure 7 - Stop 2. Interbedded sandstone and shale (top to right) dissected by gently northward dipping cleavage and milky quartz veins. These rocks are in the middle Jackfork Sandstone as exposed in the roadcut on west side of Interstate Hwy. 430.

Figure 8 - Stop 2. Highly fractured quartzitic sandstone of the upper Jackfork Sandstone (on the right) overlying intensely sheared black shale of the middle Jackfork Sandstone. These rocks are exposed in the west wall of the roadcut along Hwy. 10 access road.



Structural features caused by tectonic deformation combined with soft sediment deformation are present at a number of places in this exposure.

The folds are upright and overturned to the southwest and have nearly horizontal hinges. Throughout most of the area south of this stop the Jackfork and older strata are complexly folded and faulted. Nearly all of the rocks dip to the north as does the cleavage and most of the fault planes. The structure of these rocks is thought to be a product of a combination of geologic events – namely: (1) southward slumping of soft sediments in a submarine continental slope depositional environment; (2) northward stacking of several thrust fault slices; (3) several periods of folding; (4) backfolding and faulting caused in part by "piling up" and crowding at the toe of the larger northward moving thrust plates.

Hydrothermal quartz veins of late Paleozoic age are common and some of them contain rectorite, cookeite, pyrite, and other minerals. Dickite is present in some of the fault zones.

Continue south on access road and proceed back to Interstate Hwy. 430.

20.4 Turn right at Exit 4 (Colonel Glenn Road Junction).

20.5 **STOP 3 – POLK CREEK SHALE, BIGFORK CHERT, AND WOMBLE SHALE AT JUNCTION OF INTERSTATE HWY. 430 AND COLONEL GLENN ROAD (Plate 8 and Figures 9, 10).**

Ordovician age rocks of the Polk Creek Shale, Bigfork Chert, and Womble Shale are exposed at this roadcut. All of the rocks are sheared and tightly folded. Northward dipping thrust faults are present and are marked by small quartz veins and slickensides.

A large block of the Lower Division of the Arkansas Novaculite has been thrust over the Womble Shale on the small hill southwest of the roadcut. Two alkalic igneous dikes (altered to clay) of Cretaceous age (about 90 million years old) are present in the Bigfork Chert on the east side of the roadcut.

Graptolites of middle Ordovician age have been collected from shale in the upper part of the Womble and of late Ordovician age from shale in the Polk Creek in nearby localities.

Two opinions have been suggested to explain the complex structure of the rocks in this area (Stops 3, 4, and 5). Viele proposes gravitational sliding and cascading of rock units northward from a series of overturned nappes. We suggest a series of northward moving thrust plates with an overall southward increase in the structural complexity of the rocks in each thrust plate. The southward overturning of the rocks and of the fault planes south of Stop 2 can be attributed to backfolding at the toe of each thrust plate and also of subsequent thrust faulting. Subsequent or younger faulting is suggested by the outlier of Novaculite overlying Womble at Stop 3 and by the six mile wide belt of Ordovician rocks overlying Mississippian rocks in the area southwest of

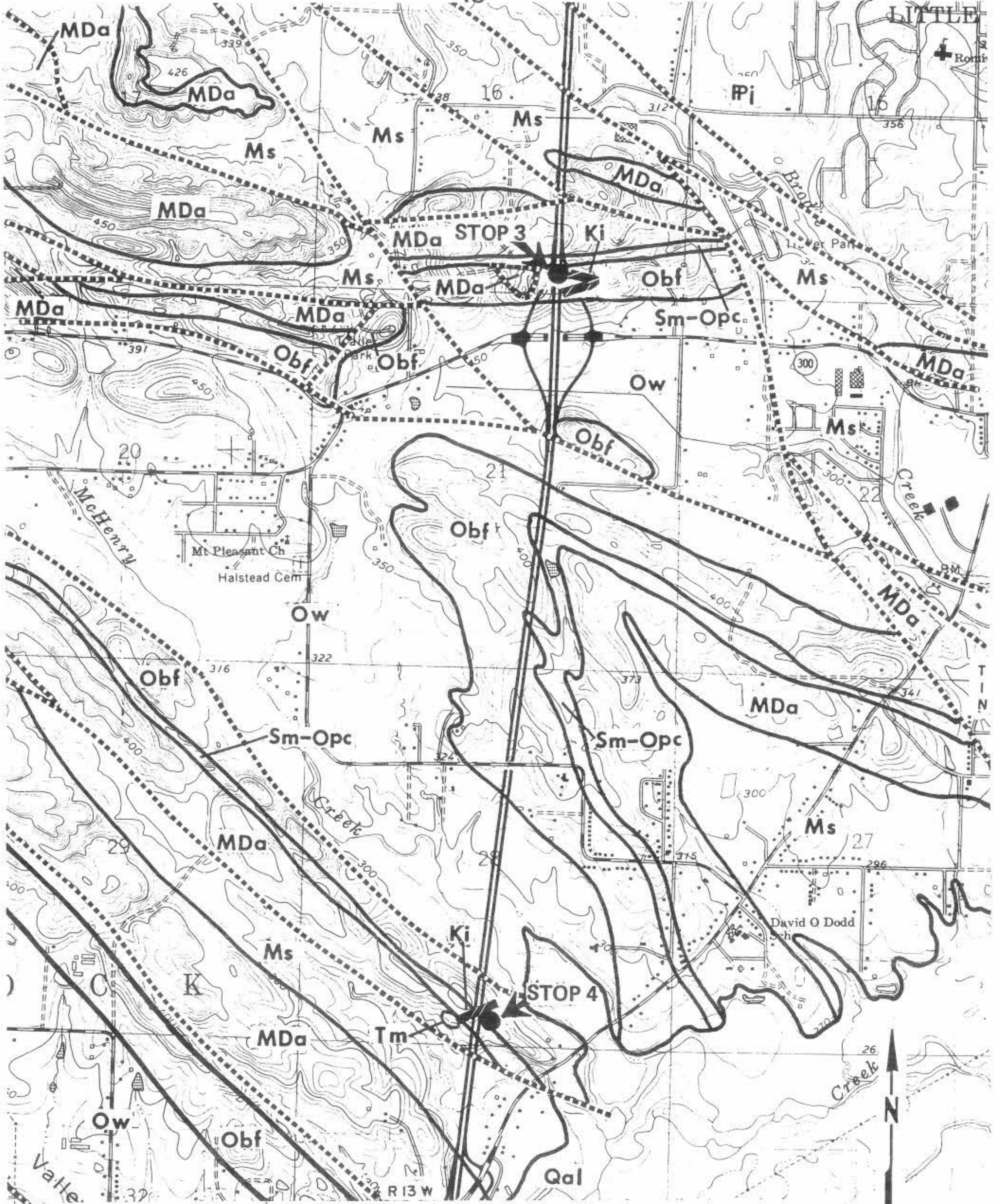


PLATE 8 — GEOLOGIC MAP OF SOUTHWESTERN LITTLE ROCK ALONG INTERSTATE HIGHWAY 430 – STOPS 3 AND 4

1000 0 1000 2000 3000 FEET

Qal	Stream Alluvium
Ki	Igneous Dikes
PPj	Jackfork Sandstone
Ms	Stanley Shale
MDa	Arkansas Novaculite
Sm-Opc	Missouri Mountain Shale – Polk Creek Shale
Obf	Bigfork Chert
Ow	Womble Shale
········	Thrust Faults
———	Contacts

Figure 9 - Stop 3. Chert and siliceous shale of the Bigfork Chert with two dissecting altered alkalic dikes exposed on the east side of Interstate Hwy. 430 north of Colonel Glenn Road.

Figure 10 - Stop 3. Closeup of overturned isoclinal folds showing pervasive shearing and internal crowding in the fold hinges in the siliceous shale and chert of the Bigfork Chert on Interstate Hwy. 430 north of Colonel Glenn Road.

Paron (25 miles west of Stop 3).

Continue south across Colonel Glenn Road and return to Interstate Hwy. 430.

22.5 **STOP 4 – MIDDLE AND LOWER DIVISIONS OF ARKANSAS NOVACULITE, MISSOURI MOUNTAIN SHALE, POLK CREEK SHALE, AND BIGFORK CHERT NORTH OF JUNCTION OF INTERSTATE HWY. 430 AND ARKANSAS HWY. 5 (Plate 8 and Figures 11,12).**

This roadcut is about 0.4 miles north of Arkansas Hwy. 5. From north to south the rocks consist of: chert and siliceous shale of the Bigfork Chert; black shale and dark gray chert of the Polk Creek Shale; gray and tan shale with chert and novaculite of the Missouri Mountain Shale; massive bedded, in part tripolitic, very light gray novaculite and chert of the Lower Division and black siliceous shale and chert of the Middle Division of the Arkansas Novaculite. The rocks are overturned to the south and the style of folding varies between the respective lithic types with pervasive northward dipping cleavage especially evident in the Bigfork Chert. Some northward dipping thrust faults with quartz veins and minor gouge are present.

An alkalic igneous dike (altered to clay) of early upper Cretaceous age (90 million years old) dissects the Middle Division of the Arkansas Novaculite and both are overlain by a remnant of gravel, sand, and clay that may be of Paleocene age (Midway Group).

Studies currently in progress (Keller and Stone) have determined that the diameter of the polygonal triple point grains developed during recrystallization of chert or novaculite is likely related to low-rank regional metamorphism. The triple point grains in the chert and novaculite from this Stop average about 40 microns in diameter and are among the coarsest observed in chert or novaculite from the Ouachita Mountains.

22.9 Turn southwest at Exit 1 onto Arkansas Hwy. 5.

23.6 Turn west on Crystal Valley Road.

27.7 Turn north on Lawson Road to Pulaski County Quarry.

28.5 **STOP 5 – ARKANSAS NOVACULITE IN PULASKI COUNTY ROCK AGGREGATE QUARRY (Plate 9 and Figure 13).**

Rocks exposed in this quarry consist of light gray novaculite, gray chert, and black siliceous shale of the Lower, Middle, and Upper Divisions of the Arkansas Novaculite. Most of the rock is obtained from the massive bedded, highly sheared Lower Division. The rocks are southward overturned and several north dipping thrust faults are present. Some conodonts, sponge spicules, and radiolaria(?) are present in the Middle Division. These early trough deposits represent exceptionally slow depositional rates with only minor clastics being deposited.

According to Viele (1973), two major fold trends have been developed

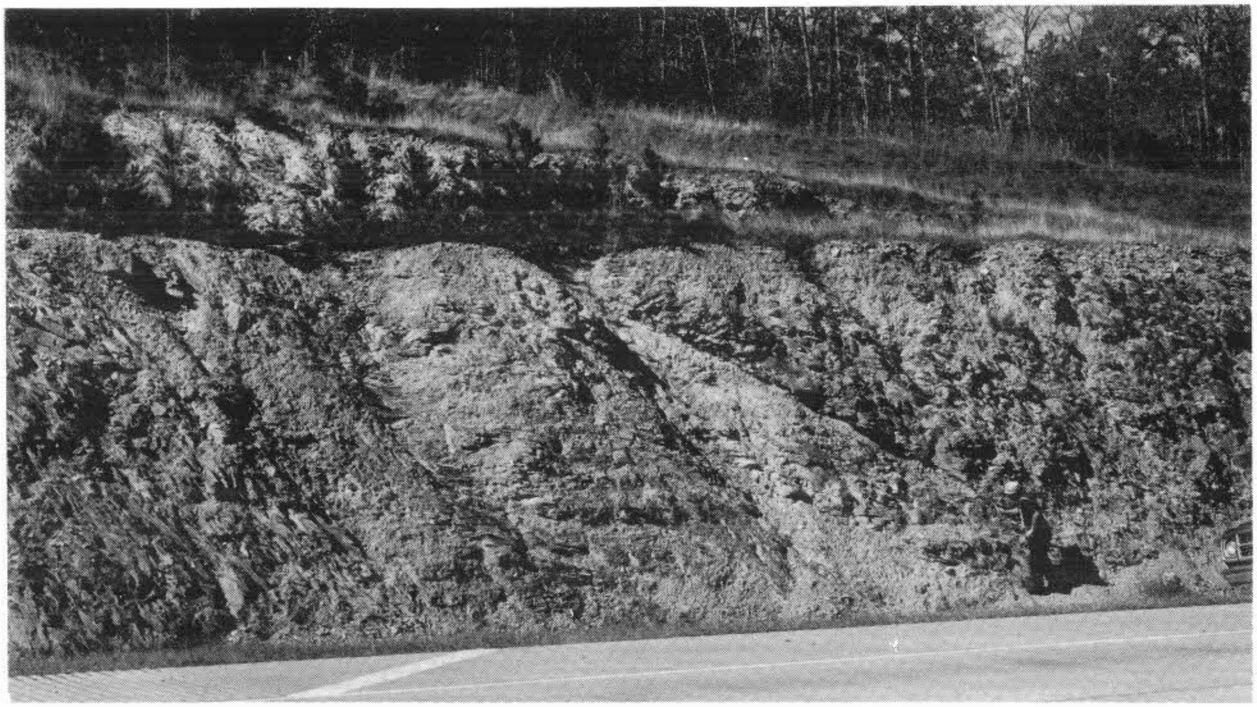


Figure 11 - Stop 4. Shale and chert of the Bigfork Chert on the north in fault contact with black shale and some chert of the Polk Creek Shale on the south on Interstate Hwy. 430.

Figure 12 - Stop 4. Massive bedded novaculite of the Lower Division of the Arkansas Novaculite on the right and thin beds of chert and siliceous shale of the Middle Division of the Arkansas Novaculite on the left. The rocks are capped by a thin sandy rubble that may be a remnant of the Midway Group. The exposure is on Interstate Hwy. 430.

PLATE 9 – GEOLOGIC MAP OF THE PULASKI COUNTY QUARRY AREA – STOP 5

1000 0 1000 2000 3000 FEET

Ki	Igneous Dikes	Sm-Opc	Missouri Mountain Shale – Polk Creek Shale	Ow	Womble Shale
Ms	Stanley Shale			▪▪▪▪▪▪▪▪	Thrust Faults
MDa	Arkansas Novaculite	Obf	Bigfork Chert	———	Contacts

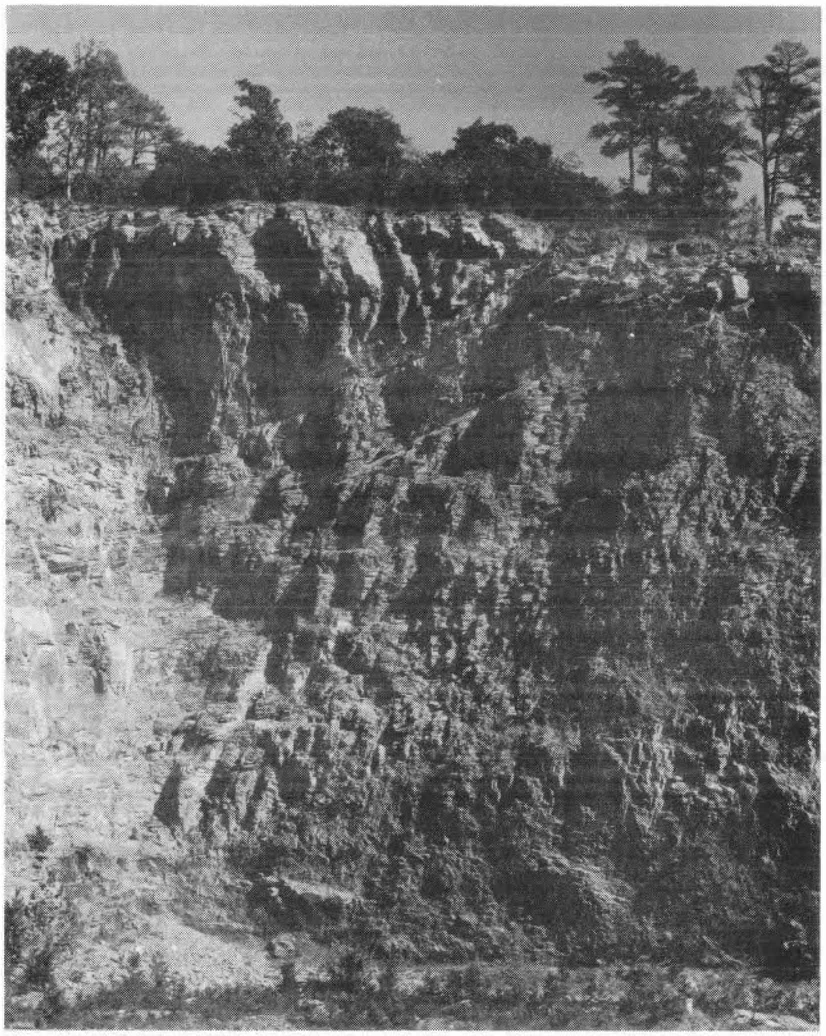
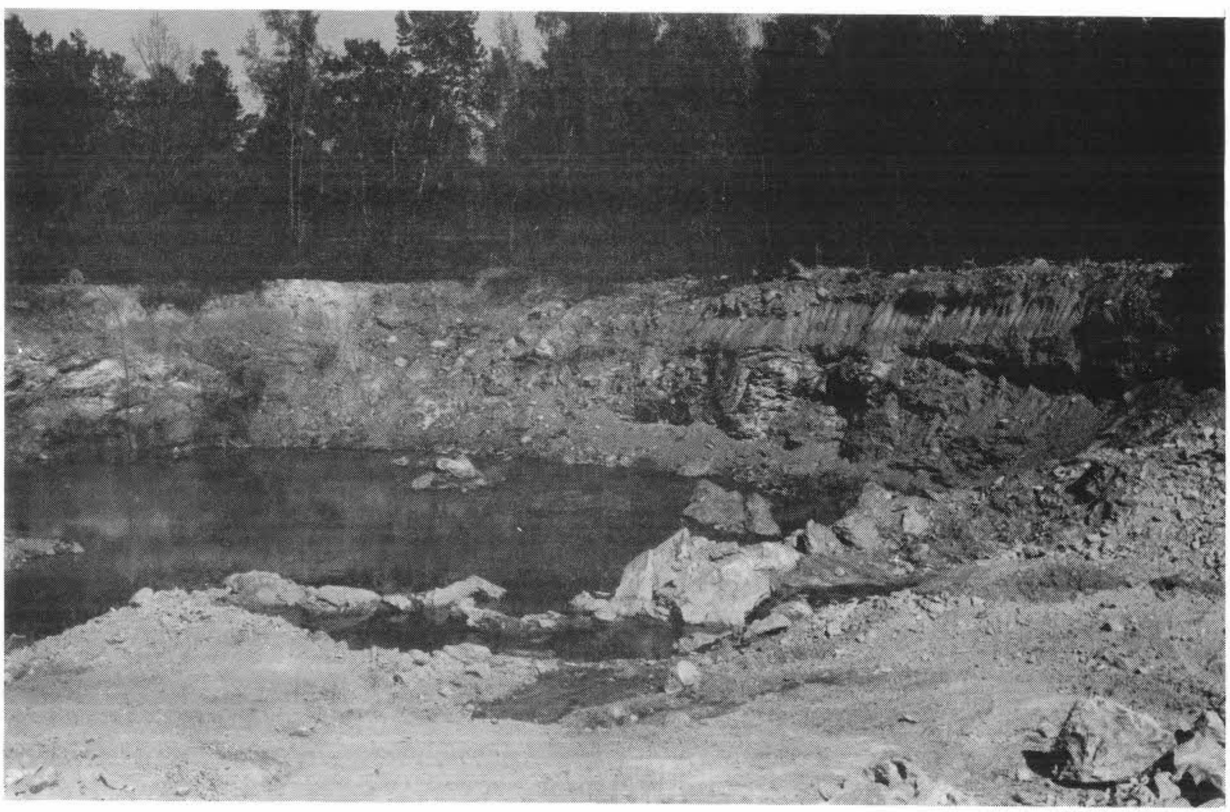


Figure 13 - Stop 5. Highly fractured, massive bedded novaculite of the Lower Division of the Arkansas Novaculite with several northward dipping thrust faults at the east end of the Pulaski County quarry.

Figure 14 - Stop 6. View of soapstone mining operations at the New Warner Soapstone Pit operated by the Milwhite Company in northern Saline County.



in the lower Paleozoic rocks in this area. The Alexander trend consists of southward overturned folds that have nearly horizontal hinges. The Ellis Mountain trend is overturned to the southwest but the fold hinges are reclined. Most of the folds at this site belong to the Alexander trend but the cleavage is believed to be associated with the Ellis Mountain trend.

Quartz veins of late Paleozoic age are present along some fracture systems. Manganese and iron oxides are present in veinlets and in coatings of rock surfaces. An altered alkalic dike (Cretaceous) is exposed at the west end of the quarry.

We wish to extend our sincerest thanks to Judge Bill Beaumont and members of his staff for permission to enter the quarry.

Proceed southwest to Lawson Road.

37.2 Turn north on Congo Road.

38.7 Turn east on gravel road to the new Warner Soapstone Pit.

39.6 **STOP 6 – SOAPSTONE AND WOMBLE SHALE AT NEW WARNER SOAPSTONE PIT (Plates 10, 11 and Figure 14).**

We wish to personally thank Buster and Johnny Warner and members of the Milwhite Mining Company for permission to enter this pit.

This is one of six pits scattered along a narrow, 2½ mile long, east-west trending belt from which soapstone has been mined for use in various industrial products. The first deposit of soapstone was described by Comstock in 1888.

Sterling and Stone (1961) reported that serpentine was exposed in one pit and was encountered in a core hole. Petrographically serpentine has olivine and pyroxene crystal forms suggesting that the original "sill-like" mass was a type of peridotite. Kern Jackson (written communication, 1963) indicated that two samples of serpentine from the Anderson Pit (about two miles to the west) contained relict mineral forms that suggested that the rock was of the Saxonite-Wehrlite-Gordunite-Herzolite type. The "sill" was intruded into the geosynclinal sedimentary layers of Womble and Bigfork probably in middle Paleozoic times and is of prime importance to some theories applied to the subduction of the Ouachita Mountains. Subsequently, later Paleozoic steatization caused by the hydrothermal solutions which created the bulk of the quartz veins in the Ouachita Mountains, altered most of the parental serpentine rock to soapstone.

Sterling and Stone (1961) indicated that the sulfide and some silicate minerals in the soapstone rocks contained significant amounts of nickel (0.05% to 1.5%). Wicklein (1967) mapped these deposits in detail and provided data on the chemistry and mineralogy of the many sulfide, silicate, and carbonate minerals. Some of the minerals of interest at the New Warner Pit are black, white, and brownish-pink calcite veins of at least two generations that cut the soapstone along the south wall; shiny veins of crystalline

PLATE 10 — GEOLOGIC MAP OF SALINE COUNTY SOAPSTONE DEPOSITS — STOP 6

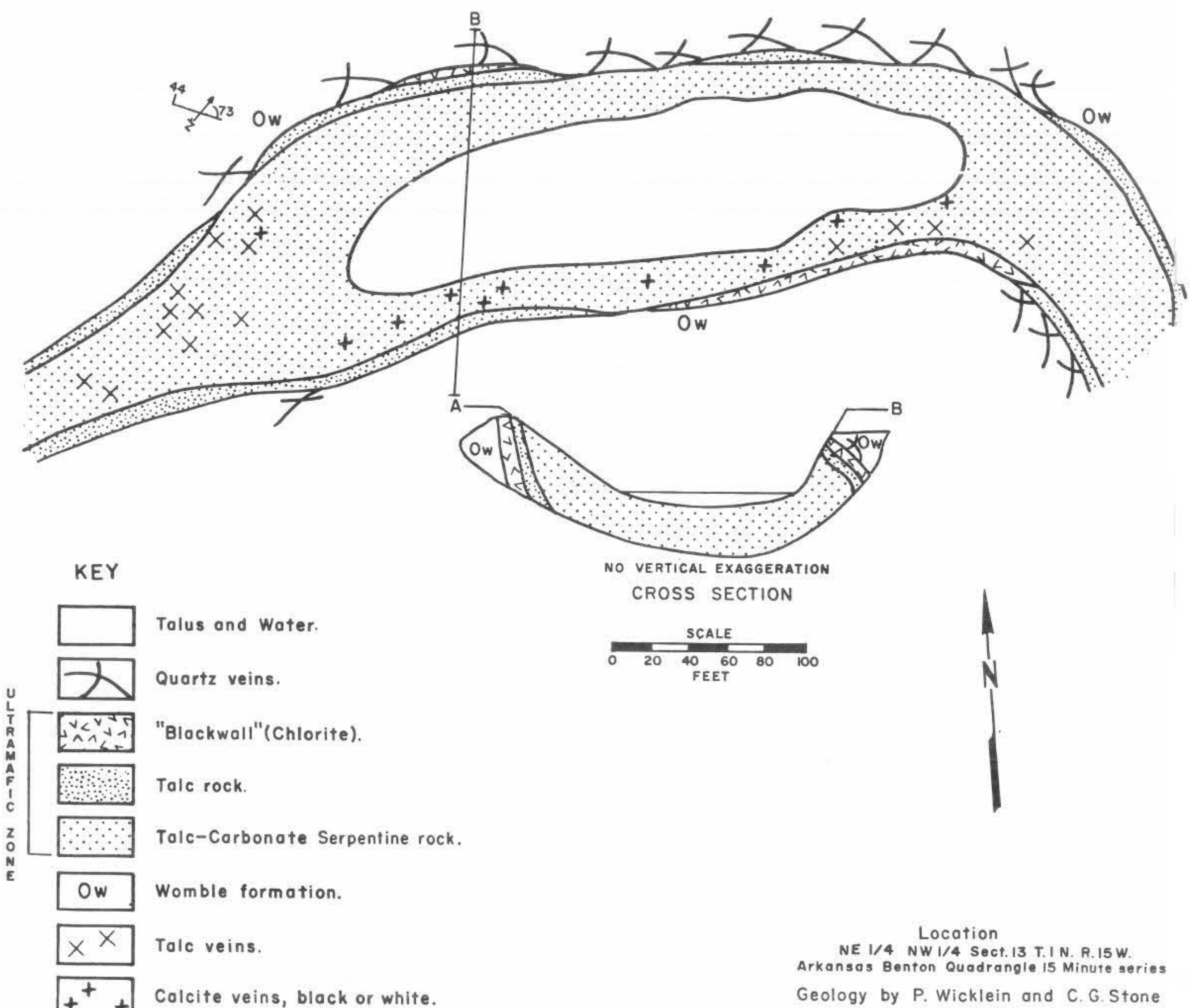
PLATE 11

GEOLOGICAL MAP OF

WARNER SOAPSTONE DEPOSIT

SALINE COUNTY, ARKANSAS

STOP 6



Location
NE 1/4 NW 1/4 Sect. 13 T. 1 N. R. 15 W.
Arkansas Benton Quadrangle 15 Minute series

Geology by P. Wicklein and C. G. Stone
1973

talc at west end of pit; dark green (blackwall) chlorite on the outer walls of the deposit; layered intervals of sulfides in some of the soapstone; and secondary, green to white nickel bloom (hexahydrite and epsomite) on overhanging walls.

At this stop Viele (1973) states that attitudes in the shale pit to the north are typical of those throughout the northeastern part of the Benton Quadrangle. Folds are greatly inclined to near recumbent toward the south and southwest. Hinge lines rake steeply, mostly toward the northeast, and many are reclined. We have mapped a major thrust fault through this locality and the large milky quartz veins are typical of these fault zones.

The only other known igneous rock of Paleozoic age reported at the surface in the Ouachita Mountains is a thin sill of diorite in Womble sandstones in Sections 10 and 15, T. 5 S., R. 22 E. in the Broken Bow area of McCurtain County, Oklahoma (Honess, 1923, p. 210--212). Honess describes the sill as being younger than the Womble (middle Ordovician) and older than the folding (late Pennsylvanian-early Permian).

Return to Congo Road.

39.8 Turn right on Congo Road.

42.3 Leave Saline and enter Pulaski County, road is now Ferncliff Road.

43.8 Ferndale, Arkansas. Continue north on Ferndale Cutoff Road.

48.2 Turn east on Arkansas Hwy. 10.

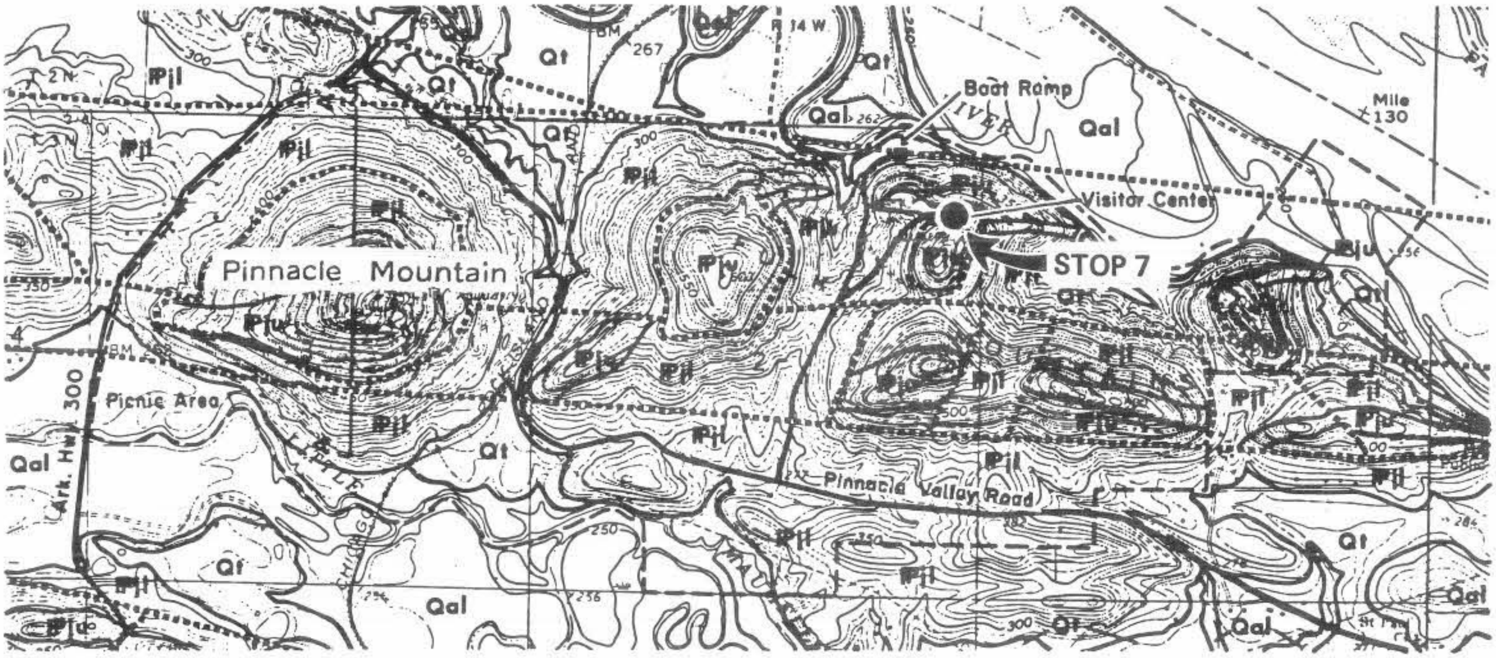
52.8 Turn east on Pinnacle Valley Road.

54.5 Turn north on Visitor Center Road.

55.3 **STOP 7 – JACKFORK SANDSTONE AT VISITOR CENTER IN PINNACLE MOUNTAIN STATE PARK (Plate 12 and Figures 15, 16, 17, 18).**

We wish to thank Superintendent Randy Frazier and Naturalists Randy Johnson and Neil Curry of the Pinnacle Mountain State Park staff for their assistance in arranging this stop. They also have a fine slide presentation on the many features of the Park for those interested.

This highly scenic sight is in the Fulk Mountains portion of the Pinnacle Mountain and Maumelle Pinnacle Chain. The rocks taken from this quarry were used as riprap along the banks of the Arkansas River. The rocks are equivalent to the strata of the middle and upper parts of the Jackfork Sandstone at Stops 1 and 2. The sandstone exposed in the west wall is representative of submarine fan channel deposits. Olistoliths ("glumps" and "gloops") of sandstone, convolute bedding, load casts, and intraformational conglomerates are present, as are fragments of plants in some of the sandstones. A loose boulder of conglomerate containing invertebrate fossils is present near the



GEOLOGIC MAP OF PINNACLE MOUNTAIN STATE PARK

0 1000 2000 3000 4000 FEET
SCALE

N

LOCATION MAP

EXPLANATION

Quaternary

Qal — Alluvium; sand, silt, clay and gravel deposited by streams and rivers in their respective flood plains.

Qt — Terrace; sand, silt, clay and gravel deposited during Pleistocene time by streams and rivers at their former levels.

Cretaceous

Igneous Dike; highly weathered dike expressed as a clay body with inclusions of altered mineral grains.

Pennsylvanian

Pju — Upper Jackfork; massive sandstone with thinner intervals of shale.

Pjl — Lower Jackfork; dark gray shale, thin sandstone beds, and boulder zones in the shale.

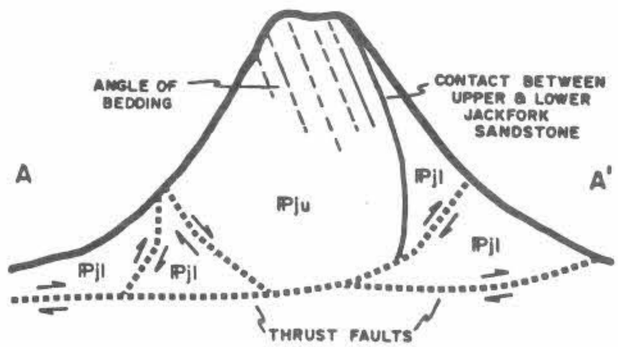
······· Fault

——— Contact

— — — Park Boundary

A A' Cross Section

ARKANSAS GEOLOGICAL COMMISSION



SOUTH TO NORTH
GEOLOGIC CROSS SECTION OF PINNACLE MT.

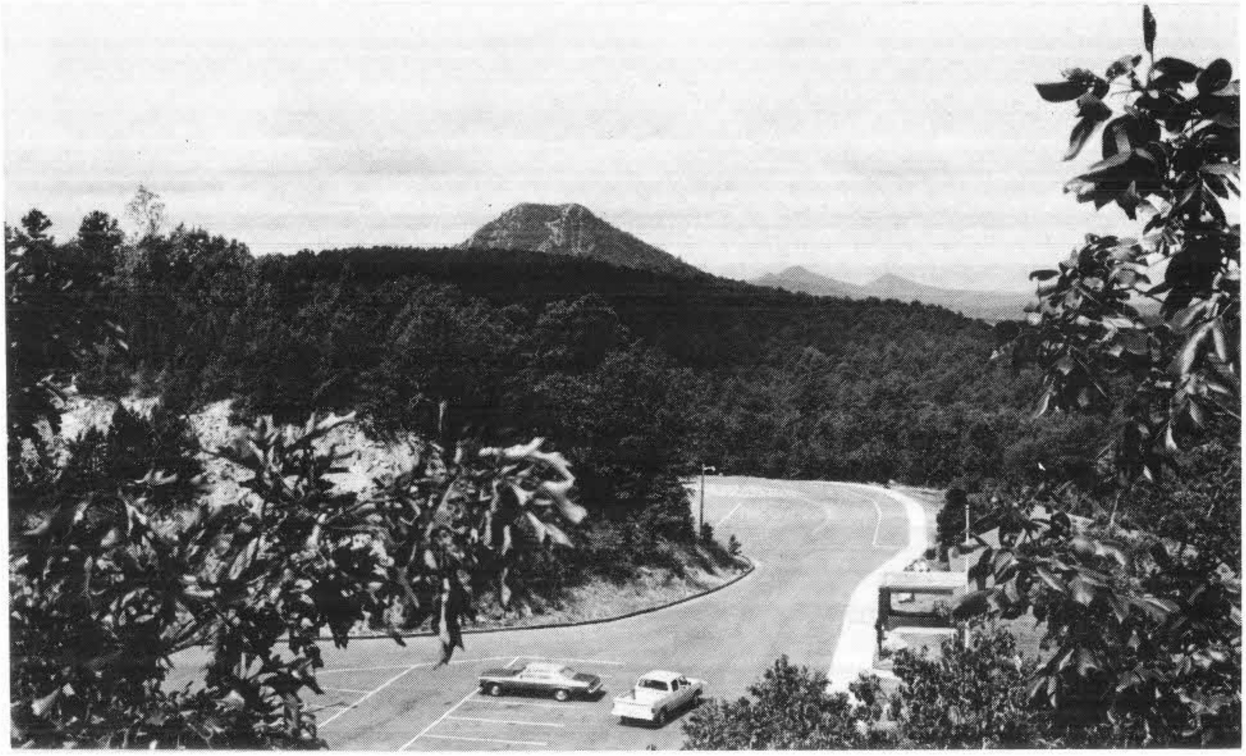


Figure 15 - Stop 7. Panoramic view to the west from the overlook at the Pinnacle Mountain State Park Visitor Center showing the Pinnacle Mountain—Maumelle Pinnacle chain formed by the upper Jackfork Sandstone.

Figure 16 - Stop 7. Quartzitic sandstone of the upper Jackfork Sandstone overlying a faulted olistolithic zone in the black shale of the middle Jackfork Sandstone. This exposure is in the abandoned West Fulk Mountain quarry at the Pinnacle Mountain State Park Visitor Center.

Figure 17 - Stop 7. Closeup of decalcified fossiliferous conglomerate from a small exotic boulder from the middle Jackfork Sandstone in the quarry floor of the Pinnacle Mountain State Park Visitor Center.

Figure 18 - Stop 7. This sequence in the upper Jackfork Sandstone consisting of quartzitic sandstone with a rubbly interval at the top represents an upper submarine fan channel deposit. It is exposed on the west side of the parking lot at the Pinnacle Mountain State Park Visitor Center.

front of the quarry. The fault zones are marked by dickite coated slickensides and by quartz veins containing cookeite and rectorite.

The resistant masses of sandstone forming this mountain can be explained by: (1) they are parts of a sheet of sandstone that has been separated by differential movement between two thrust faults; (2) they are remnants of individual submarine fans; or (3) they are parts of a sheet of sandstone that became separated as it slid southward into the deeper part of the trough.

Invertebrate fossils have been collected from sandstone olistoliths in two zones of the shale of the middle Jackfork in the area west of this Stop. These fossil-bearing sandstone olistoliths appear to have been limy and are thought to have slid southward from a shallow-water depositional environment. The following ammonoid cephalopods of early Morrowan (Hale) age were identified: *Syngastrioceras globosum* (Easton), *Bisatoceras (Schartymites) paynei* (Gordon), *Reticuloceras tiro* (Gordon), *Retites semiretia* (McCaleb), *Cymoceras adonis* (Gordon), and *Stenopronorites quinni* (Gordon) (Gordon, 1968 and Gordon and Stone, 1977).

Return to Arkansas Hwy. 300.

57.9 Turn south on Arkansas Hwy. 300.

58.8 Turn west on Barber Road.

61.6 Turn west on Arkansas Hwy. 10.

68.1 **STOP 8 – OLISTOLITHIC INTERVAL IN THE MIDDLE PART OF THE JACKFORK SANDSTONE AT LAKE MAUMELLE (Plate 13 and Figures 19, 20).**

The rocks exposed in this roadcut consist of black and reddish-brown shale with angular to rounded olistoliths of light gray quartzose sandstone very similar lithologically to the typical sandstone of the Jackfork. When olistoliths very similar to these are weathered out of the shale, they rest on the surface of the ground and resemble the "knockers" described by alpine geologists. Fossil-bearing sandstone olistoliths are not present in this outcrop but they are present in nearby outcrops. Thrust faults are present and are marked by slickensides and quartz veins. Some of the quartz veins contain minor amounts of lead, zinc, copper, and silver minerals.

Olistolithic zones of the type observed in this outcrop are common in the middle part of the Jackfork Sandstone in Pulaski County and are common in the middle part of the Jackfork for a distance of as much as 130 miles to the west. Similar zones are also present in the lower part of the Atoka Formation, very common in the Johns Valley Shale and common in the Stanley Shale. Tectonic deformational indicators such as faults, slickensides, dickite, quartz veins, and cleavage are not unique to this outcrop; they are present in many olistolithic zones.

78.5 Turn south on Arkansas Hwy. 9.

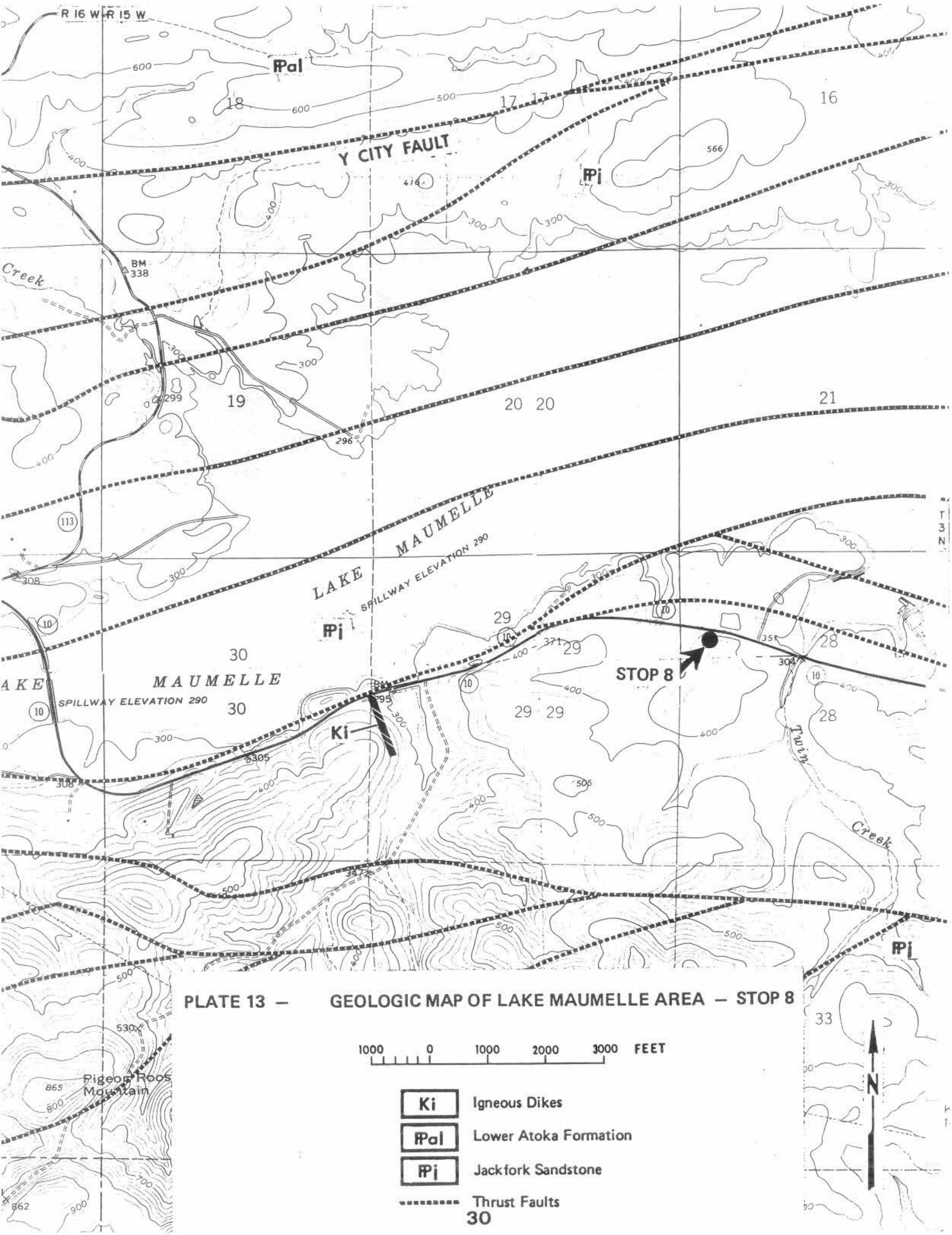


PLATE 13 — GEOLOGIC MAP OF LAKE MAUMELLE AREA — STOP 8

Figure 19 - Stop 8. Olistoliths of quartzitic sandstones and some iron carbonate concretions in black shales of the middle Jackfork Sandstone on Arkansas Hwy. 10 south of Lake Maumelle.

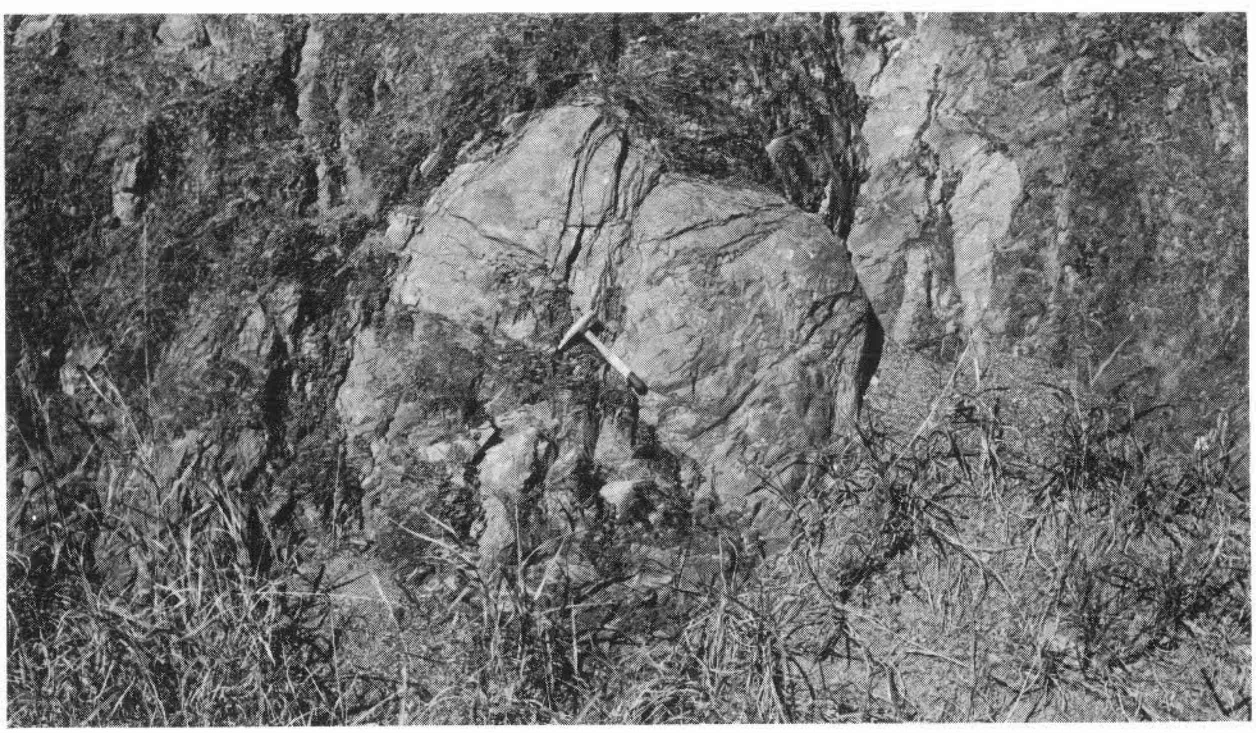


Figure 20 - Stop 8. Closeup of healed fractures in an olistolith of quartzitic sandstone in shale of the middle Jackfork Sandstone on Arkansas Hwy. 10 south of Lake Maumelle.

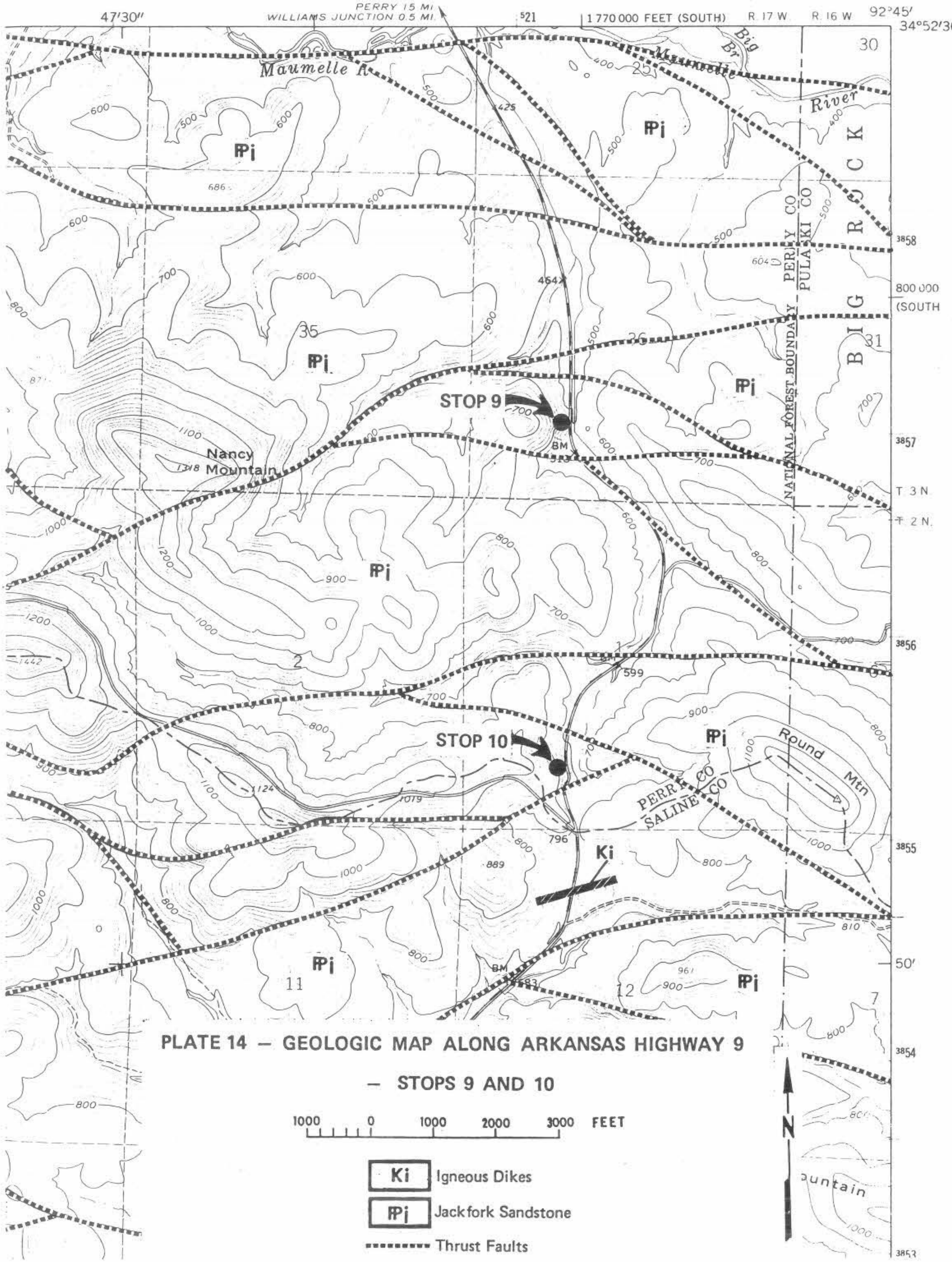


PLATE 14 – GEOLOGIC MAP ALONG ARKANSAS HIGHWAY 9 – STOPS 9 AND 10

80.3 **STOP 9 – UPPER JACKFORK SANDSTONE AT ROCK SHELTER ON ARKANSAS HWY. 9 (Plate 14 and Figure 21).**

Interbedded shale and sandstone of the upper part of the Jackfork Sandstone are exposed on the west side of the road. This sequence of rocks was deposited in a submarine fan channel. Bottom marks, graded bedding, convolute bedding, and soft-sediment slump features are present. Several high-angle faults dip to the north and the apparent movement along these was towards the south. Slickensides coated with dickite are common. Steep northward dipping cleavage is well-developed in the shale. Three generations of quartz veins were emplaced in the following order: (1) veins that are folded and sheared and contain pyrophyllite; (2) veins of milky quartz with dickite; and, (3) veins of milky quartz with rectorite, cookeite, and pyrophyllite.

81.8 **STOP 10 – LOWER JACKFORK SANDSTONE ON ARKANSAS HWY. 9 (Plate 14 and Figure 22).**

Interbedded, vertically dipping sequence of light gray quartzose sandstone and reddish-black shale (bottom to north) of the lower Jackfork Sandstone are exposed at this stop. An intraformational conglomerate is evident at the base of one submarine fan channel sequence. A small southward inclined fold near the center of the outcrop has been related by some workers to tectonic deformation and there is a small thrust fault at the base of the fold with dickite coated slickensides. Other workers have related the fold to southward directed sedimentary slumping prior to the faulting.

Quartz veins fill some fractures in the rock and contain needle quartz, rectorite, and cookeite. Quartz veins of this type are thought to have been emplaced during the latest part of the Ouachita Orogeny.

These Jackfork Stops are in the area that Viele has referred to as the "Maumelle Chaotic (Subduction) Zone", taking the name from the seemingly structural complexities of the rocks exposed (at Stops 8, 9, 10) along the Lake Maumelle trend. The structure and the lithology of these rocks has evoked much discussion among Haley, Stone, Viele, and others, quite a bit of it most noisy. Does the chaos of the sandstone and shale in some of the Jackfork along this trend represent zones of submarine slumping and sliding from the north into the Ouachita trough or zones that slid from the south off the backs of northward-advancing nappes or zones of tectonic melange related to subduction faults?

The following summary of the tectonic history of the Ouachita Mountains was published by Viele (1979):

> The plate-tectonics history of the Ouachitas is believed to comprise two phases (Viele, 1977). The first, recorded in the lower to middle Paleozoic strata of the Benton uplift is one of late Precambrian to early Paleozoic rifting and the opening of an ocean between North America and a southern continental plate, Llanoria. Emplaced during this phase were

the exotic blocks of granitic and carbonate rocks lying within the lowermost Ordovician formations of the Benton uplift. These formations are viewed as a continental slope-rise facies deposited downslope from the rifted North American margin, which was blanketed by carbonate strata. Continued spreading and subsidence of the ocean floor formed abyssal depths in which Ordovician to Mississippian shale, chert, and novaculite slowly accumulated.

The slow rate of accumulation of strata abruptly accelerated with the deposition of the Stanley Shale, this flysch signalling the onset of the second phase of tectonic history: the closing of the ocean by south-directed subduction, and the subsequent collision of the North American and Llanorian plates. The early to middle Paleozoic slope and abyssal strata were scraped off the subducting oceanic crust and incorporated into an accretionary wedge, the present day Benton uplift. Deposition of as much as as 10 km of Carboniferous flysch engulfed a trench and the plate margins on both shores of a remnant ocean. Within the Maumelle zone these strata were in part incorporated into the subduction complex, for the broken and sheared Maumelle terrain is regarded as the toe of an accretionary wedge on the Llanorian side of the trench. The Benton uplift and more southerly regions are believed to lie on an upper plate,which is viewed as a microcontinent, because seismic velocities (Martin and Case, 1975) and other evidence indicate a continental crust to within a few kilometers of the present shoreline of the Gulf of Mexico.

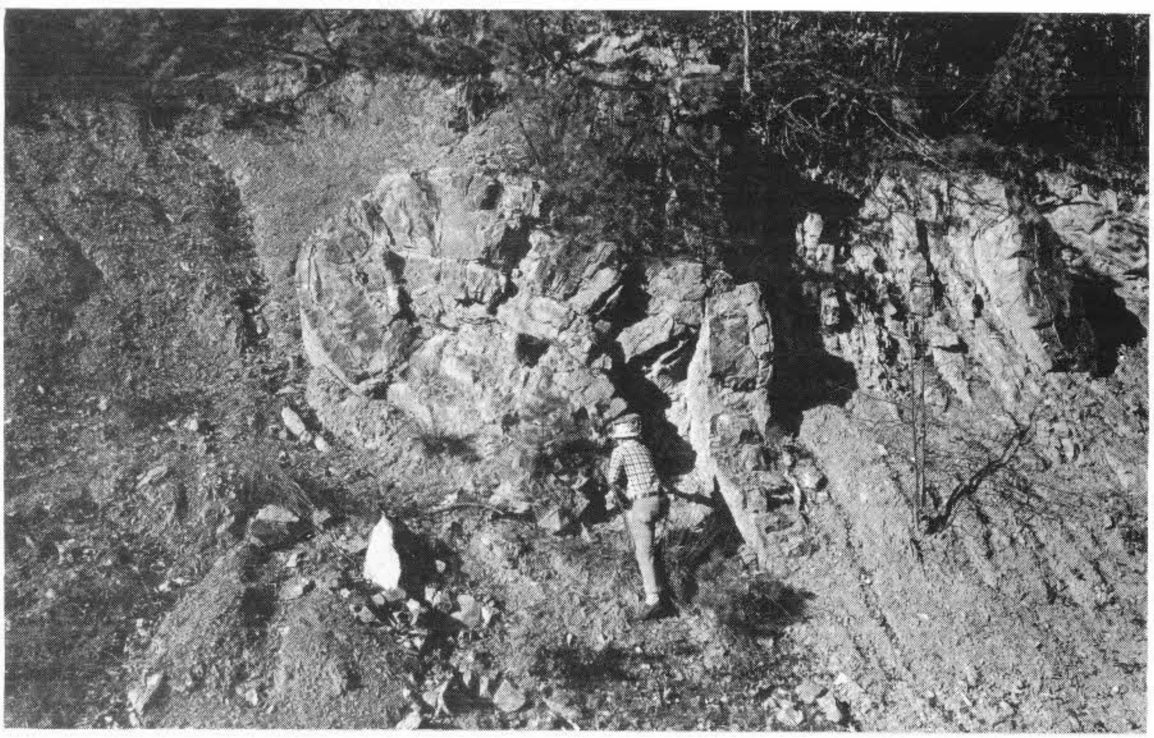
Relative to some other cross sections prepared by the Plate Margins Group, the section across the Ouachitas is necessarily more speculative, because of the age of the folded belt. The intent of this work is not so much to describe a plate margin as to advance the hypothesis that the Ouachita Mountains do indeed constitute a suture between plates. Resolution of the hypothesis must await seismic investigation of the configuration and nature of the basement both north and south of the folded belt.

The Chickasaw Creek Siliceous Shale Member of the uppermost Stanley Shale has been recognized in the frontal Ouachita Mountains of Oklahoma and has been traced eastward by Stone and Haley to Lake Sylvia (4 miles west of here). At Lake Sylvia and at Forked Mountain (10 miles further west) the member contains exotic boulders of rocks identified as Pitkin Limestone and Fayetteville Shale of the Ozark shelf sequence (Gordon and Stone, 1977, p. 80–81). Some of the characteristic fossils from the Pitkin Limestone boulders are as follows:

Coral:	*Lonsdaleia major* Easton ?
Bryozoan:	*Archimedes cf. A. lunata* Condra and Elias

Figure 21 - Stop 9. The interbedded sandstone and shale represents a submarine fan channel deposit in the upper Jackfork Sandstone on west side of roadcut on Arkansas Hwy. 9.

Figure 22 - Stop 10. A small inclined fold of soft-sediment slumping (?) or tectonic (?) origin in the middle Jackfork Sandstone on Arkansas Hwy. 9.



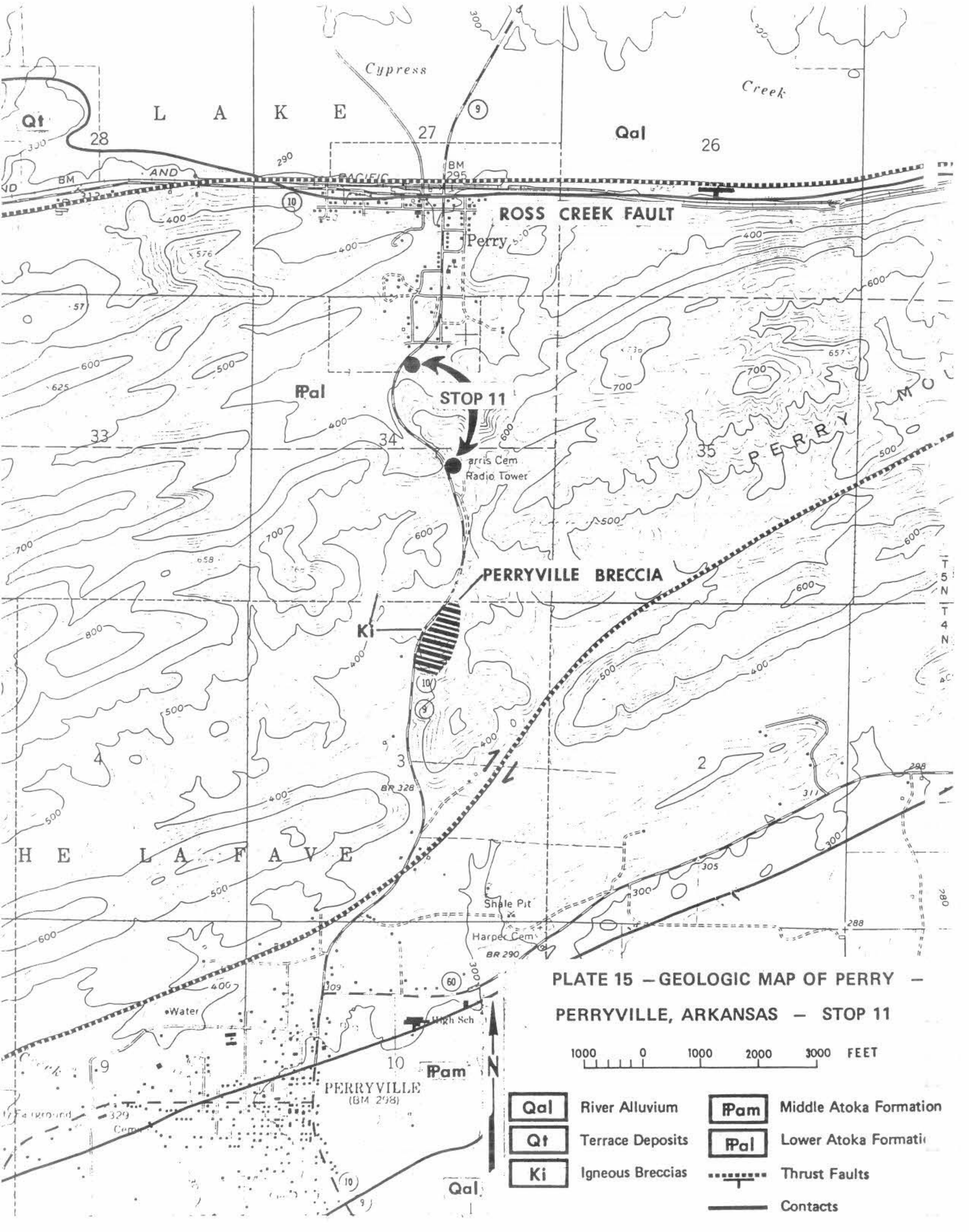


PLATE 15 – GEOLOGIC MAP OF PERRY – PERRYVILLE, ARKANSAS – STOP 11

1000 0 1000 2000 3000 FEET

Qal	River Alluvium	Pam	Middle Atoka Formation
Qt	Terrace Deposits	Pal	Lower Atoka Formati[on]
Ki	Igneous Breccias		Thrust Faults
			Contacts

Blastoid:	*Pentremites laminatus* Easton
Brachiopods:	*Leptagonia n. sp.*
	Streptorhynchus suspectum Girty
	Rotaia neogenes (Girty) ?
	Athyris pitkinensis Snider
	Hustedia multicostata Girty
Bivalves:	*Schizodus chesterensis* Meek and Worthen
	Edmondia pitkinensis Snider
	Sphenotus quadriplicatus Snider

[Coral identified by W. J. Sando, U. S. Geological Survey; other fossils identified by Mackenzie Gordon, Jr., U. S. Geological Survey]

A characteristic Fayetteville shale fossil, the large orthoconic nautiloid *Rayonnoceras solidiforme* Croneis, was found in a boulder of Fayetteville Shale. Another boulder of Fayetteville Shale yielded the conodonts *Gnathodus bilineathus* (Roundy) and *G. commutatus* (Branson and Mehl) which are Chesterian forms that are not, however, known in the upper Chesterian rocks in the American midcontinent. These erratic blocks were derived from the slope and shelf to the north and represent another pulsation of southward submarine slumping of rocks into the Ouachita trough.

Return northward to Arkansas Hwy. 10.

84.7 Continue north on Arkansas Hwy. 10.

96.4 Perryville, Arkansas.

97.8 **STOP 11 – LOWER ATOKA FORMATION ON ARKANSAS HWY. 10 NEAR PERRYVILLE, ARKANSAS (Plate 15 and Figure 23).**

Begin walking north along Arkansas Hwy. 10 to the bottom of the hill. **Be careful** – there is considerable traffic on this road! These exposed rocks of the lower Atoka Formation exemplify flysch deposition with monotonous repetitions of: southward dipping, thick to thin bedded, graded, bottom marked, and convolute bedded subgraywacke; very micaceous siltstone containing coalified plant fragments (blue beds); and, black fissile shale with some sideritic iron concretions. Submarine fan channel and lobe sequences are present and these rocks are representative of midfan deposition (Plates 16, 17). Deep water trace fossils are numerous in this sequence. Some minor dickite coated slickensides and minute quartz veins are present.

This is a portion of the 10,000 foot sequence placed in the Atoka Formation by Croneis (1930) and is in the lower Atoka by Stone (1968). We know now that the lower Atoka Formation in this area is about 13,000 feet thick and that the total Atoka Formation is about 20,000 feet thick. The basal part of the lower Atoka may be late Morrowan in age. Near the railroad tracks at Perry, Arkansas some 0.5 miles to the north, the Ross Creek fault has thrust lower Atoka rocks northward over upper Atoka rocks.The stratigraphic displacement across the fault is more than 15,000 feet.

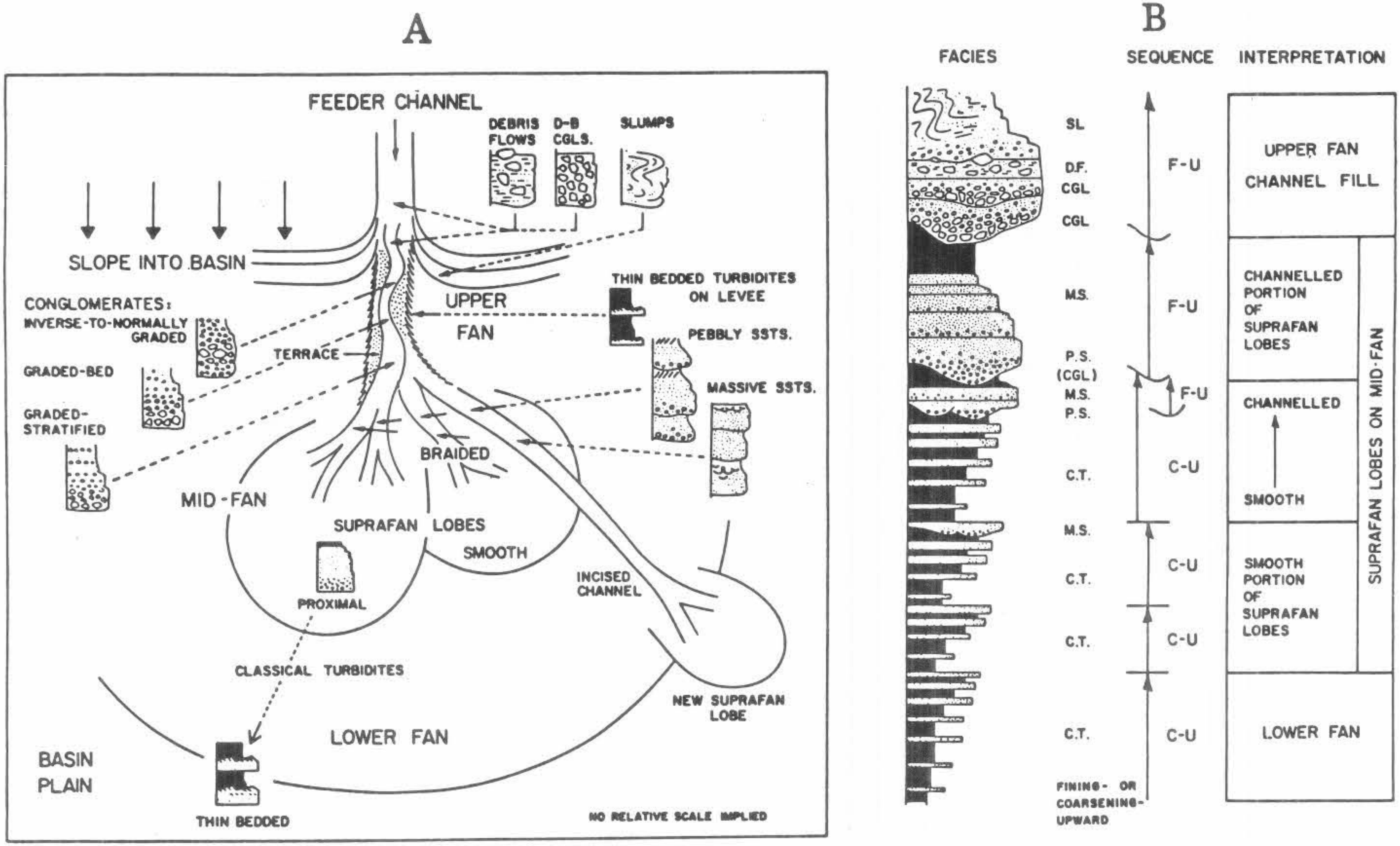


PLATE 16 – A. SUBMARINE–FAN MODEL AND ASSOCIATED TURBIDITE FACIES OF WALKER (1978). B. HYPOTHETICAL STRATIGRAPHIC SEQUENCE THAT COULD BE DEVELOPED DURING FAN PROGRADATION: **C–U.**, represents thickening-and coarsening-upward sequence; **F–U.**, represents thinning-and fining upward sequence; **C.T.**, classic turbidites; **M.S.**, massive sandstones; **P.S.**, pebbly sandstones; **CGL**, conglomerate; **D.F.**, debris flows; **SL.**, slumps; from Walker (1978).

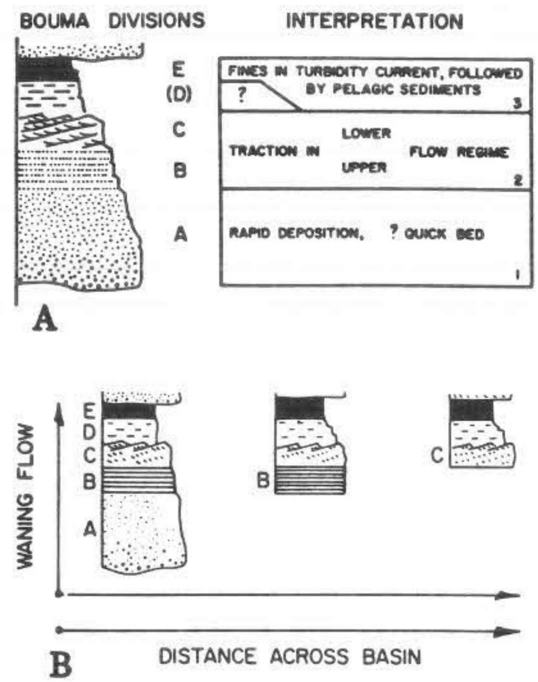


PLATE 17 – A. BOUMA MODEL FOR CLASSIC TURBIDITES: division **A** is massive or graded, **B** is parallel laminated, **C** is rippled, **D** consists of faint laminations of silt and mud, and **E** is pelitic; after Walker (1978). **B. INTERPRETATION OF BOUMA SEQUENCE IN TERMS OF WANING FLOW:** suggests that groups of turbidites beginning with divisions **B** and **C** represent deposition from progressively slower flows, presumably related to distance from source; after Walker (1978).

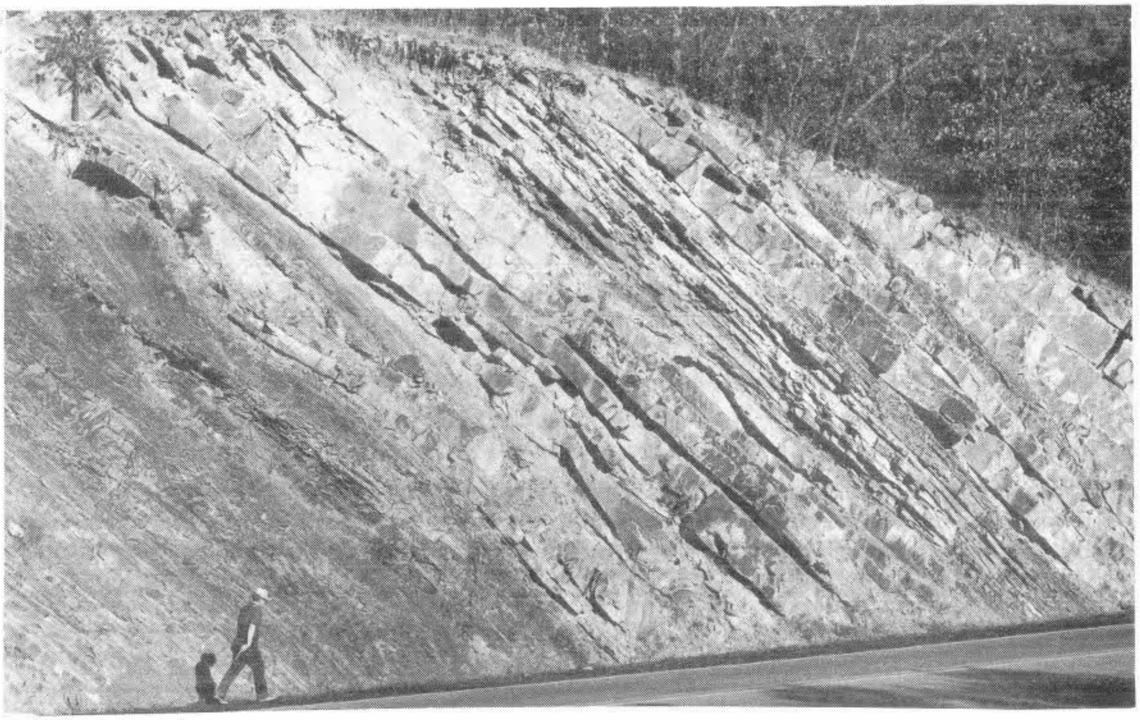


Figure 23 - Stop 11. Interbedded sandstone and shale mostly in thinning (of beds) and fining (of grains) upward sequences that represent midfan submarine channel deposits in the lower Atoka Formation north of Perryville on Arkansas Hwy. 10.

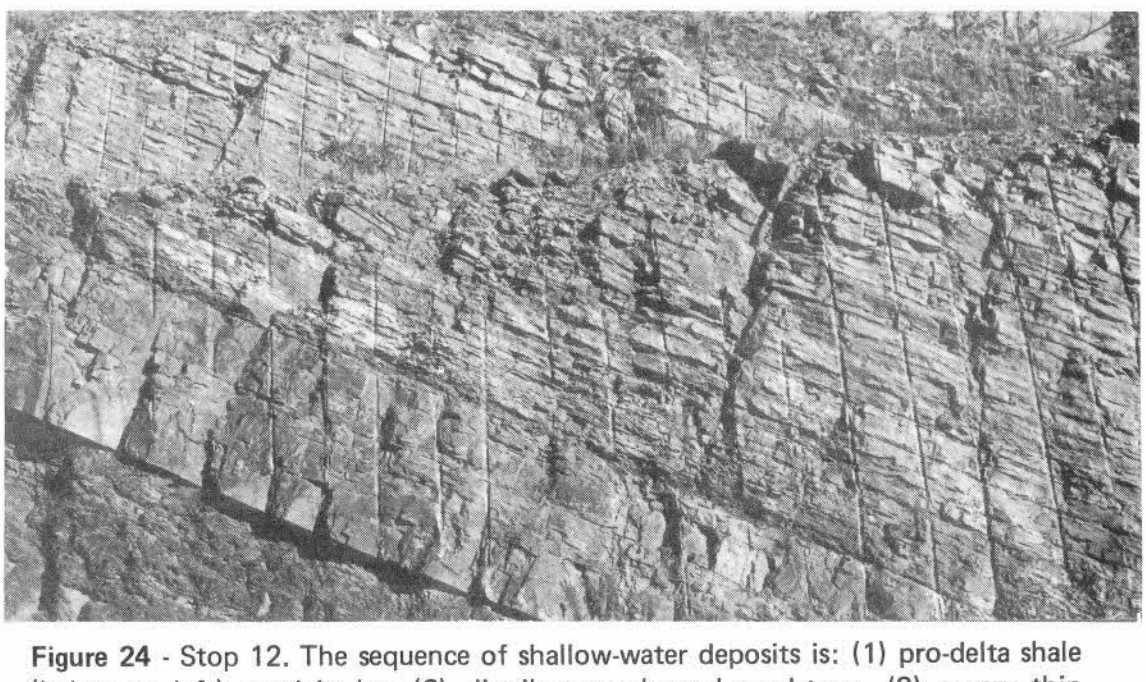


Figure 24 - Stop 12. The sequence of shallow-water deposits is: (1) pro-delta shale (below to left) overlain by, (2) distributary channel sandstone, (3) a very thin transgressive marine sandstone, and (4) middle to inner fringe sandstone. These rocks are in the upper Atoka Formation on the Morrilton Bypass.

The Perryville igneous breccia (lamprophyre—carbonate intrusive) of probable early Upper Cretaceous age is exposed to the south of this area near the house on the east side of the highway.

98.9 Perry, Arkansas, Junction of Arkansas Hwys. 9 and 10. Continue north on Arkansas Hwy. 9.

102.9 Oppelo, Arkansas and Junction of Arkansas Hwy. 154 to Petit Jean State Park. Continue on Arkansas Hwy. 9.

108.0 **STOP 12 – UPPER ATOKA FORMATION ON ARKANSAS HWY. 9, MORRILTON BYPASS – TOP INTERVAL (Plate 18 and Figures 24, 25).**

It is with much pleasure that we acknowledge the considerable sedimentological information provided by Rufus J. LeBlanc and others of the Shell Oil Company on the following four Stops of this trip. See Plates 19A and 19B furnished by Mr. LeBlanc for a brief summary of deltaic depositional models.

The rocks exposed in this roadcut are in the lower part of the upper Atoka Formation and on the south flank of the Morrilton anticline. From north to south the sandstone and shale sequences represent parts of four deltaic depositional cycles as follows: (1) pro-delta with overlying outer fringe strata; (2) distributary channel with a transgressive marine unit at the top; (3) inner fringe overlain by a river mouth bar interval; and, (4) inner fringe capped by a distributary channel.

Flaser bedding and small ripple marks are common in the rocks of the outer fringe. Thin, even bedded rocks are present in inner fringe deposits. Load features, scour channels, shale and sandstone clasts, and cross bedding mostly in a single direction are present in the rocks of the distributary channel sequences. Cross bedding oriented in many directions with some load and slump features typlifies the rocks in the river mouth bar deposits. Small shale clasts, fragments of coalified plants, and invertebrate fossils are present in the rocks of the transgressive marine unit. Shallow-water trace fossils are especially numerous in the rocks of the outer fringe interval. These delta sequences had a probable source to the northeast as indicated by the cross-beds and ripple marks.

108.2 **STOP 13 – UPPER ATOKA FORMATION ARKANSAS HWY. 9, MORRILTON BYPASS – MIDDLE INTERVAL (Plate 18 and Figures 26, 27 28).**

From north to south these rock units are: (1) marine black shale with a thin bed of fossiliferous limestone; (2) a pro-delta silty gray black shale; (3) outer fringe deposits of silty sandstone and shale; (4) inner fringe even-bedded sandstone; (5) a transgressive unit of fossiliferous sandstone; and, (6) pro-delta black silty marine shale.

The rocks in the outer delta fringe interval are extensively bioturbated—note *Conostichthus* and other shallow water forms. A water expulsion feature

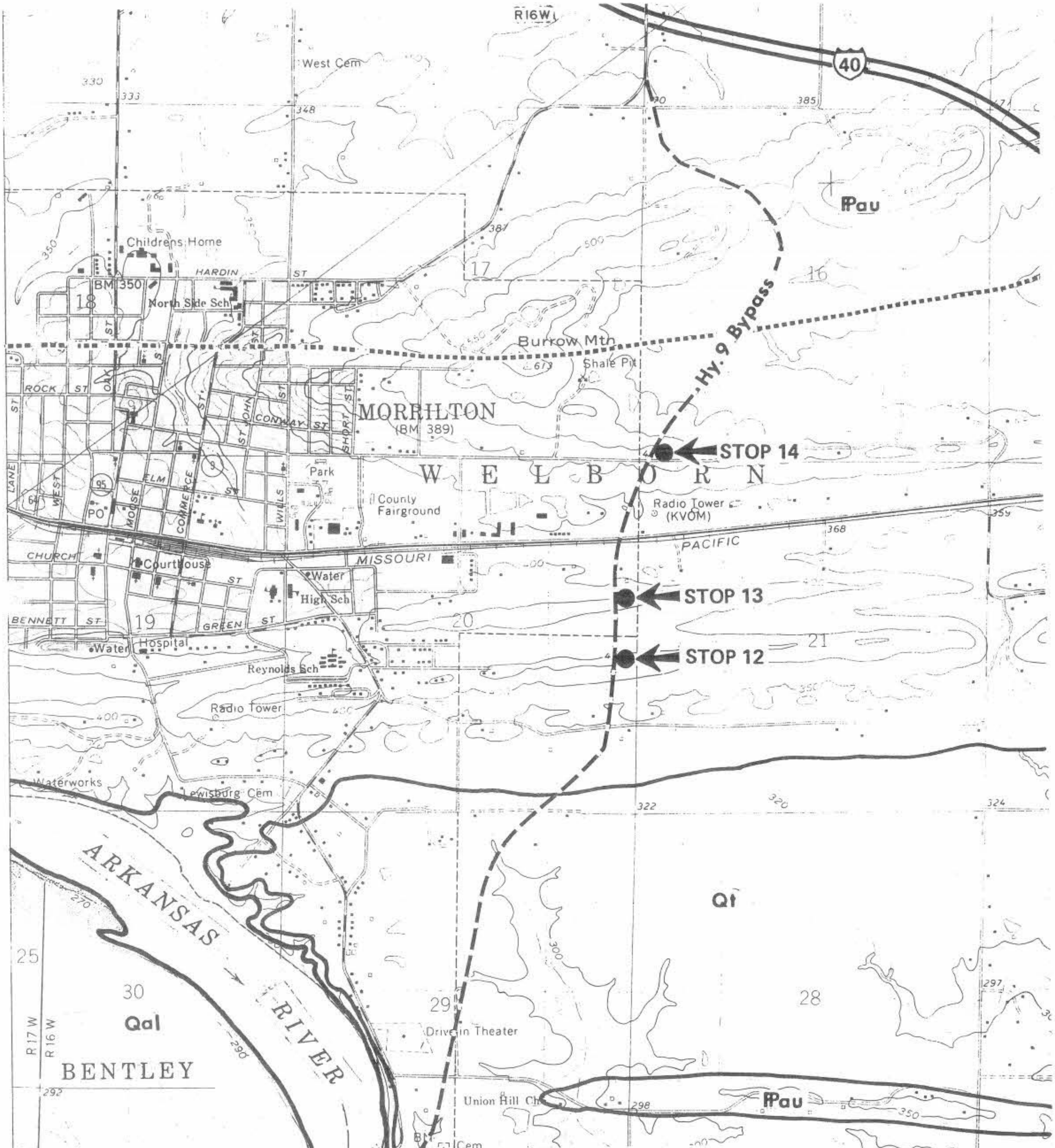


PLATE 18 – GEOLOGIC MAP OF MORRILTON AREA – STOPS 12, 13, and 14

1000 0 1000 2000 3000 FEET

N

Qal	River Alluvium
Qt	Terrace Deposits
Pau	Upper Atoka Formation
....	Thrust Faults
——	Contacts

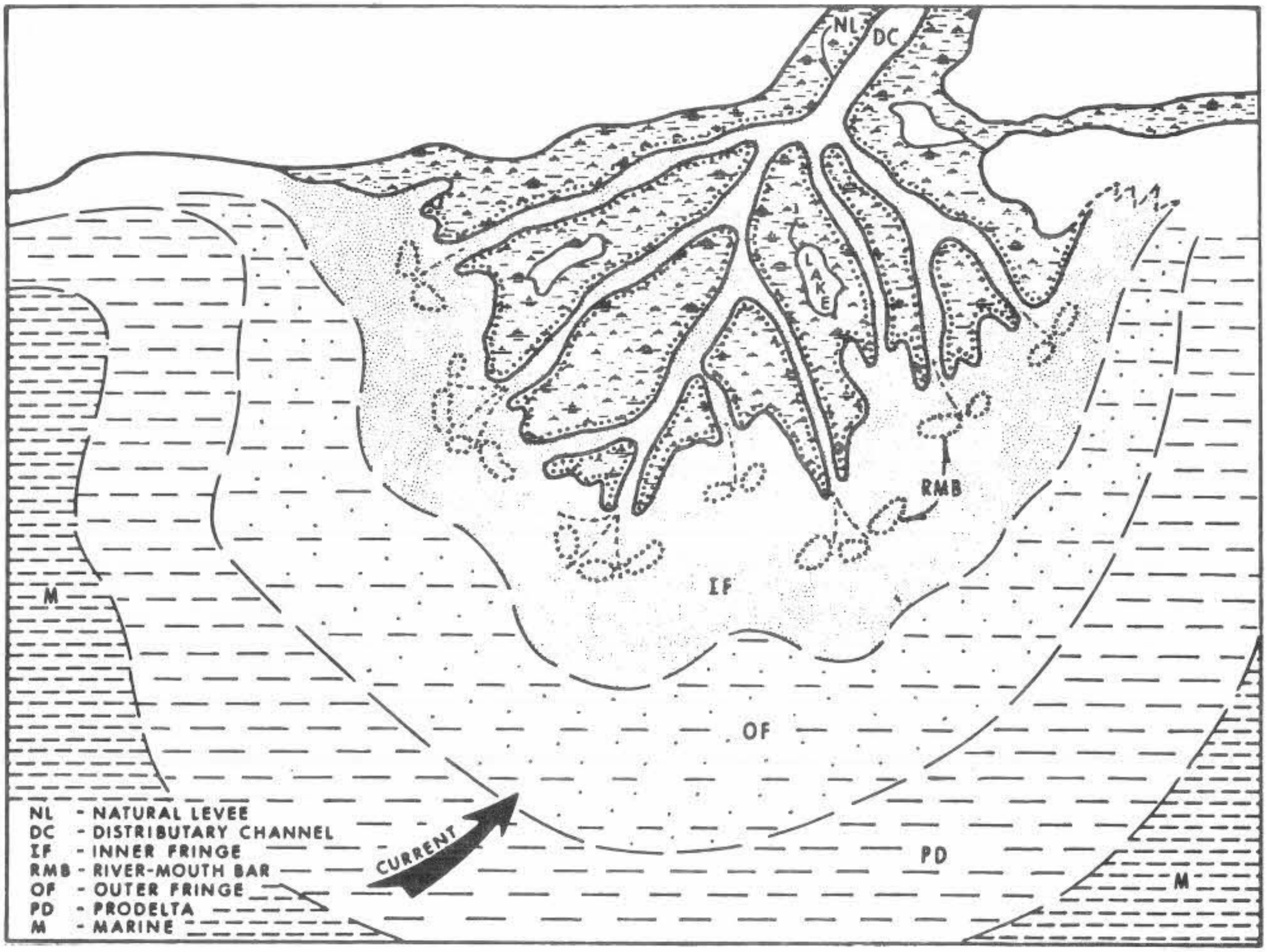


PLATE 19 A – DEPOSITIONAL ENVIRONMENTS TYPICAL OF MODERN DELTAS. From Le Blanc (1977).

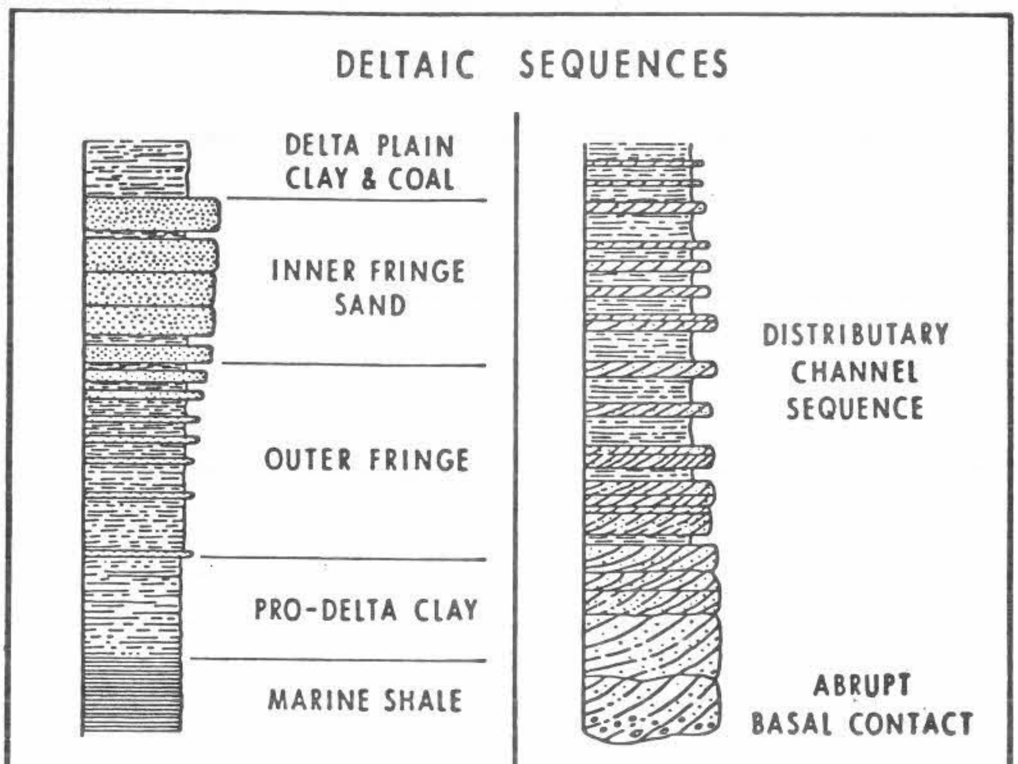


PLATE 19 B – TYPICAL SEQUENCES OF DELTAIC DEPOSITS. From Le Blanc (unpublished).

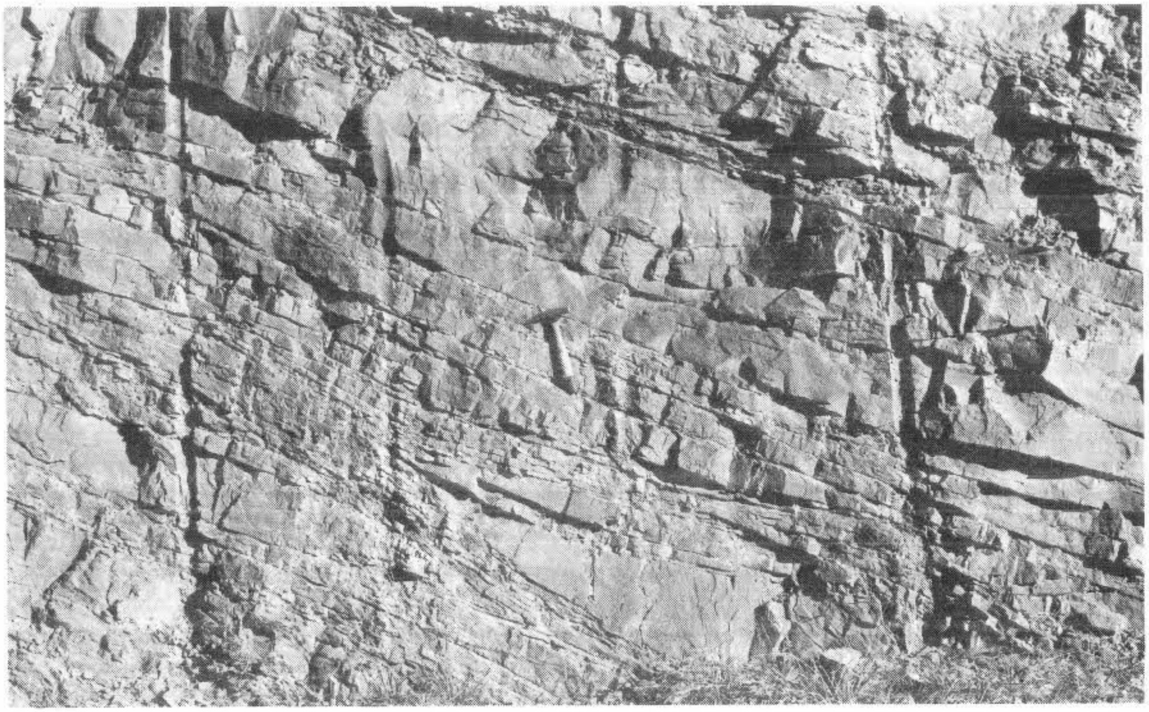


Figure 25 - Stop 12. River mouth bar sandstone in the upper Atoka Formation on the Morrilton Bypass.

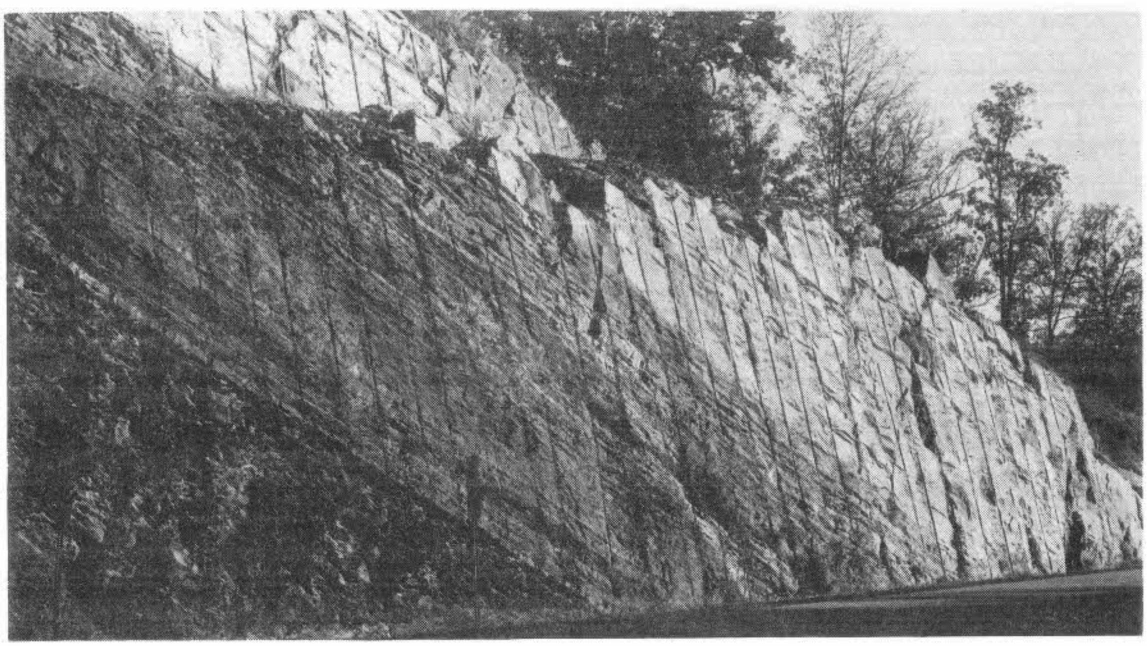


Figure 26 - Stop 13. A nearly complete delta sequence consisting of: (1) marine and pro-delta silty shale (below to left) overlain by, (2) thin bedded outer fringe sandstone, (3) massive even bedded inner fringe sandstone, and (4) a thin bed of transgressive marine sandstone. These rocks are in the upper Atoka Formation on the Morrilton Bypass.

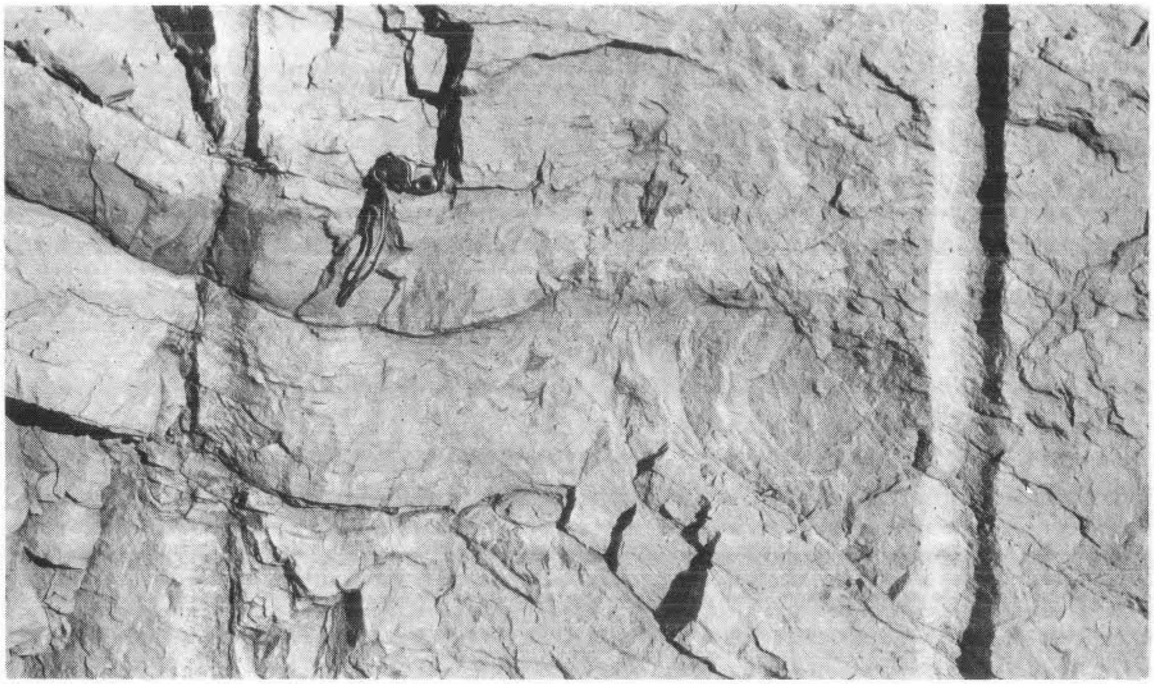


Figure 27 - Stop 13. Closeup of water expulsion feature in the inner fringe sandstone of the upper Atoka Formation on west side of roadcut on the Morrilton Bypass.

Figure 28 - Stop 13. Bioturbated rocks (including Conostichus) in the outer fringe deposits of the upper Atoka Formation on the Morrilton Bypass.

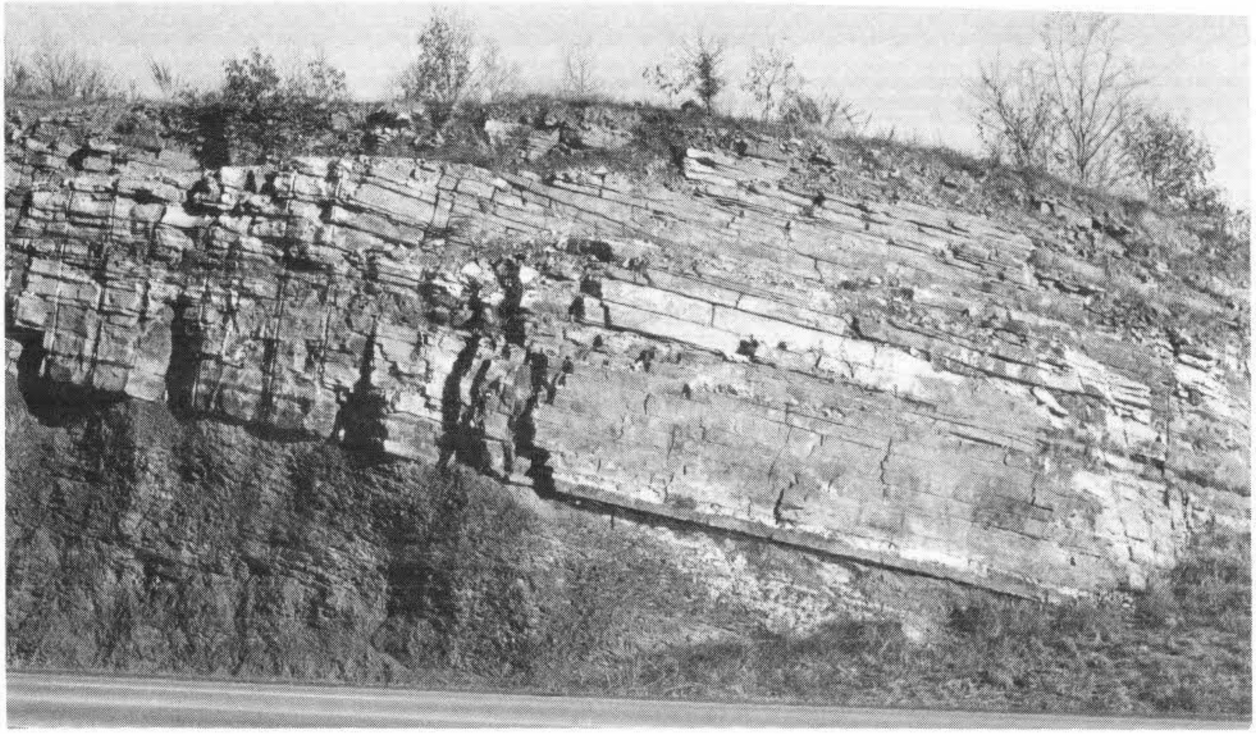


Figure 29 - Stop 14. This sequence of rocks consists of: (1) pro-delta silty shale and very thin flaser bedded sandstone (below) overlain by, (2) even bedded, inner fringe sandstone, and capped by (3) a cross-bedded distributary channel sandstone. These rocks are in the upper Atoka Formation on the Morrilton Bypass.

Figure 30 - Stop 14. Distributary channel sandstone below overlain by shale (clay plug) deposited in an abandoned channel.

is present on the east side of the roadcut in the sandstone of the inner fringe sequence.

108.7 **STOP 14 – UPPER ATOKA FORMATION ARKANSAS HWY. 9 MORRILTON BYPASS – LOWER INTERVAL (Plate 18 and Figures 29, 30).**

The rocks exposed in this outcrop represent two major delta sequences; one is quite "dirty" and the other is "clean". From north to south there is a very thick "dirty" delta sequence composed of silty gray-black shale, thin flaser bedded, gray siltstone, and silty sandstone forming pro-delta and outer fringe sequences. Overlying this sequence of rocks is a much cleaner delta interval composed of thin, even bedded, inner fringe sandstone, cross-bedded distributary channel sandstone capped locally by a shale lense (clay plug) and all overlain by more delta fringe sandstone. Some bioturbations are present in the "dirty" delta outer fringe rocks. Also note the pyritic interval and its white oxidation product melanterite (iron sulphate) at the base of the inner fringe sandstone.

109.7 These rocks are equivalent to the rocks of the upper Atoka at Stop 14. From south to north the rocks are marine and pro-delta shale and siltstone; inner fringe sandstone; cross-bedded sandstone of a river mouth bar; even bedded inner fringe sandstone capped by distributary channel deposits at the top. Small thrust faults are present in the exposure.

110.6 Turn west onto Interstate Hwy. 40.

137.7 Turn south onto Arkansas Hwy.7 at Exit 81 and proceed through Russellville.

142.3 Road to Robinson Quarry to right. Proceed south on Arkansas Hwy. 7.

144.6 Dardanelle, Arkansas. Turn northwest on 2nd Street.

145.3 Turn north on road to Dardanelle Dam and Powerhouse.

145.7 Dardanelle Rock formed by Hartshorne Sandstone.

146.5 **STOP 15 – HARTSHORNE SANDSTONE AT DARDANELLE DAM (Plate 20 and Figures 31, 32).**

This stop begins at the observation tower overlooking the Arkansas River and Dardanelle Dam. These massive to thin bedded, rather clean sandstones of the Hartshorne Sandstone (middle Pennsylvanian – Desmoinesian Series) are on the north flank of the Pine Ridge anticline and the south side of the Shinn syncline.

At this site, festoon and foreset beds, laminar beds, convolute or loaded or slumped beds, channel fills, and shale lenses (clay plugs) characterize the Hartshorne Sandstone. Plant fossils are common in the sandstone especially on the surface of the steeply inclined cross-beds. The Hartshorne

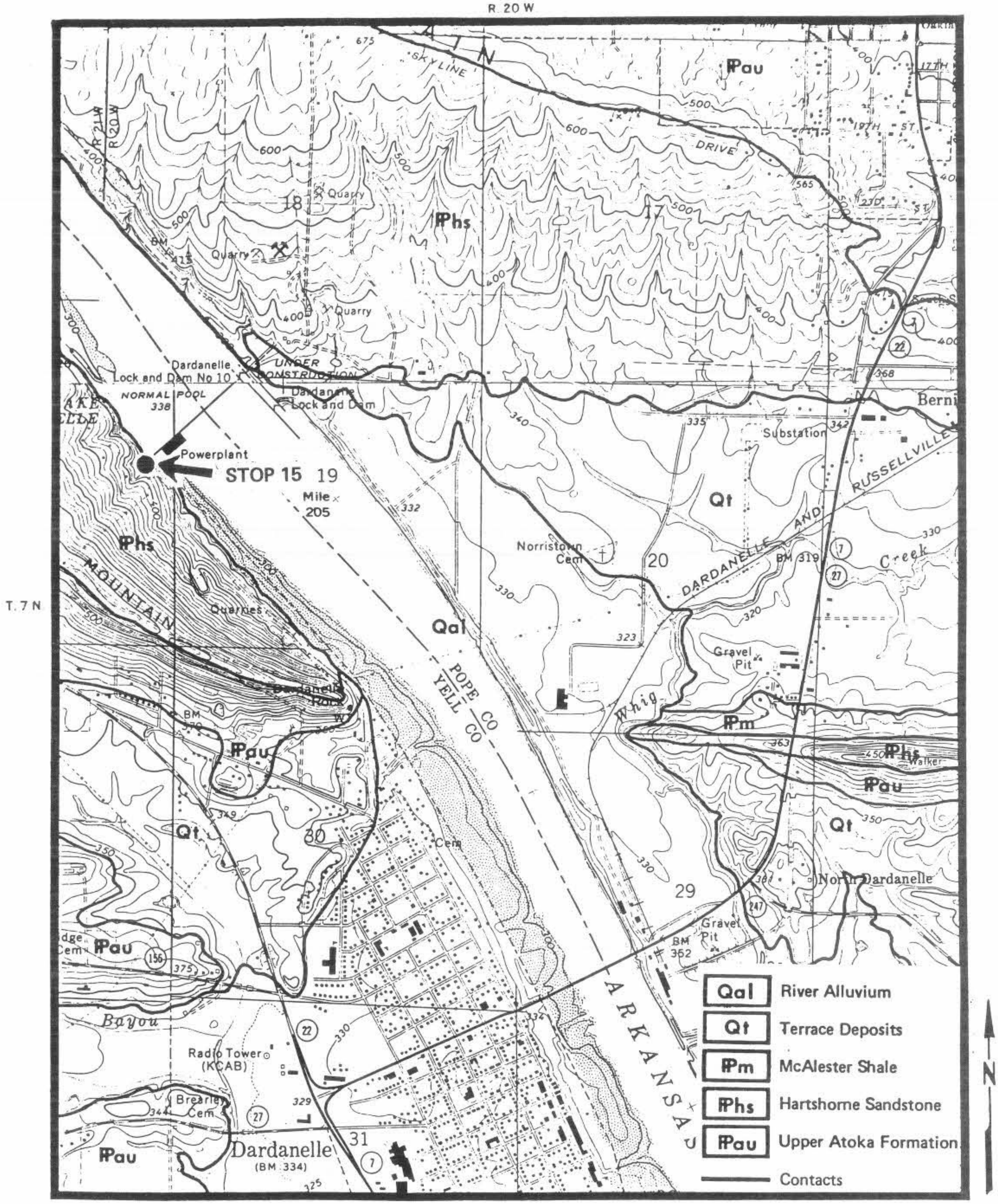


PLATE 20 — GEOLOGIC MAP OF DARDANELLE DAM — STOP 15

1000 0 1000 2000 3000 FEET

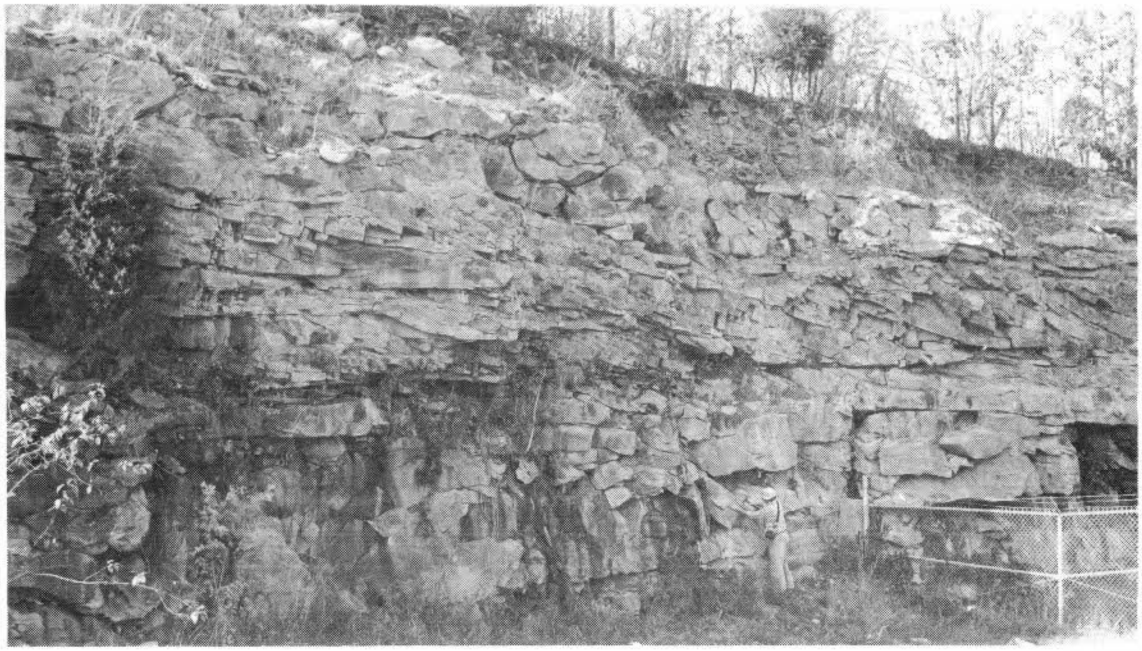


Figure 31 - Stop 15. Massive cross-bedded quartzitic sandstone representing fluvial deposition in the Hartshorne Sandstone at roadcut near overlook on west side of Dardanelle Dam.

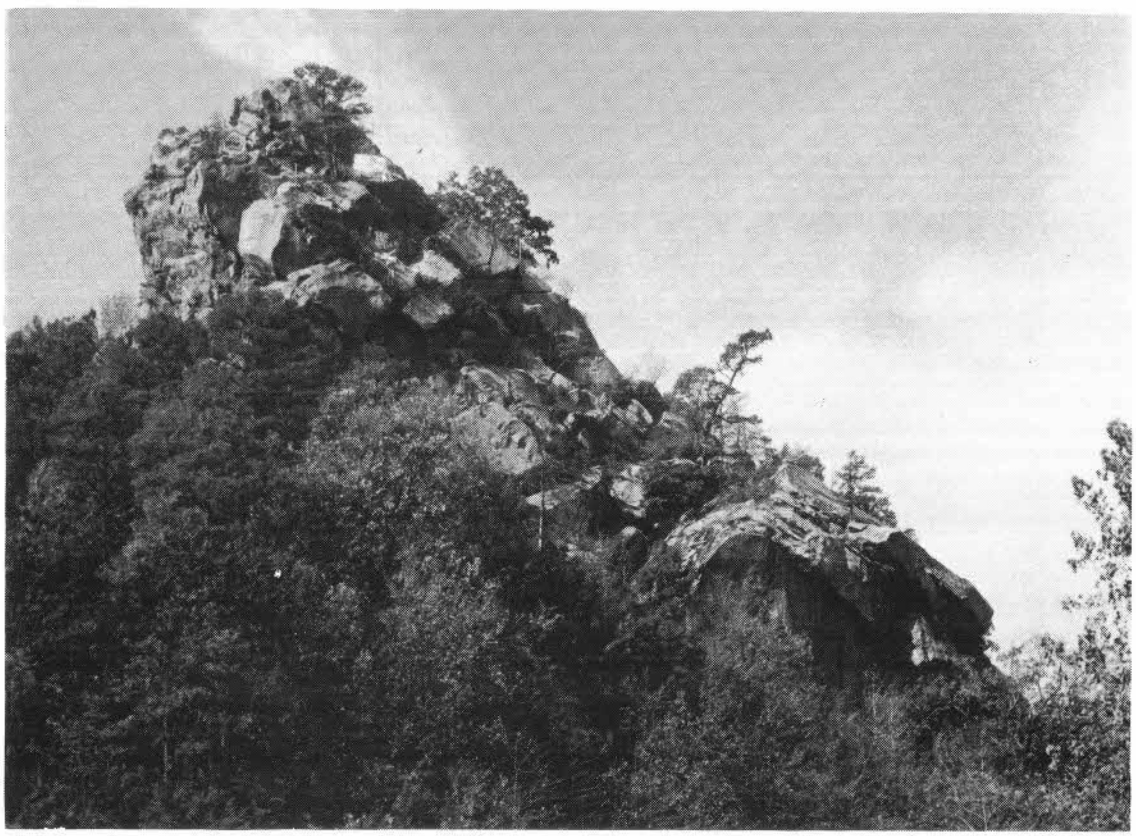
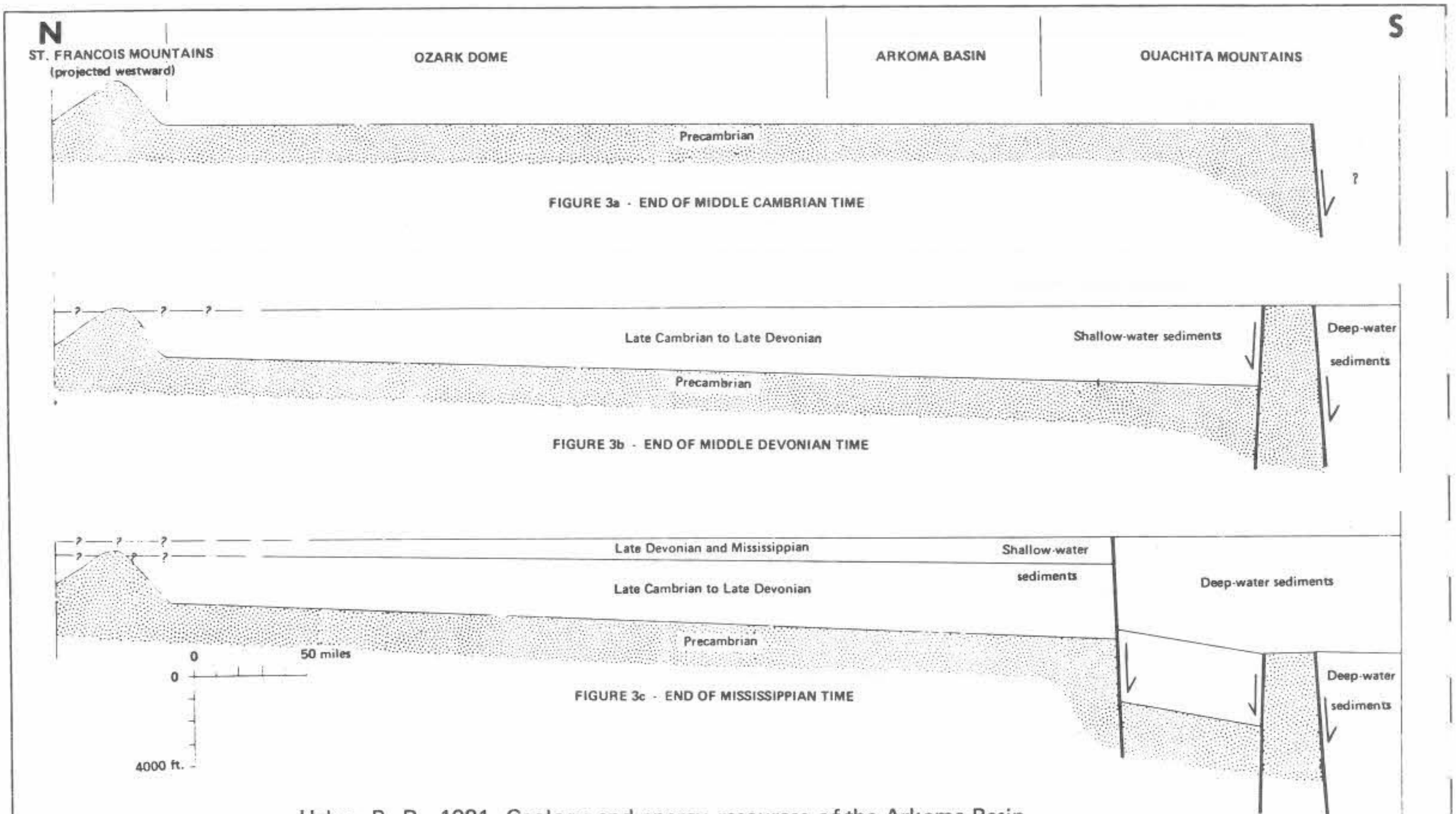
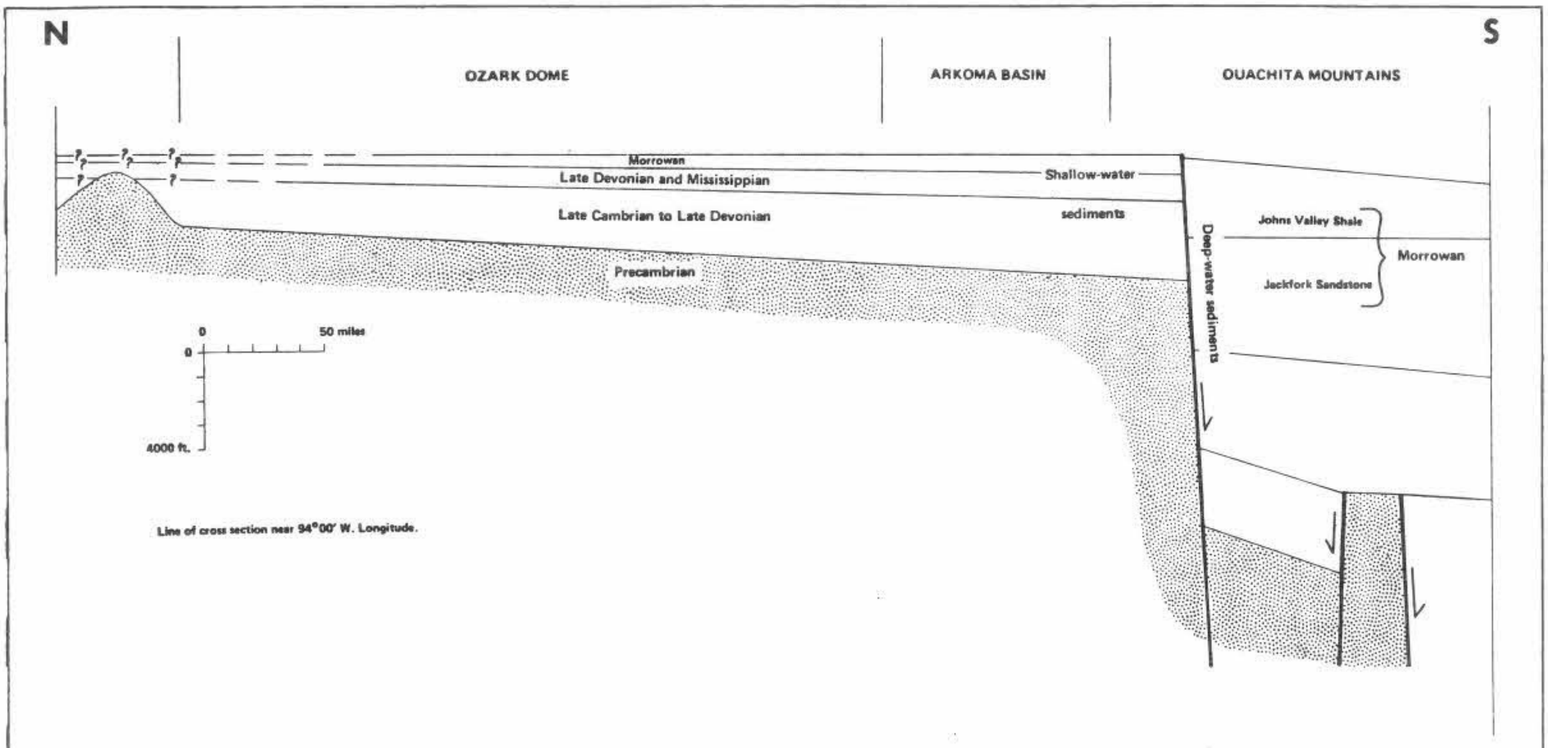


Figure 32 - Mileage 145.7. Dardanelle Rock - this scenic feature is a hogback formed by the steeply dipping Hartshorne Sandstone south of Dardanelle Dam.



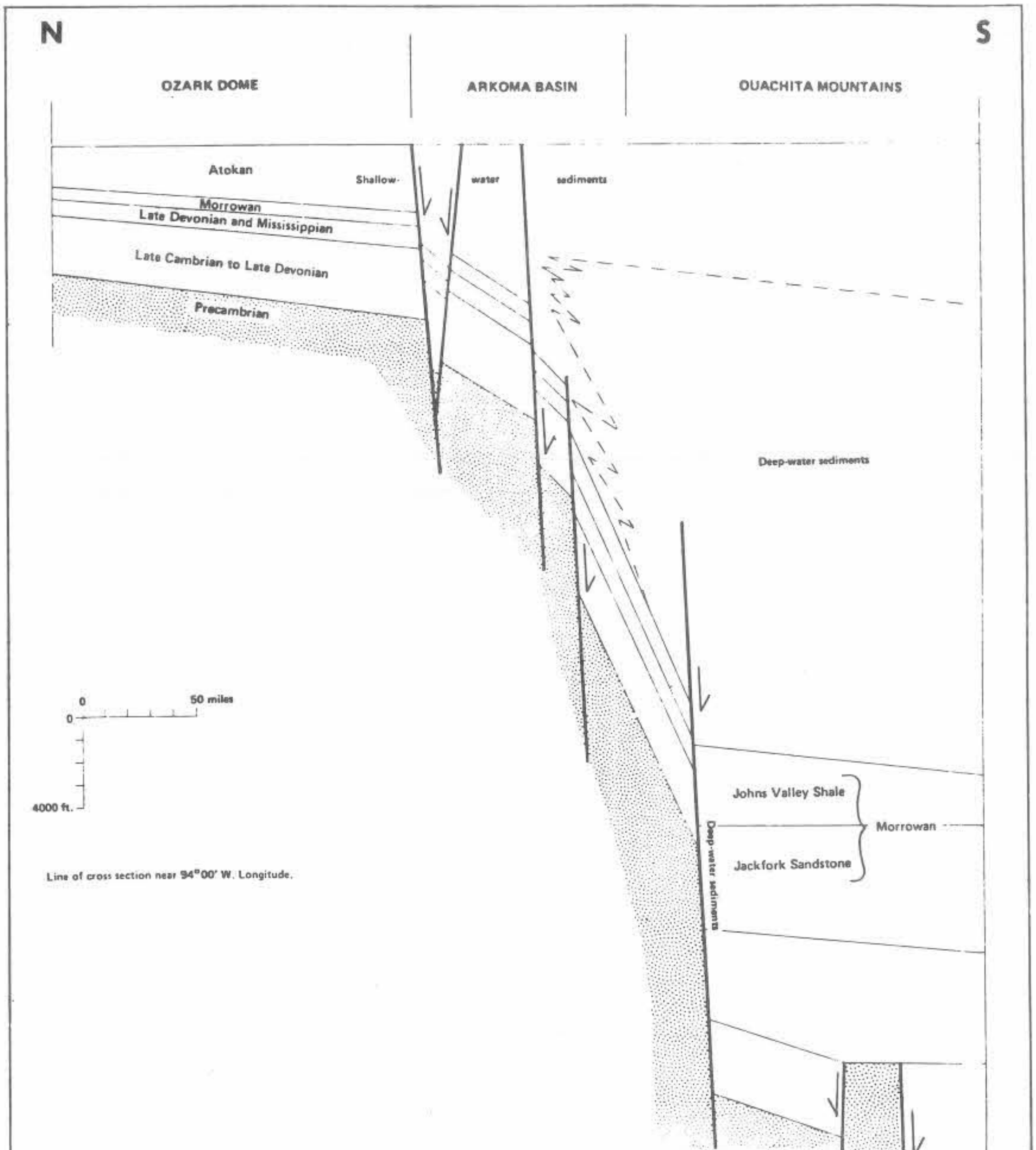
Haley, B. R., 1981, Geology and energy resources of the Arkoma Basin, Oklahoma and Arkansas: University of Missouri–Rolla, H. V. McNutt colloquium (in preparation); Figure 3

PLATE 21 — SCHEMATIC CROSS SECTION ACROSS THE ARKOMA BASIN AND VICINITY AT THE END OF MISSISSIPPIAN TIME



Haley, B. R., 1981, Geology and energy resources of the Arkoma Basin, Oklahoma and Arkansas: University of Missouri–Rolla, H. V. McNutt colloquium (in preparation); Figure 4

PLATE 22 — SCHEMATIC CROSS SECTION ACROSS THE ARKOMA BASIN AND VICINITY AT THE END OF MORROWAN TIME



Haley, B. R., 1981, Geology and energy resources of the Arkoma Basin, Oklahoma and Arkansas: University of Missouri–Rolla, H. V. McNutt colloquium (in preparation) Figure 6

PLATE 23 — SCHEMATIC CROSS SECTION ACROSS THE ARKOMA BASIN AND VICINITY AT THE END OF ATOKAN TIME

Sandstone is thought to have been deposited by a westward flowing stream with a north-south meander belt at least 40 miles wide. The scenic Dardanelle Rock to the south is a hogback formed by the steeply dipping Hartshorne Sandstone.

The vertical progression of rocks in the local area is as follows: marine and pro-delta shale of the upper Atoka Formation; fluvial sandstone of the Hartshorne Sandstone; delta plain deposits including the Lower Hartshorne Coal Bed of the McAlester Shale; and, pro-delta and marine shale of the McAlester Shale.

The following abstract and schematic cross sections (Plates 21, 22, 23) showing the general depositional and tectonic history of the Arkoma Basin from Precambrian to middle Pennsylvanian time are extracted from the report by Boyd R. Haley that is in press by the Missouri School of Mines at Rolla.

> Haley, Boyd R., 1980, LITHOLOGY, STRUCTURE, AND ENERGY RESOURCES OF THE ROCKS IN THE ARKOMA BASIN: V. H. McNutt Coloquium, October, 1980, Rolla, Missouri.
>
> Pre-Pennsylvanian age rocks in the Arkoma Basin consist of shallow-water carbonate, sandstone, chert, and shale. Pennsylvanian age rocks consist of shallow-water limestone, sandstone, and shale in the north and deep-water shale and sandstone in the south.
>
> Normal faults are common, and in the south the larger of these have been obscured by thrust plates related to the structural deformation of the Ouachita Orogeny. The rocks, gently folded in the north, become more intensely folded southward until they are overturned in some areas adjacent to the thrust faults.
>
> About 2 trillion cubic feet of natural gas has been produced from the rocks in the Arkansas part of the Arkoma Basin; more than 80 percent of the gas has been found in sandstone reservoirs deposited in a deltaic environment. About 90 percent of the 105 million tons of coal produced in Arkansas has been from the Lower Hartshorne Coal Bed. The depositional environment of this coal bed is closely related to that of the underlying lower Hartshorne Sandstone.

Return to Arkansas Hwy. 7.

148.3 Turn southwest on Arkansas Hwy. 7.

148.8 Junction of Arkansas Hwys. 7 and 22, turn south on Hwy. 7.

148.9 Frontier Inn Motel. Your home for tonight!

END OF FIRST DAY

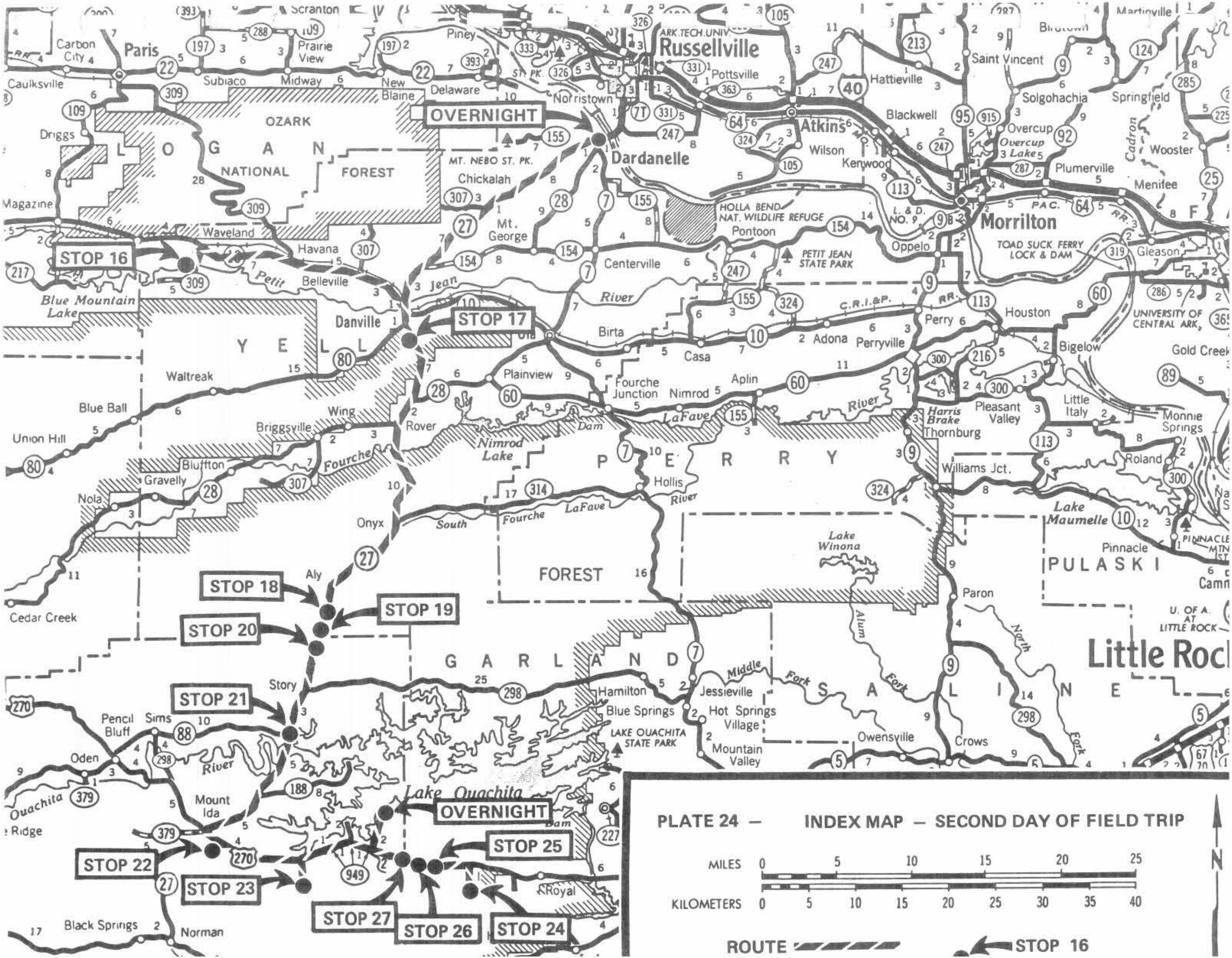


PLATE 24 — INDEX MAP — SECOND DAY OF FIELD TRIP

ROAD LOG – SECOND DAY

ARKANSAS VALLEY AND CENTRAL OUACHITA MOUNTAINS, ARKANSAS

Dardanelle, Chickalah, Belleville, Havana, Danville, Onyx, Aly, Washita, Mount Ida, Hurricane Grove, Crystal Springs (Plate 24).

MILEAGE	DESCRIPTION
0.0	Turn south from the Frontier Inn Motel onto Arkansas Hwy. 27.
0.6	Mount Nebo ahead is capped by the Hartshorne Sandstone.
19.3	Junction of Arkansas Hwys. 27 and 10. Turn west on Hwy. 10.
22.7	Belleville, Arkansas.
28.6	Havana, Arkansas.
34.9	Turn west on Arkansas Hwy. 309 to Blue Mountain Dam.
37.3	**STOP 16 – UPPER SUBMARINE FAN AND SLOPE DEPOSITS IN LOWER ATOKA FORMATION AT BLUE MOUNTAIN DAM (Plate 25 and Figures 33, 34, 35, 36).**

These mostly turbidite sequences near the top of the lower Atoka Formation consist of alternating brownish-gray, micaceous, fairly clean to silty sandstone, gray siltstone, and black shale are considered to be of proximal deep-water origin. The exposure contains various sedimentary features including graded bedding with sharp basal contacts, bottom marks, convolute bedding, load features, channels, contorted structures, and trace fossils along with small to quite large lenticular sandstones and shale submarine slump and slide masses. The trace fossils have not been studied but they appear to be of the Chrondrites assemblage which Chamberlain (1975, p. 51) indicates are typical of slope deposits. There is a total thickness of about 19,000 feet of Atoka in this area; this exposure is about 9000 feet below the Hartshorne Sandstone. The various sedimentary and other features at the dam and nearby exposures indicate that the top of the lower Atoka in this area represents southward oriented, narrow to fairly wide, upper submarine fan channels that dissect and impart laterally coalesce with shale and some sandstone masses of probable slope facies. The overlying middle and upper Atoka in this area represent deltaic and related shallow-water deposits.

The following summary on the Atoka Formation in west Arkansas is modified from Haley (1966).

> The turbidic transition from shallow-water marine deposition to deep-water marine flysch is well shown within the Atoka Formation at several localities in northwestern Arkansas (Plate 26). For example, the middle part of the Atoka Formation as exposed north of Clarksville along Arkansas Hwy. 21 in Sections

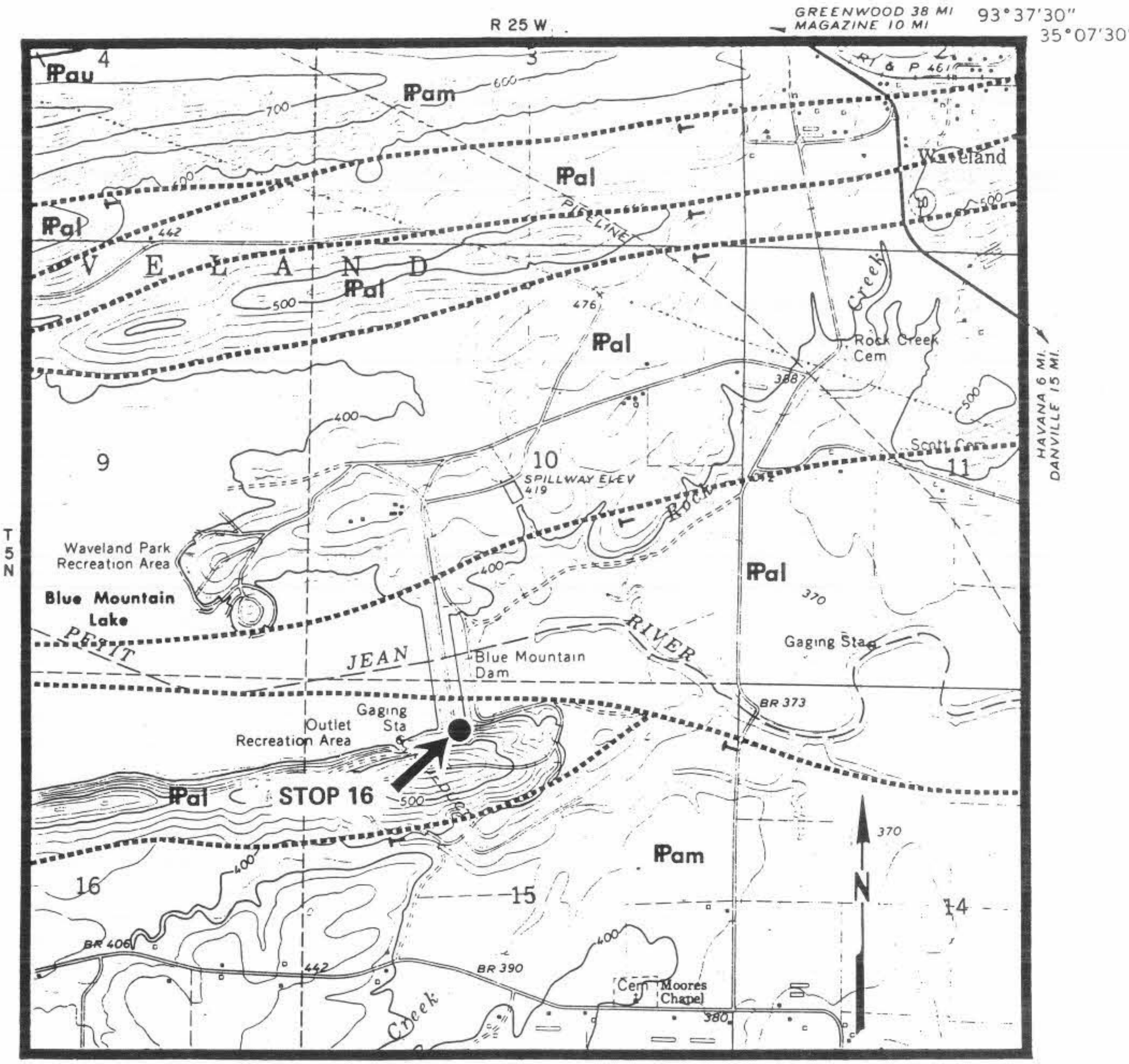


PLATE 25 — GEOLOGIC MAP OF BLUE MOUNTAIN DAM AREA – STOP 16

1000 0 1000 2000 3000 FEET

- IPau — Upper Atoka Formation
- IPam — Middle Atoka Formation
- IPal — Lower Atoka Formation
- Thrust Faults
- Contacts

21 and 22, T. 11 N., R. 23 W. (locality A, Plate 26)) consists of sandstone, siltstone, and shale deposited in a shallow-water marine environment. Most of the rocks in this area are thought to have been deposited by prograding deltas, although some have lithologic characteristics suggesting deposition by advancing seas. Criteria indicative of sedimentary slump or flow are rare. In the Clarksville area the middle part of the Atoka Formation was deposited on a very gentle slope where the gradient was not great enough to induce soft-sediment flow.

The middle part of the Atoka Formation, as exposed in the overflow channel of Paris Lake Dam in Section 14, T. 7 N., R. 26 W. (locality B, Plate 26) consists of sandstone, siltstone, and shale deposited in a shallow-water marine environment. At this locality soft-sediment flow features are common and the most significant of these are termed "pull-aparts". "Pull-aparts" are thought to represent lenticular remnants of a moving sheet of sand that tended to stretch and thus pull itself apart. This stretching movement and resultant "pull-aparts" is in sharp contrast to the thickening movement and the resultant contorting of beds seen in subsequent stops during this field trip. At Paris Lake Dam the middle part of the Atoka was deposited on a slope whose gradient was great enough to permit soft-sediment flow.

The top of the lower Atoka, as exposed at the south end of Blue Mountain Dam in Section 15, T. 5 N., R. 25 W. (locality C, Plate 26) consists of sandstone, siltstone, and shale deposited in a rather deep marine environment. The exact depth of the water is conjectural because most of the exposed rocks at the dam site and in the immediate vicinity contain few criteria that would indicate that they were deposited in shallow-water above wave base, but trace fossils may be useful in making an interpretation. Abundant features in this area indicate southward directed soft-sediment slump and flow, as well as erosion and deposition caused by turbidity currents. At this locality the slope gradient was steep enough to permit soft-sediment flow within a bed and also to permit blocks as large as 10 feet square of bedded sediments to slump or slide downhill. The slope gradient was also great enough to support turbidity currents, some of which eroded channels in the earlier sediments in which these or subsequent turbidity currents deposited sand.

The lower Atoka Formation, as exposed north of Chula along the Forest Service road in Section 8, T. 2 N., R. 24 W. (locality D, Plate 26) consists of sandstone, siltstone, and shale, and is a classic example of flysch in the sense that flysch is characterized by being gradational rhythmic depositional cycles of sandstone, to siltstone, to shale, with a sharp contact at the base of of the sandstone and each rhythmic unit being widespread laterally. Here the middle part of the Atoka Formation was deposited on a slope with a gradient that may have been great

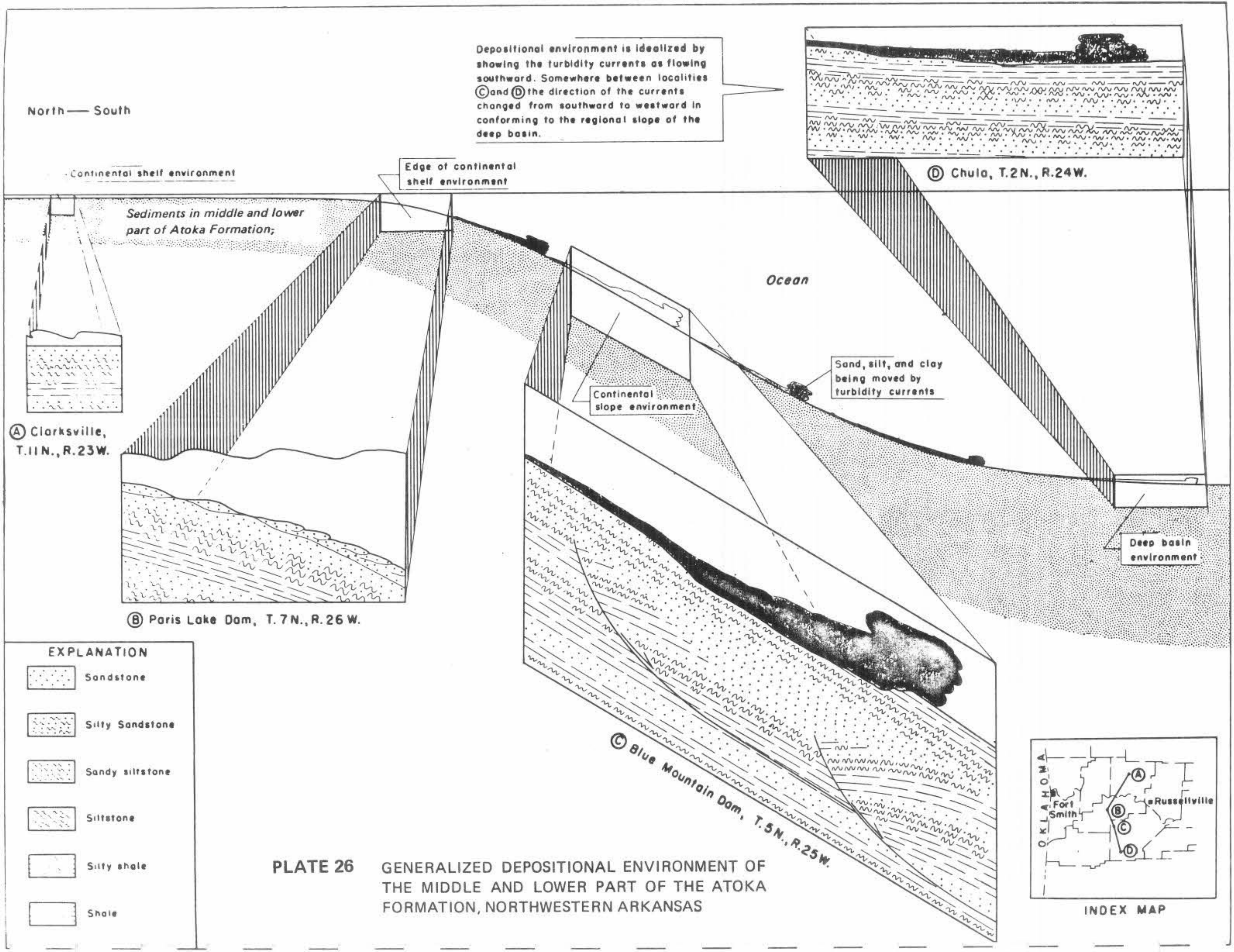


PLATE 26 GENERALIZED DEPOSITIONAL ENVIRONMENT OF THE MIDDLE AND LOWER PART OF THE ATOKA FORMATION, NORTHWESTERN ARKANSAS

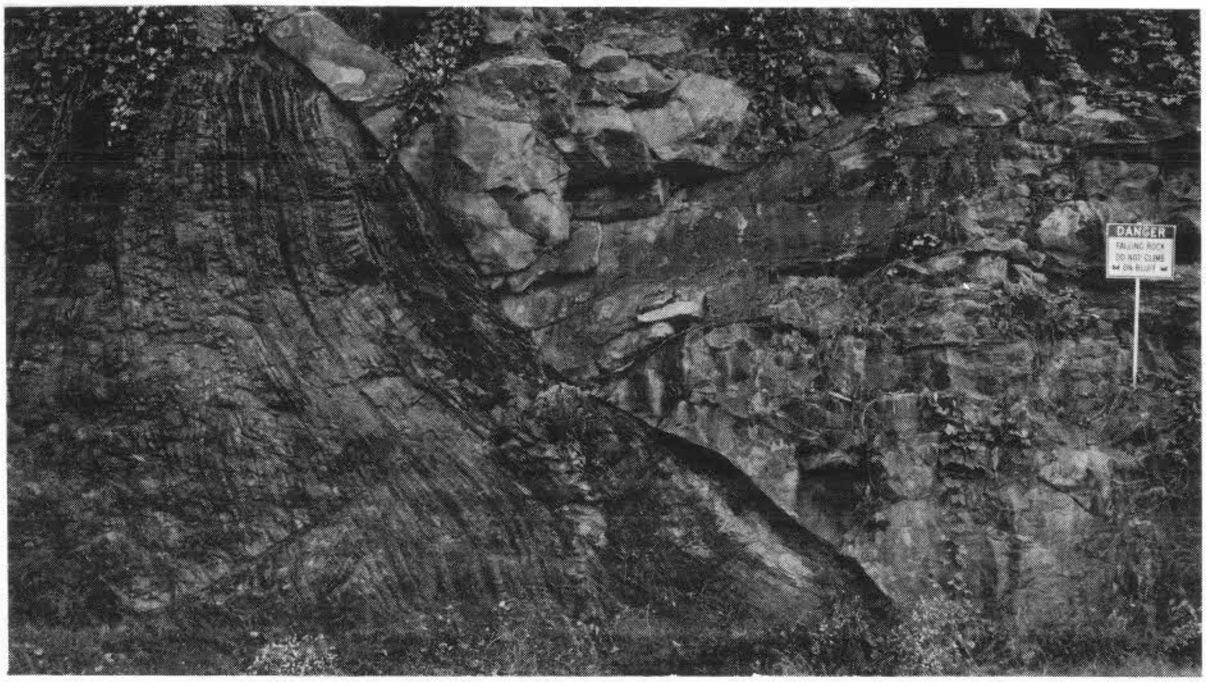


Figure 33 - Stop 16. A fairly clean sandstone of an upper submarine fan channel (right) incised in shale and siltstone of the fan lobe (interchannel) or slope facies (left), at the top of the lower Atoka Formation at Blue Mountain Dam.

Figure 34 - Stop 16. This exposure shows a slumped upper submarine fan lobe (interchannel) or slope shale and siltstone interval overlying similar but discordant rocks at the top of the lower Atoka Formation at Blue Mountain Dam.

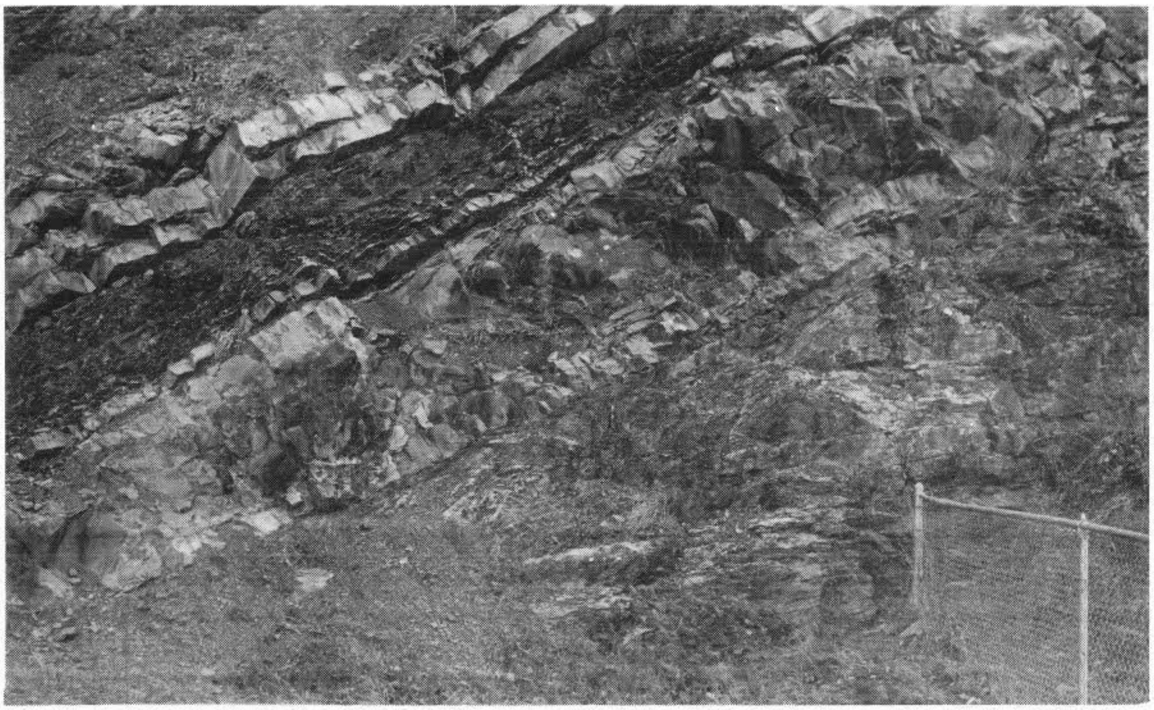


Figure 35 - Stop 16. Thick bedded, contorted, slumped sandstone overlain discordantly by thin bedded, graded, bottom marked, thinning and fining upward sequences that represent upper submarine fan channels at the top of the lower Atoka Formation at Blue Mountain Dam.

Figure 36 - Stop 16. Closeup showing small folds at the top of the lower Atoka Formation at Blue Mountain Dam formed by sedimentary slumping when the rock was fairly competent with pervasive horizontal fracturing through siltstones and shales.

enough to sustain the turbidity currents, or the slope gradient may have been comparatively flat and the turbidity currents, through their momentum, were extended this far into the depositional basin.

Return to Danville, Arkansas and resume road log for second day.

49.2 Junction of Arkansas Hwys. 27 and 10, continue south.

50.0 Danville, Arkansas and Junction of Arkansas Hwys. 27 and 10, continue south on Hwy. 27.

52.2 **STOP 17 – TURBIDITE – FLYSCH DEPOSITS IN THE LOWER ATOKA FORMATION AT DANVILLE, ARKANSAS (Plate 27 and Figures 37, 38).**

This alternating sandstone and shale sequence is in the lower part of the Atoka about 0.3 miles south of a major thrust fault known as the Ross Creek fault. This sequence of lower Atoka is stratigraphically about 16,000 feet below the Hartshorne Sandstone and probably about 6000 feet above Morrowan age rocks. The Ross Creek fault has thrust the lower Atoka over middle Atoka strata with a stratigraphic displacement of about 14,000 feet. This fault marks the boundary in this area between the frontal Ouachita Mountains and the southern Arkansas Valley.

The rocks at this Stop consist of sandstone, siltstone, and shale and are fine examples of turbidites or flysch. Graded bedding, bottom marks, nearly complete Bouma sequences, soft-rock loading, ball and pillow structures, convolute bedding, and other sedimentary features occur in the section. Flute marks, prod marks, and groove casts indicate the paleocurrent direction was to the west and southwest down the axis of the Ouachita trough. The overall thinning and fining of the sandstone beds upward indicate that these units represent submarine midfan channel deposits. Thickening and coarsening upward of sandstone beds are interpreted as submarine lobe or interchannel deposits. The trace fossils have not been studied but appear to be the Nereites deep-water assemblage. Wiegel (1958) performed heavy mineral studies of samples from this region and indicated that a metamorphic suite of minerals is present in the lower Atoka here that is absent in the Atoka to the north.

From lithologic and other data we suggest that the lower Atoka sediments in the Ouachita Mountains were from major delta systems to the north, northeast, and east-southeast and were carried by turbidity currents through a series of complex coalescing submarine fan systems into the rapidly subsiding Ouachita trough. The surface structure in the frontal Ouachita Mountains is characterized by steeply dipping beds that may be overturned and by a complex system of faults which generally parallel the mountains' east-west trend and dip at high to fairly low angles to the south.

From our study of the Ouachita Mountains for the Geologic Map of

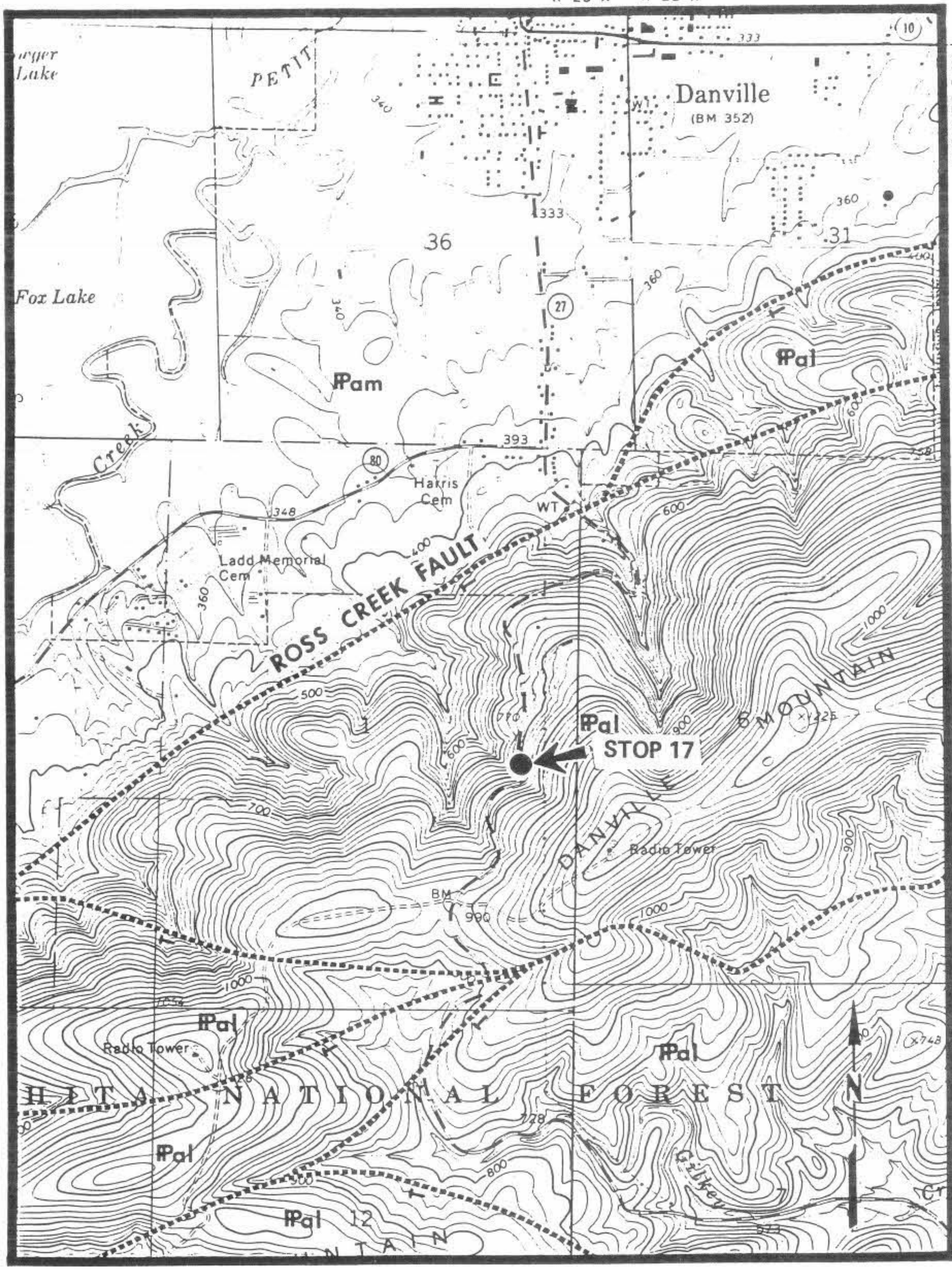


PLATE 27 — GEOLOGIC MAP OF DANVILLE AREA – STOP 17

1000 0 1000 2000 3000 FEET

ℙam	Middle Atoka Formation
ℙal	Lower Atoka Formation
	Thrust Faults

Arkansas (Haley et al., 1976) some additional theories were formulated about the structural deformation in the province.The following abstract summarizes some of these concepts.

Haley, Boyd R., and Stone, Charles G., 1981, STRUCTURAL FRAMEWORK OF THE OUACHITA MOUNTAINS, ARKANSAS: South Central GSA Meeting, April 13, 14 , at San Antonio, Texas.

In most previous investigations the deformed Paleozoic rocks of the Ouachita Mountains of Arkansas have been divided into three poorly defined structural parts; the "core area", the "frontal belt" to the north, and the "southern Ouachitas" or "southern belt" to the south. Through recent studies of the surface geology we have divided the area into six generally east-west trending structural belts. Each belt is a unit having similar structural features bounded by major fault systems. From north to south these belts are named Rover, Aly, Mount Ida, Little Rock, Hopper, and Amity. The Mount Ida and Little Rock belts include most of the older Paleozoic rocks and are the most intensely deformed.

The belt formation likely requires the following simplified sequential phases in its structural development: (A) extensional faults and minor igneous intrusions; (B) major uplift with folding and decollement of the more competent units; (C) thrust faulting; (D) folding with further decollement; (E) thrust faulting and related backfolding; (F) cross faulting and folding with arching; and, (G) further arching. It is suggested that phase A took place during the early to middle Paleozoic, phases B–D during middle to late Pennsylvanian, phases E–F during late Pennsylvanian through Permian and possibly Triassic, and phase G from Triassic to Recent.

We conclude that: (1) the Ouachita Mountains in Arkansas are allochthonous and formed by northward overriding imbricately faulted thrust plates with major sole faults; (2) some thrust plates possibly involved Precambrian rocks in the subsurface; (3) the structural deformation likely narrowed the initial width of the Ouachita depositional basin by as much as 300 miles; and, (4) a northward (?) dipping fossil Benioff subduction system was present to the south of the Ouachita Mountain outcrop belt.

58.0 Junction of Arkansas Hwys. 27 and 28. Continue west on Hwy. 27.

59.9 Rover, Arkansas. Continue south on Arkansas Hwy. 27.

61.3 Fourche La Fave River.

68.5 Onyx, Arkansas. The exposures in this area are in the Johns Valley Shale

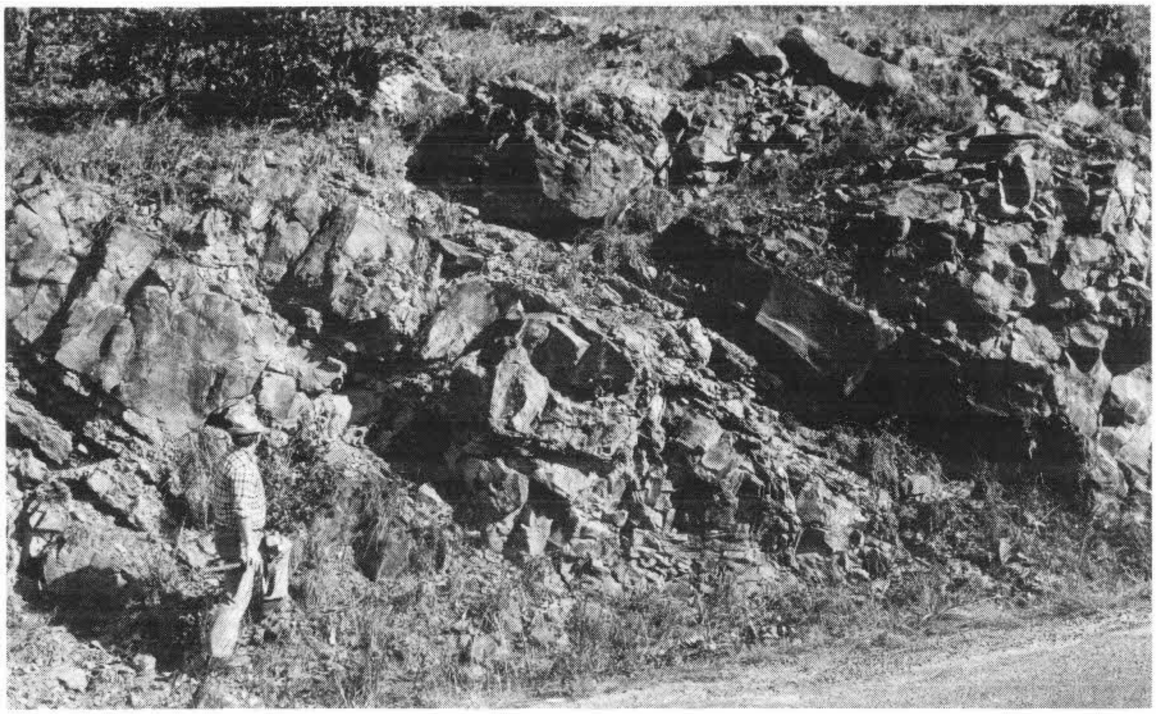


Figure 37 - Stop 17. Two, rather thick, graded bedded, thinning and fining upward sandstone sequences of probable middle submarine fan channel facies in the lower Atoka Formation. There are ball and pillow and convolute features in the partially weathered (spheroidal) rocks.

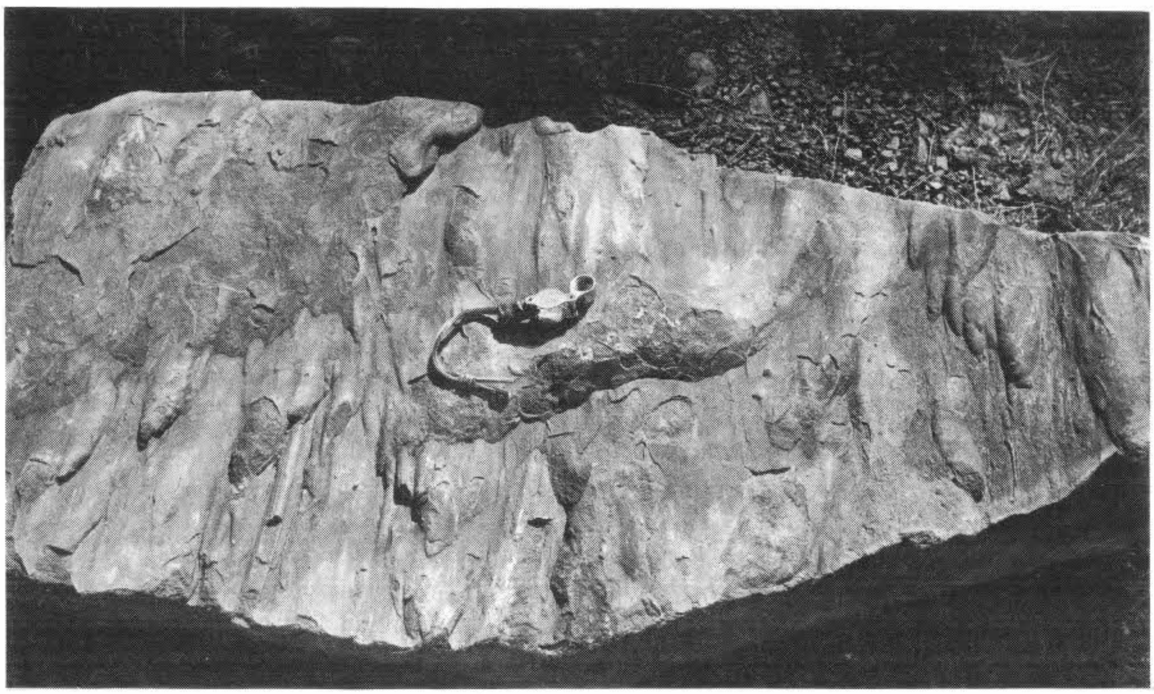


Figure 38 - Mileage 50.6. Bottom marks showing paleocurrent flow (from bottom to top) in the deep-water subgraywackes of the lower Atoka Formation at the base of Danville Mountain on Arkansas Hwy. 27.

which is about 1900 feet thick and contains gray clay shale, brown subgraywacke, iron carbonate concretions, and some olistoliths. Slickensides with dickite are common in most of the Johns Valley exposures. About 8.4 miles to the east on the north side of Hwy. 314 in the SE¼, NE¼, Sec. 31, T. 3 N., R. 21 W., about three miles east of Steve, Arkansas the Johns Valley Shale contains a discontinuous mass of silty limestone with Morrowan fossils (Mackenzie Gordon, Jr., written communication, 1971).

In recent years the Johns Valley Shale has been delineated in the southern, central, and frontal Ouachita Mountains of Arkansas (Haley, et al., 1976). Gordon and Stone (1977, p. 82–83) indicate a middle to upper Morrowan age for the Johns Valley Shale based on ammonoid and other fossil collections from this and other Carboniferous formations in the Ouachita Mountains.

Along the north side of the Ouachita Mountains from the vicinity of Forester (15 miles to the west) in western Arkansas to Atoka, Oklahoma (a distance of about 140 miles) erratic rocks ranging from small fragments to immense masses of upper Cambrian to lower Pennsylvanian age were derived from the miogeosynclinal and foreland Arbuckle and Ozark facies and redeposited in the Johns Valley Shale.

The emplacement of these erratics has been the subject of many theories (see Shideler, 1979, for review). We believe that a series of normal faults downthrown to the south began developing in Chesterian (late Mississippian) time and continued until early Atokan (Pennsylvanian) time. Fragments of rocks from the formations exposed along the fault scarps and along submarine channels crossing the fault scarps fell into the mud accumulating at the base of the scarps and moved downslope as individual pieces, in conglomeratic masses, or as debris or turbidity flows. Nearly all of the erratics in the Johns Valley Shale can be identified as belonging to existing formations north of their present site. The suite of erratics gradually changes from an Arbuckle type in the west to an Ozark type in the east which would be expected if the erratics all came from north of their present site. The amount of displacement across the normal faults is unknown, but it would have to exceed 2200 feet in order to provide the fragments of the Cotter Dolomite (lower Ordovician) found in the Johns Valley Shale at Boles, Arkansas.

75.0 Aly, Arkansas.

77.1 **STOP 18 – OLISTOLITHS IN MIDDLE JACKFORK SANDSTONE AT IRONS FORK CREEK (Plate 28 and Figure 39).**

This roadcut on Arkansas Hwy. 27 just to the west of Irons Fork Creek is in the middle of the Jackfork Sandstone. Most of the exposure is reddish-black shale, but there is an interval that contains lenticular, quartzitic sandstone masses (olistoliths) that are rounded or irregular lenses ("glumps and "gloops"). These sandstone masses are completely enclosed by shale and have bottom marks, particularly load features on all surfaces and healed joint planes dissecting them. Note also the virtually undisturbed shale sequences associated with this interval and the lack of fault planes.

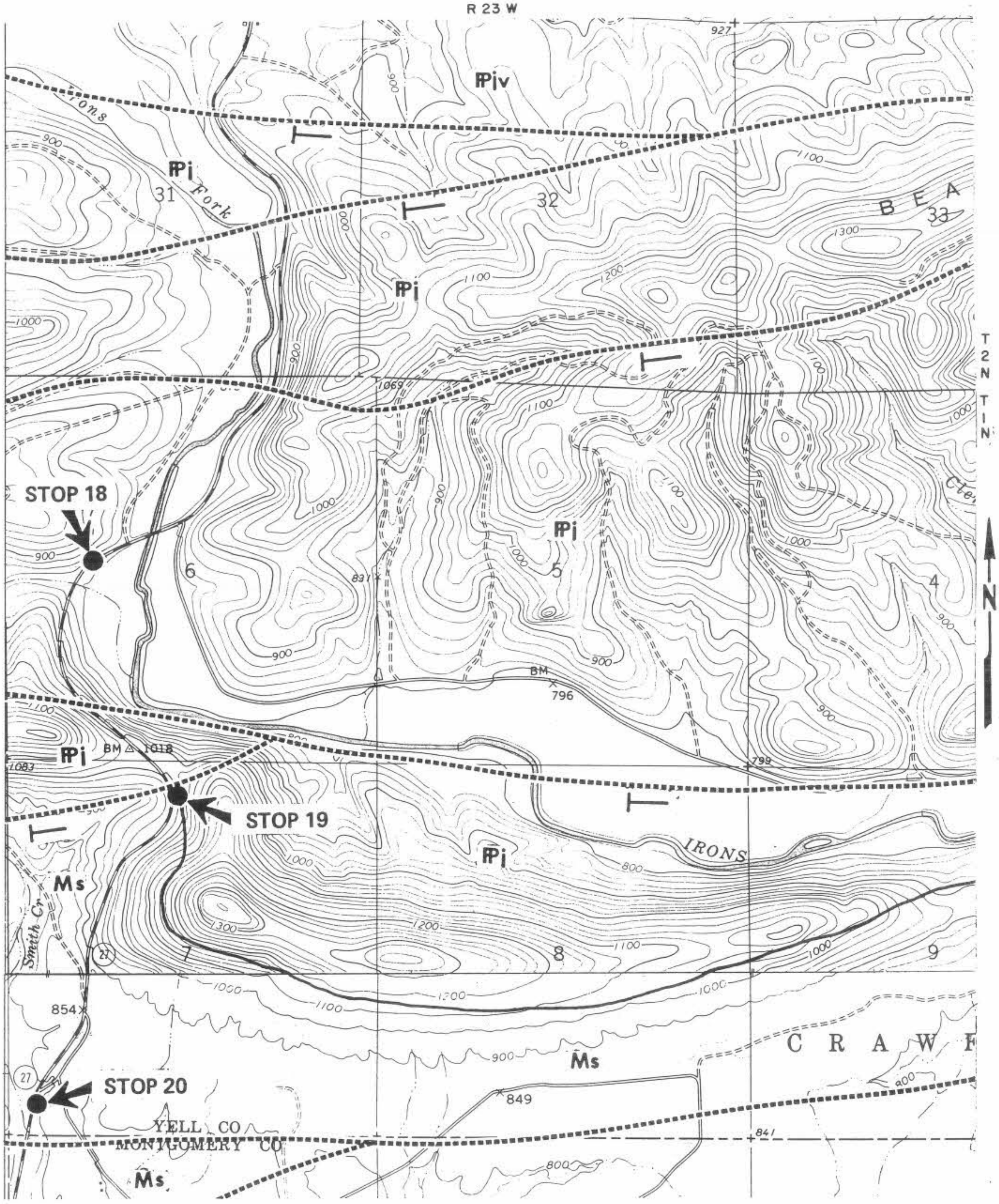


PLATE 28 — GEOLOGIC MAP OF IRONS FORK CREEK AREA — STOPS 18, 19, and 20

1000 0 1000 2000 3000 FEET

IPjv	Johns Valley Shale	··········	Thrust Faults
IPj	Jackfork Sandstone	———	Contacts
Ms	Stanley Shale		

While a tectonic origin has been ascribed to these masses by some investigators the notable lack of actual fault planes containing slickensides with the hydrothermal mineral dickite disputes such a theory. Intervals of this type are particularly common in many of the exposures of the middle and lower Jackfork Sandstone in Arkansas and Oklahoma. It is our conclusion that these and other similar units in the Carboniferous flysch deposits of the Ouachita Mountains reflect the highly unstable conditions that commonly prevailed within or adjacent to the Ouachita trough during this time. These masses are considered a fine example of soft-sediment deformation, probably of local origin. However, some similar intervals contain erratics of foreland facies. The youngest fossils found in the exotic masses in the Jackfork near Little Rock are lower Morrowan in age.

77.8 **STOP 19 – FAULTED UPPER STANLEY SHALE AT OUACHITA TRAIL CROSSING (Plate 28 and Figures 40, 41).**

This roadcut at the top of the ridge on Arkansas Hwy. 27 is in the upper part of the Stanley Shale (probably the Chickasaw Creek Siliceous Shale Member). A sizeable fault has thrust the upper Stanley shale and graywacke northward over the quartzitic sandstone and shale of the lower Jackfork Sandstone that is exposed in roadcuts to the north. The upper Stanley is composed of greenish-gray shale, intervals of nearly chaotic graywacke, and siltstone with some beds of black siliceous shale and chert. The chert has not been thoroughly examined but may contain conodonts, Radiolarians, and sponge spicules. Thin tuffaceous beds occur locally in the upper Stanley Shale. Note the reclined fold hinges, slickensides coated with dickite and filled with small quartz veins, and locally intense fracturing and shearing. These Stanley graywackes likely had a source area to the south and southeast; whereas the quartzitic sandstones of the Jackfork were mostly derived from the northeast and east. In exposures about 20 miles east of this site the upper Stanley Shale contains some erratic boulders derived from the Ozark foreland facies (Pitkin Limestone and Fayetteville Shale of Chesterian age) according to Gordon and Stone (1976).

79.3 **STOP 20 – SEQUENCE OF MIDDLE STANLEY SANDSTONE AND SHALE (Plate 28 and Figure 42).**

This exposure on the east side of Arkansas Hwy. 27 is in the partially faulted and disrupted upper middle part of the Stanley Shale (Chesterian Series) about 1500 to 2000 feet below the Jackfork Sandstone.The Stanley sequence is composed of thin, contorted, silty graywackes interbedded with olive-black shale and some thin, silty iron carbonate concretions and lenses containing cone-in-cone structures. Thin, graded, and bottom marked sandstones are thought to represent lobe sequences of an outer submarine fan of less likely, a basin plain depositional environment. It is thought that these sandstones were derived from sources to the south and southeast. The sands were probably built out as large north-northwest prograding submarine fans and, in part, directed westward by turbidity currents down the axis of the Ouachita trough.

Hydrothermal quartz (water-bubble quartz crystals are present locally),

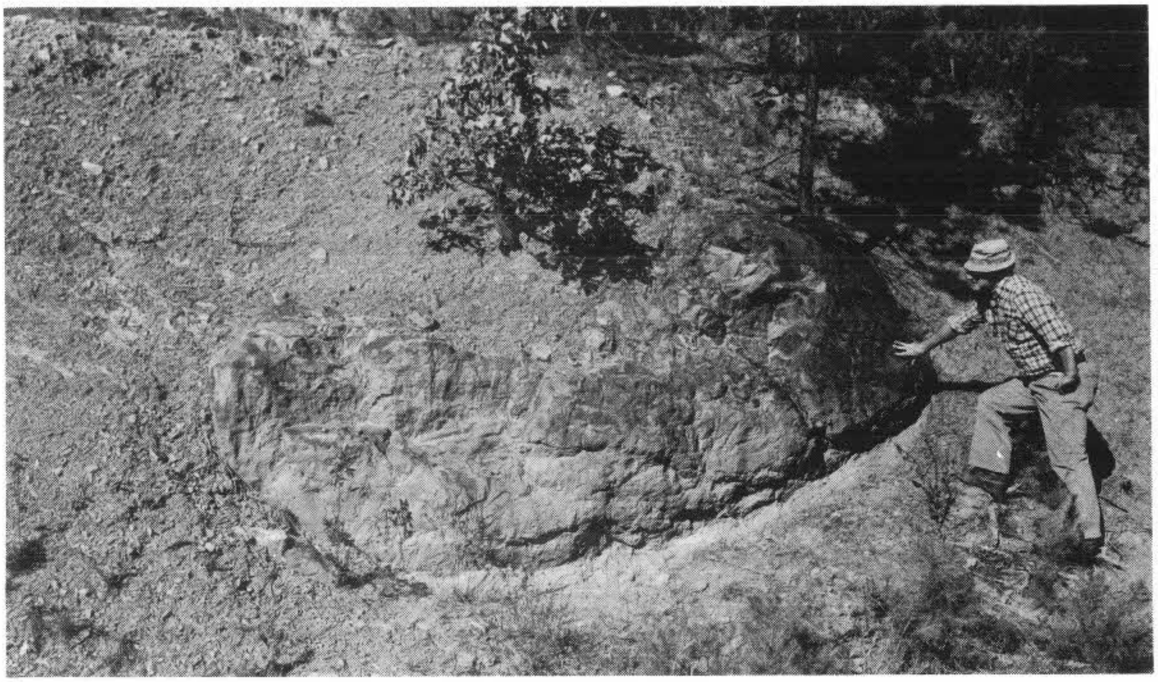


Figure 39 - Stop 18. Elliptical quartzitic sandstone olistolith "gloop" surrounded by shale in the middle Jackfork Sandstone on Arkansas Hwy. 27.

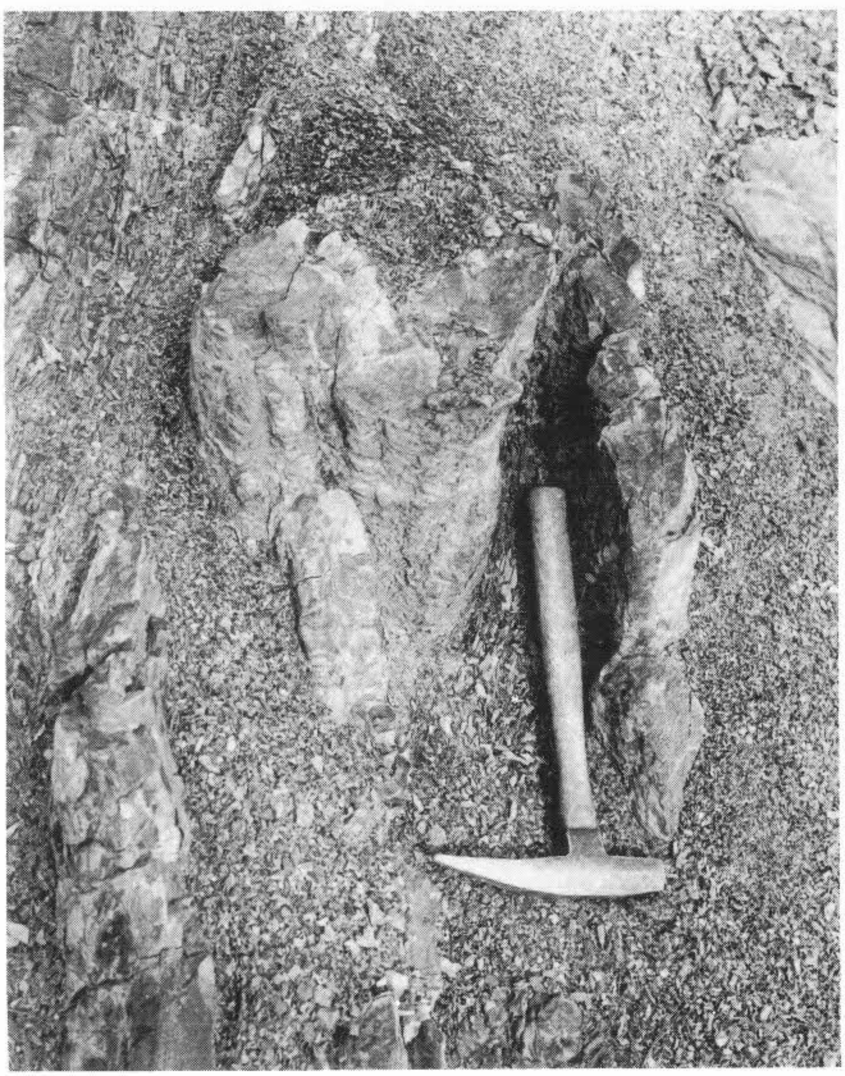


Figure 40 - Stop 19. Nearly vertical plunging fold hinges in the thin graywackes and shales of the upper Stanley Shale in a thrust faulted interval on Arkansas Hwy. 27.

Figure 41 - Stop 19. Parallel laminations enhanced by weathering on a subgraywacke in the upper Stanley Shale on Arkansas Hwy. 27.

Figure 42 - Stop 20. Closeup of cone-in-cone structures developed in a calcareous siltstone concretion or lens in the middle Stanley Shale on Arkansas Hwy. 27.

calcite, and dickite occur in small veins in the sequence. Dickite is particularly common along the slickenside surfaces. Close inspection of the sandstones shows both sedimentary pull-aparts and structural boudinage. Weathered Stanley shale is commonly greenish-brown as can be seen at the top of this exposure.

Because of the recent interest in the oil and gas potential of rocks in the Ouachita Mountains the following abstract by Morris et al., is reprinted here.

> Morris, Robert C., Proctor, Kenneth E., and Koch, Michael R., 1979, PETROLOGY AND DIAGENESIS OF DEEP–WATER SANDSTONES, OUACHITA MOUNTAINS, ARKANSAS AND OKLAHOMA: SEPM Special Publication No. 26, p. 263–279.
>
> The Stanley and Jackfork Groups of the Ouachita Mountains consist of 18,000 feet of interbedded sandstones and shales deposited during the late Mississippian and early Pennsylvanian. Interest in their hydrocarbon potential has led to study of textures, compositions, and diagenetic alterations of these sandstones. The data and conclusions presented in this study are based on petrographic examination and porosity and permeability measurements of 187 samples collected from outcrop.
>
> The Stanley sandstones are generally poorly sorted, very fine-grained feldspathic and quartz wackes. They average 8% feldspar, 14% matrix, and 5% silica cement. Porosities range from 0.5–26% in permeabilities from 0.05–23 md.
>
> Jackfork Sandstones are predominantly moderately to poorly sorted, fine to very fine-grained quartz arenites. They contain an average of 2% feldspar, 5% matrix, and 9% quartz cement. Porosities range from 0.5–14% and permeabilities from 0.05–9 md.
>
> Pressure solution, silica cementation, and replacement of plagioclase by calcite have acted to reduce reservoir potential in both units, whereas corrosion and dissolution of framework grains have added secondary porosity. The presence of halloysite and kaolinite characterizes sandstones affected by surface leaching. Well sorted quartz arenites have poor reservoir quality as a result of extensive silica cementation. Characteristics associated with the retention or secondary development of reservoir potential include poor sorting, small mean grain sizes, and high matrix contents.

82.6 Story, Arkansas.

85.6 **STOP 21 – NORTHERN "CORE AREA" FACIES OF THE ARKANSAS NOVACULITE–BIGFORK CHERT AT WASHITA (Plate 29 and Figures 43, 44).**

This exposure is along Arkansas Hwy. 27 at and near the Arkansas

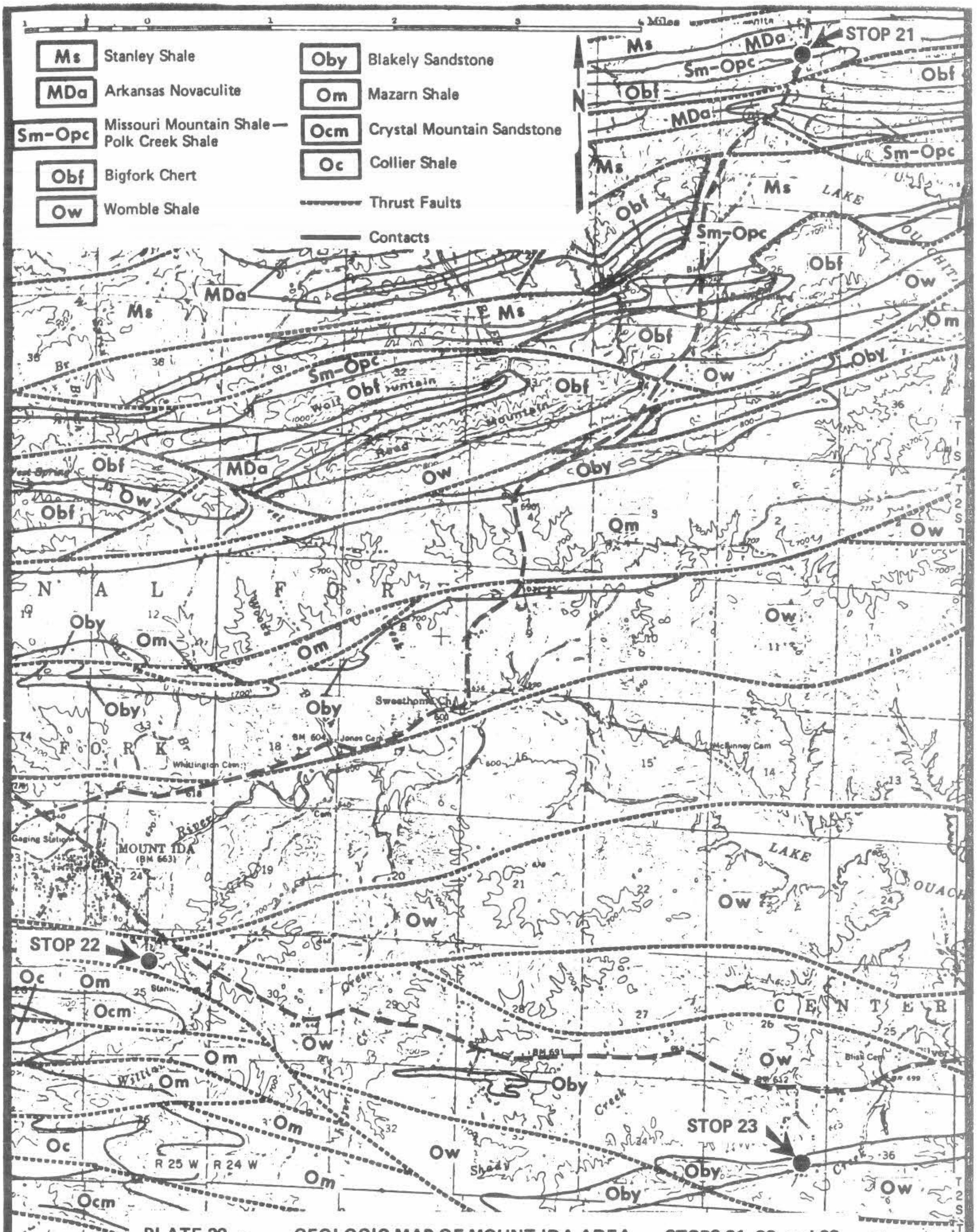


PLATE 29 — GEOLOGIC MAP OF MOUNT IDA AREA — STOPS 21, 22, and 23

Hwy. 88 Junction.

This sequence of early Ouachita trough rocks from north to south includes: greenish-black shale or slate and thin gray cherts in the lower Stanley Shale; greenish-tan, light brown, and gray shale, gray chert, grayish-white novaculite and minor speckled dark-gray conglomerate of the Arkansas Novaculite; greenish-gray to maroon shales of the Missouri Mountain Shale; black carbonaceous shale of the Polk Creek Shale (on the northwest side of the bridge over an upper arm of Lake Ouachita); and, gray to black chert and black shale of the Bigfork Chert (south of bridge).

While it has not been recognized at this exposure a thin conglomerate commonly occurs at the base of the Stanley throughout much of this area and is considered equivalent to the Hot Springs Sandstone Member. The Hatton Tuff which occurs above this member in the southern and central Ouachita Mountains has not been observed in this area. Massive novaculite is rarely present in the northern Ouachita Mountains. The conglomerates in the Arkansas Novaculite interval may exceed 20 feet in thickness at some places in the northeastern and north-central "core area" of the Ouachita Mountains of Arkansas. These conglomerates of of the Arkansas Novaculite are composed of small to quite large subrounded to angular clasts of siliceous shale, chert, novaculite, and sandstone. Stone and Haley (1977, p. 110) report some granitic fragments in these conglomerates. Many of these beds are channel-like, others are more in the form of lenses. The granitic source was to the north of the depositional site possibly from an intrusive associated with submarine scarps. These coarse sediments likely were transported in the form of submarine slumps and slurries, aided by turbidity currents down the slope and through the canyon systems into the deeper early Ouachita trough. Honess (1923, p. 126--128) describes a ten inch bed containing a conglomerate composed of subangular to rounded pieces of chert, weathered feldspar, grains of granite, basalt, and volcanic ash or glass in a cherty matrix near the top of the Lower Division of the Arkansas Novaculite west of Glover, Oklahoma in the western Broken Bow uplift. Some intervals of the Arkansas Novaculite at this Stop contain abundant "large" Radiolarians. The Missouri Mountain Shale locally contains a conglomerate composed in part of frosted sand grains in a chert matrix. Note that the Blaylock Sandstone is not present in the northern Ouachita Mountains of Arkansas. Smeared graptolites of late Ordovician age occur in Polk Creek Shale at this locality. Numerous tight chevron folds, generally overturned to the south, and small faults occur in the Bigfork Chert. The Bigfork Chert is probably the most lithically consistent and recognizable unit throughout the Ouachita Mountains. In this area veinlets of hydrothermal quartz along with the aluminum phosphate minerals wavellite and variscite occur in the Bigfork Chert. A fairly intense development of low-angle cleavage occurs in various formations.

95.9 Turn southeast at Junction onto U. S. Hwy. 270.

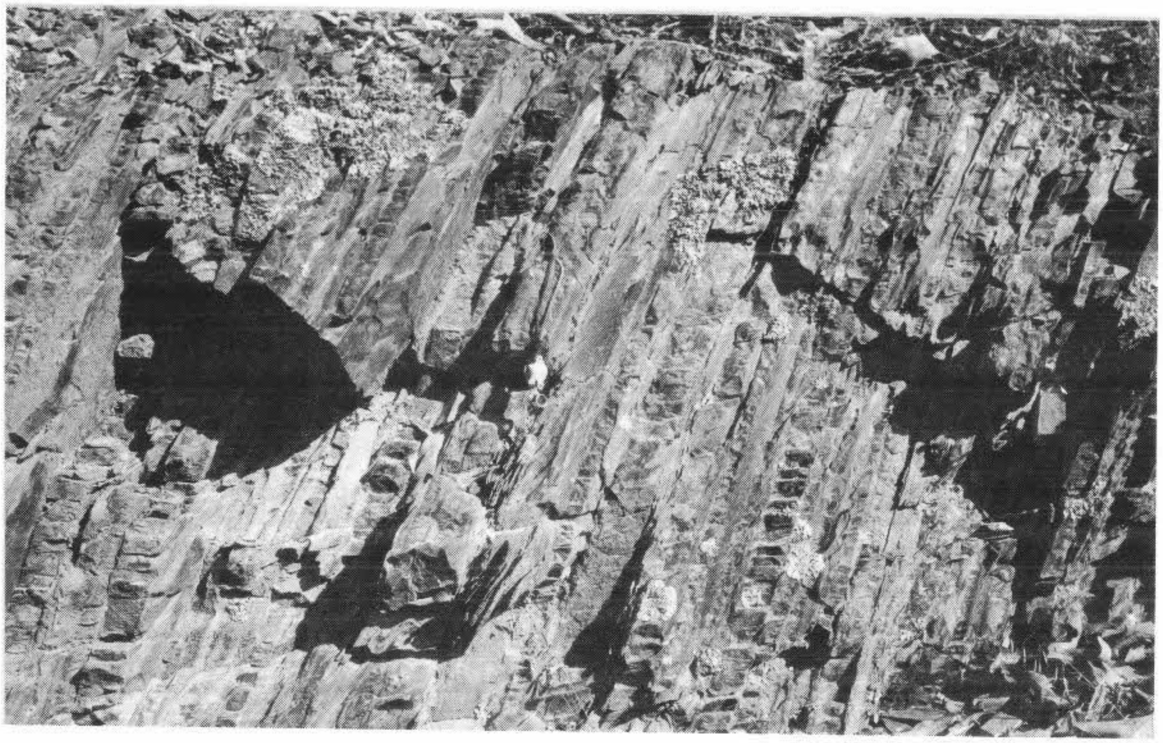


Figure 43 - Stop 21. Thin interbedded, often radiolarian-bearing, shale and chert with low northward dipping cleavage in the middle Arkansas Novaculite on Arkansas Hwy. 27. Note the cleavage refraction between the shales and cherts.

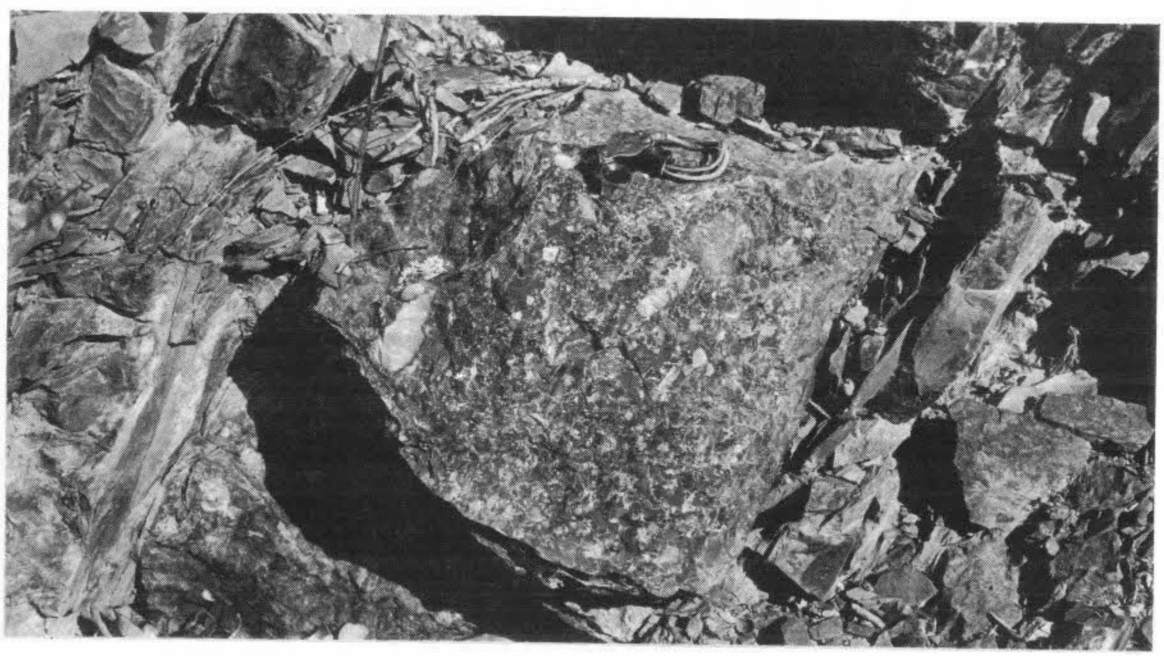


Figure 44 - Stop 21. Thin conglomerate interval containing chert, novaculite, sandstone and other clasts in the upper Arkansas Novaculite on Arkansas Hwy. 27.

97.2 Turn south onto road to Stanley's Mineral Shop at Mount Ida, Arkansas.

97.3 **STOP 22 – OCUS STANLEY MINERAL SHOP, MOUNT IDA (Plate 29).**

Ocus, Irene, and Sonny Stanley are among the better known dealers in clear quartz crystals and other minerals generally common through the region.

Quartz crystals have been mined in the Ouachita Mountains of Arkansas for many decades, first by the Indians who shaped them into arrowheads. More recently quartz has been used for making optical and electrical equipment and jewelry. Stones that are cut from quartz crystals are sold in Hot Springs, Arkansas under the trade name "Hot Springs Diamonds". These should not be confused with genuine diamonds from the diamond mines at Murfreesboro, Pike County, Arkansas nor with "rock crystal" (glass). Most of the quartz crystals from Arkansas find their way into mineral collections of institutions and individuals, and a relatively large volume is used in construction of water fountains and religious or memorial shrines. The value of the natural crystals sold each year has ranged from a few hundred to many thousands of dollars.

During World War II, there was a great demand for oscillator quartz. At that time quartz crystal mining was greatly accelerated by individuals, the Diamond Drill Carbon Company, and the U. S. Government. Clear crystals of oscillator grade are, however, so scarce that only about five tons of this quality were produced during the war years. This quantity was very small in comparison with the wartime requirements of 2000 tons, nearly all of which was imported from Brazil. At the present time quartz crystals are marketed for transparent fused quartz which has many chemical, thermal, and electrical applications not met by glass. Some production of crushed milky quartz for precast concrete products has also been recorded. The quartz crystal deposits are numerous and are found in many localities in a wide belt extending from Little Rock, Arkansas westward to near Broken Bow, Oklahoma. They and their few associated minerals are hydrothermal deposits of probable tectonic origin formed during the closing stages of the late Pennsylvanian–early Permian orogeny in the Ouachita Mountians.

Milky quartz veins (up to 60 feet or more in width) have been noted in the shale sequences in the central "core area" of the Ouachita Mountains and commonly contain traces of adularia, chlorite, calcite, and dickite. Interestingly, these quartz veins locally contain lead, zinc, copper, silver, and antimony in this region.

In our work on the Ouachita Mountains we found that there was a direct association of quartz veins with fault zones. The suggestion is that the quartz veins represent, in part, dewatering processes that took place in the rocks along the fault zones. The increase in pore fluids may well have contributed to localized lubricating conditions and enhanced the overall faulting and folding processes.

Return to U. S. Hwy. 270.

98.1 Turn east onto U. S. Hwy. 270.

103.4 Turn south on U. S. Forest Service Road 85.

104.2 **STOP 23 – THE OCUS STANLEY FOLD IN THE BLAKELY SANDSTONE (Plate 29 and Figure 45).**

A spectacular fold named for Ocus Stanley occurs in a sequence of flaggy to fairly massive, quartzitic, in part calcareous sandstone with thin interbeds of siltstone and banded gray to black shale of the Blakely Sandstone. The top of the beds is to the south, thus we have southward vergence of the strata. Note the low-angle cleavage that refracts across the sandstone beds near the hinge of the fold at the south end of the exposure. There are other less obvious structures near the middle of the roadcut that probably represent soft-sediment deformation. The sandstones of the Blakely in this area and to the west and northwest are somewhat discontinuous in exposure, generally forming only small ridges, but the formation provides, in most cases, a reliable stratigraphic marker in the overall shale-rich sequence of the lower and middle Ordovician. The Blakely in this area likely represents a low-energy sedimentary regime composed of submarine fan channels and lobes possibly in the middle or outer fan depositional environment. It is suggested that the submarine slope and canyon that fed this deep-sea fan complex was located to the northeast.

In the eastern and central Ouachita Mountains of Arkansas Stone and Haley (1977, p. 107–111) and others describe numerous granite–metaarkose cobbles and boulders (up to 45 feet in diameter) mostly in conglomeratic intervals in the Blakely Sandstone. These boulders are considered Precambrian or possibly Cambrian in age and were derived through slumping, aided by turbidity currents, from a simple metamorphosed granite-rich terrane that existed as submarine highs immediately to the north or northeast of the depositional site. Erratics of this type are not known in the Blakely Sandstone exposures in this area or farther to the west.

Return to U. S. Hwy. 270.

105.0 Turn east on U. S. Hwy. 270.

105.4 To the south are many fold hinges parallel to the roadcut with a slight plunge to the east (Figure 46). This exposure is in too dangerous an area for a stop, but it exhibits several periods of folding. One system of folds could represent an earlier sedimentary slump or slide.

106.3 Silver, Arkansas. Small fracture-filling hydrothermal quartz veins containing calcite (some pinkish tinted) with varying proportions of adularia, pyrite, silver-bearing galena, sphalerite, chalcopyrite, tetrahedrite, and other minerals were mined mostly prior to 1900 at several prospects in this vicinity (Stroud et al., 1967). These deposits are also reported to contain traces of gold. More recently there were thesis investigations on these deposits by Santos (1972, 1977) and Kurrus (1980); they have further defined the tenor, grade, and genesis of the ore.

Figure 45 - Stop 23. This southward inclined and folded sequence in the Blakely Sandstone is the famous **Ocus Stanley Fold** on U. S. Forest Road 85 about 0.8 miles south of U. S. Hwy. 270. The rocks consist of quartzitic and calcareous sandstones and thin shales.

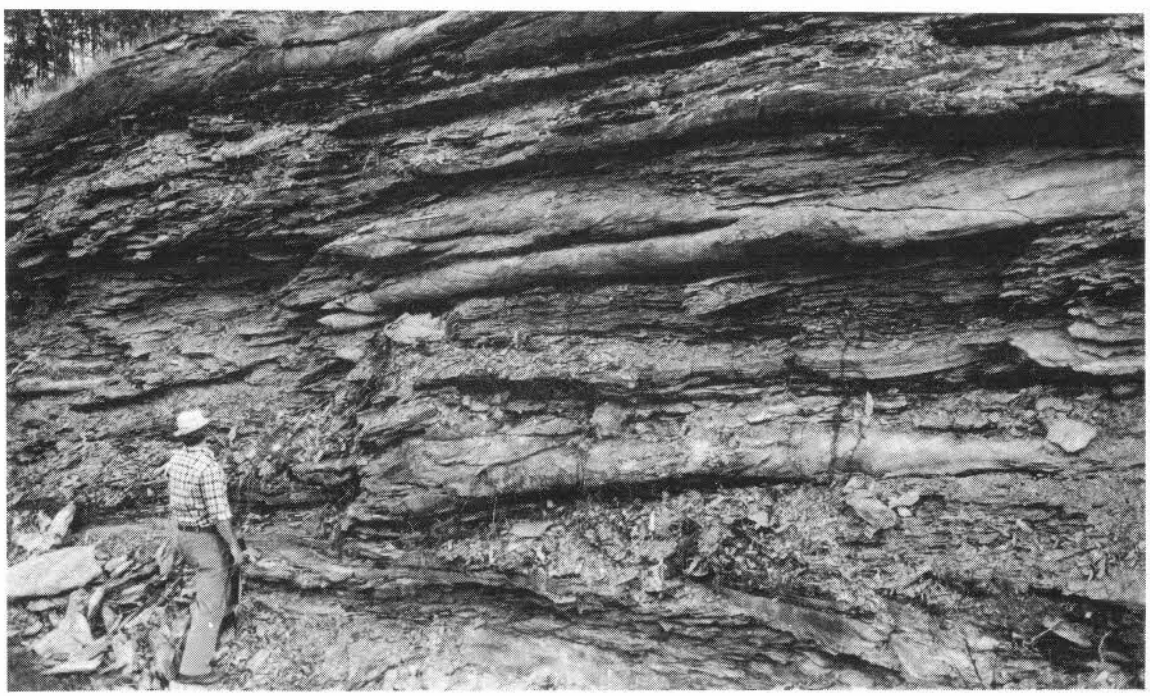


Figure 46 - Mileage 105.4. Exceptionally tight, eastward trending fold hinges in shales and calcareous siltstones of the Womble Shale to the west of the bridge over Denby Creek on U. S. Hwy. 270.

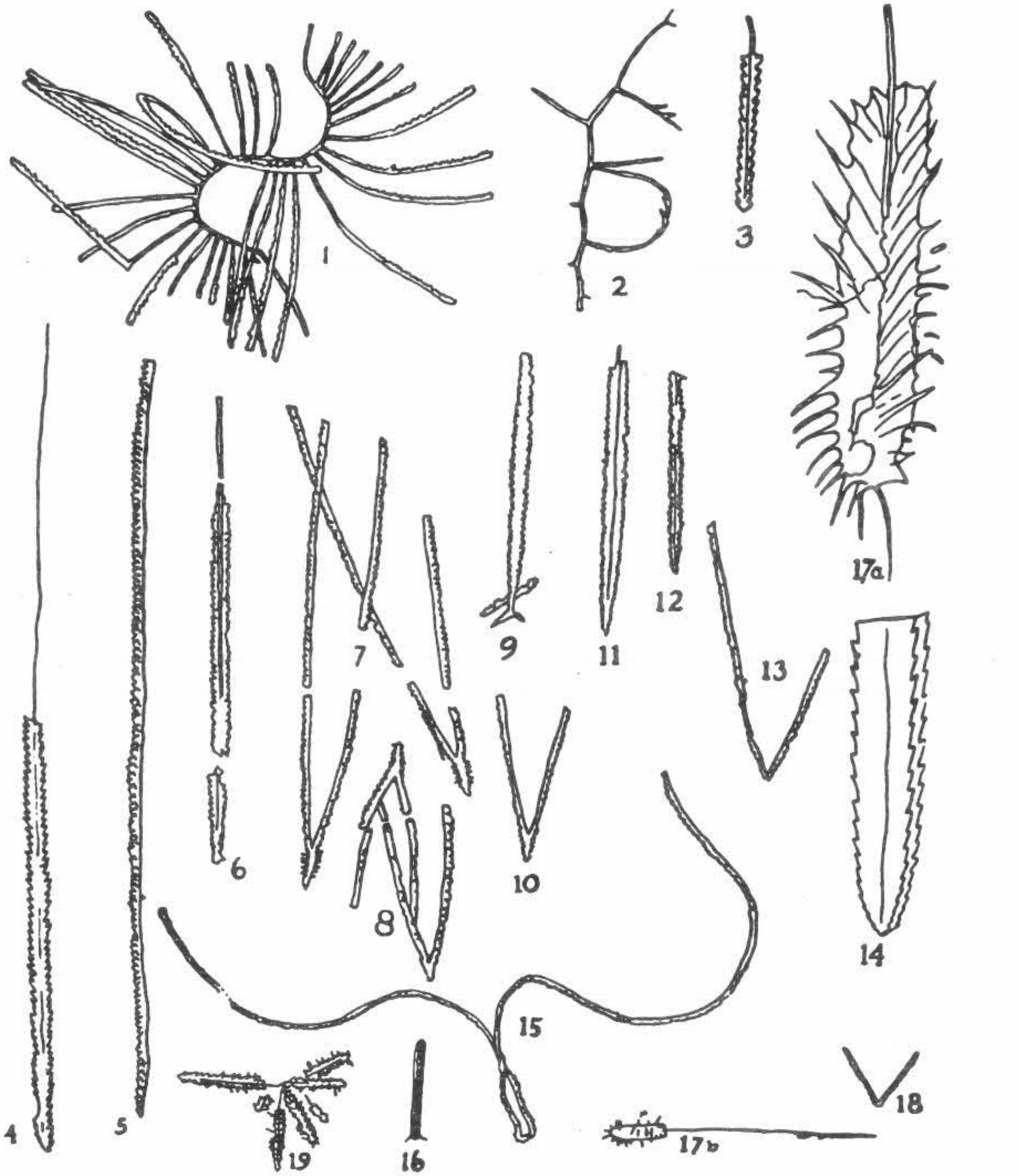


PLATE 30 — GRAPTOLITES

1 - Nemagraptus gracilis Hall
2 - Thamnograptus capillaris (Emmons)
3 - Glyptograptus angustifolius (Hall)
4 - Diplograptus foliaceus incisus (Lapworth)
5 - Didymograptus sagitticalis (Gurley)
6 - Diplograptus basilicus (Elles & Wood)
7 - Dicranograptus nicholsoni parvangulus Gurley
8 - Dicranograptus diapason Gurley
9 - Climacograptus bicornis Hall
10 - Dicranograptus rectus Hopkinson
11 — Diplograptus acutus (Elles & Wood)
12 - Glyptograptus euglyphus Lapworth
13 - Dicellograptus divaricatus rigidus Elles & Wood
14 - Retiograptus geinitzianus Hall
15 - Dicellograptus gurleyi Lapworth
16 - Cryptograptus tricornis (Carruthers)
17 - Glossgraptus ciliatus Emmons
18 - Dicellograptus sextans (Hall)
19 - Lasiograptus mucronatus (Hall)

GRAPTOLITES FROM WOMBLE SHALE AT CRYSTAL SPRINGS, ARKANSAS.

From Guide Book of 5th Annual Field Conference - Kansas Geological Society 1931

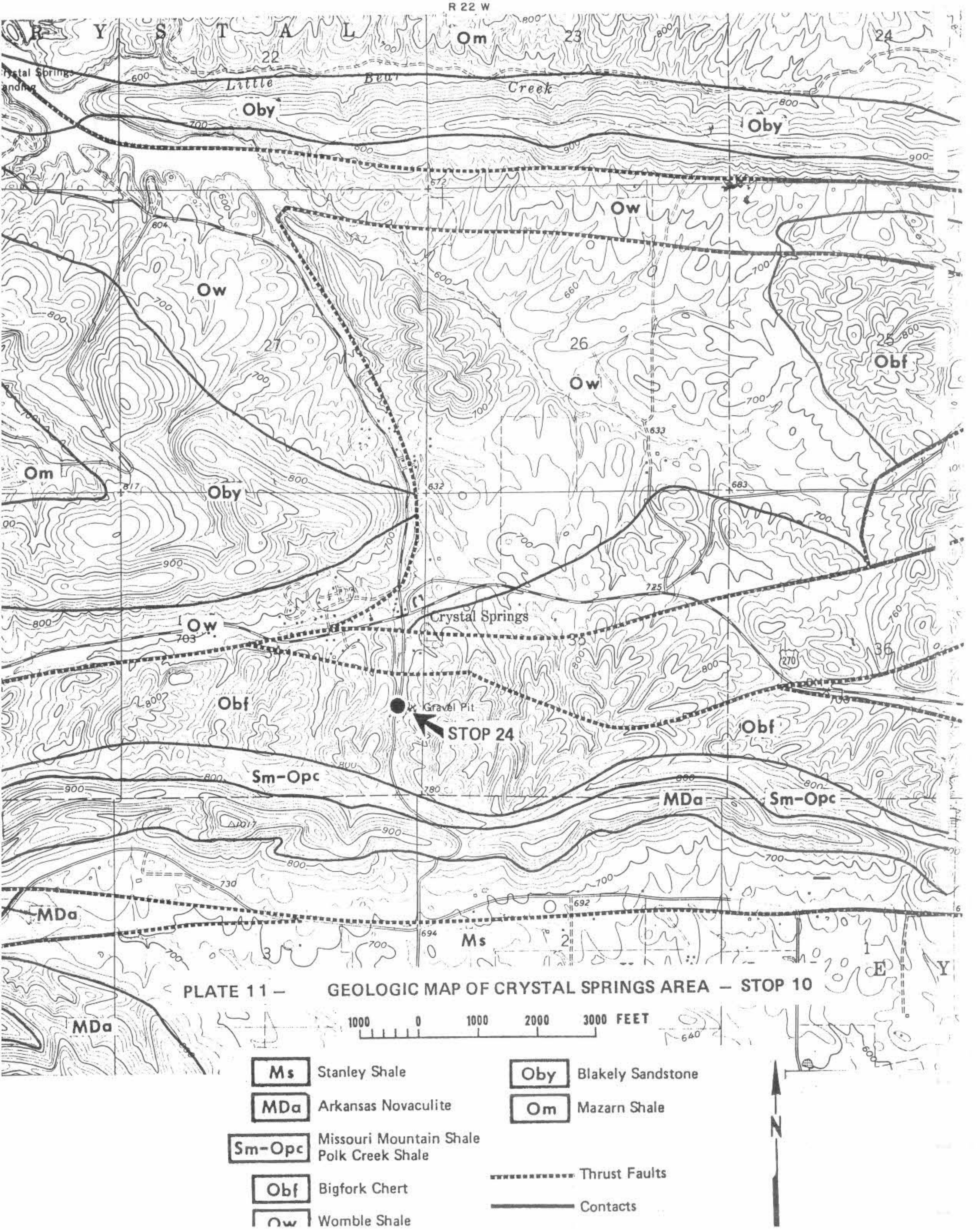


PLATE 11 — GEOLOGIC MAP OF CRYSTAL SPRINGS AREA — STOP 10

117.2 The Texas Tunnel, one of the early misdirected mining adventures for precious metals in the Ouachita Mountains, was dug a short distance to the south in carbonaceous graptolite-bearing shale of the extreme upper Womble Shale near the Bigfork Chert contact.

117.6 Crystal Springs, Arkansas. Turn south on dirt road to quarry in Bigfork Chert.

A possible side trip may be made to the graptolite-bearing upper Womble Shale 0.1 miles to the east on the north side of U. S. Hwy. 270. These black carbonaceous shales contain an abundant middle Ordovician graptolite fauna (Normanskill) (Plate 30). Miser (oral communication, 1965) reported that the inarticulate brachiopod *Lingula* occurred with graptolites in a dense, gray, fine-grained limestone in the Womble Shale along a small creek immediately north of the town.

117.9 **STOP 24 – FOLDED BIGFORK CHERT AT CRYSTAL SPRINGS QUARRIES (Plate 31 and Figure 47).**

These quarries in Bigfork Chert south of Crystal Springs are worked with little equipment for rock aggregate. The Bigfork commonly forms low hummocky hills ("Potato Hills") with rather large talus slopes composed of small angular fragments. In this area the Arkansas Novaculite is quite massive and forms the high ridges to the south. The Bigfork is complexly folded with both chevron and buckle folds inclined to the south. The strata dips gently or steeply to the north. The sequence is composed of many thin interbedded and often thin graded, calcareous (often decalicified), rather punky, silty chert (brown), thin bedded, gray chert and siliceous shale. It is thought that that the basal silty part of these interbedded sequences represent many minor influxes of fine clastics brought into the Ouachita trough by turbidity and bottom currents with each chert and siliceous shale representing the normal deep-water pelagic accumulations. Note the low-angle northward dipping cleavage in some intervals and its refraction across the more massive chert. There is some flowage of rock into the hinges of the folds.

The Bigfork Chert is the most reliable aquifer in the Ouachita Mountains and often has small chalybeate (iron) springs issuing from along the base of the exposures. This water-bearing characteristic is due to the extensive jointing and fracturing in the thin-bedded sequences.

Return to U. S. Hwy. 270.

118.2 Turn west on U. S. Hwy. 270.

121.7 **STOP 25 – LOWER WOMBLE SHALE AND BLAKELY SANDSTONE AT CHARLTON RECREATION AREA (Plate 32 and Figure 48).**

These exposures begin in the lower Womble Shale at the eastern end of the roadcut on U. S. Hwy. 270 and proceed through the Blakely Sandstone to the west along both the roadcut and in Murphy Creek. The Womble is composed of black shale that weathers to a brown color with some thin lenses and beds of medium grained, slightly phosphatic, sandy limestone.

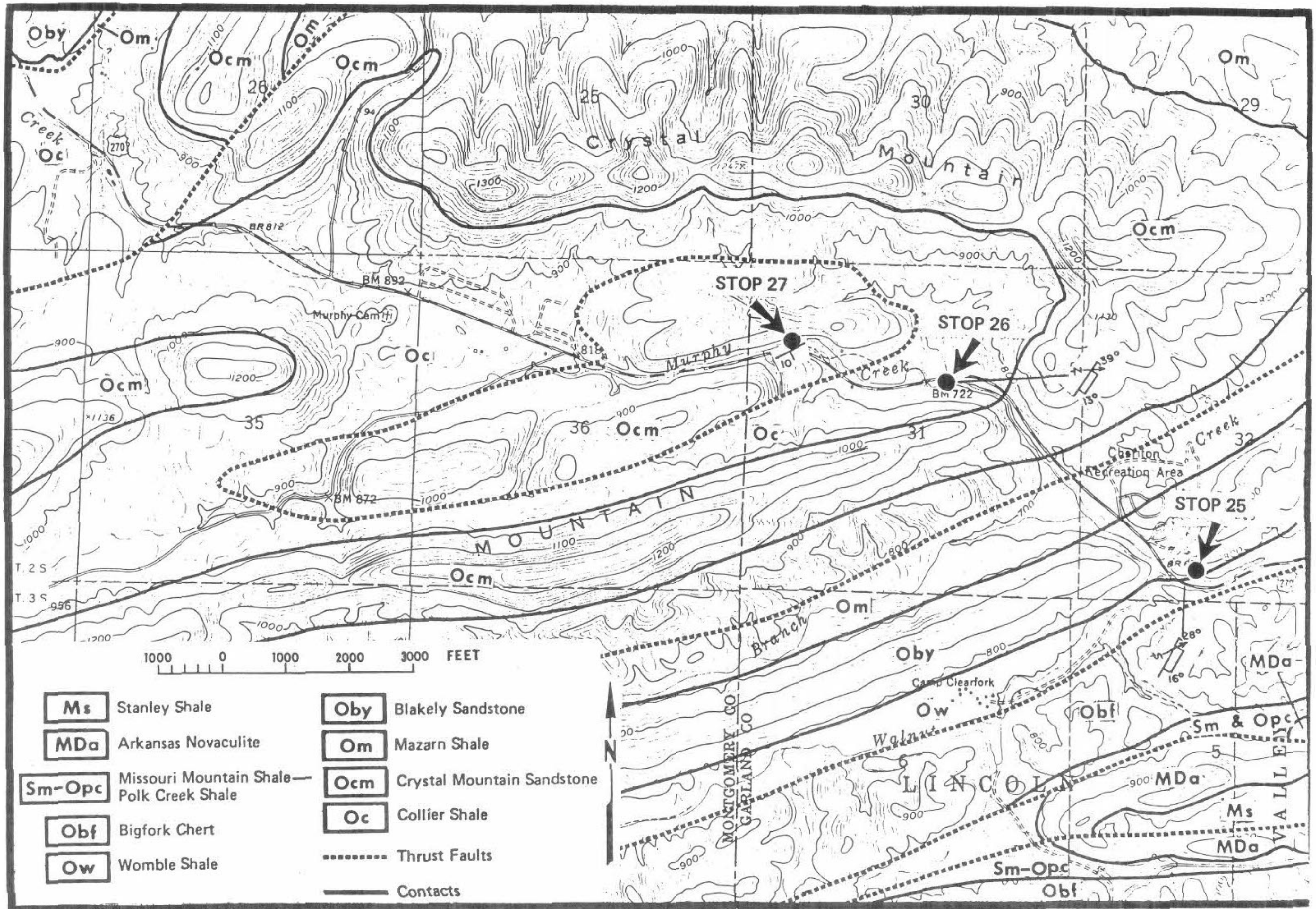


PLATE 32 — GEOLOGIC MAP OF McGRAW MOUNTAIN AREA — STOPS 25, 26, and 27

Some of the limestones contain sponge spicules and other bioclastic remains. Near the Blakely contact some thin quartzitic sandstones occur with gray-black banded shales. A few bottom marks, small cross-laminations and a degree of graded bedding indicate that the tops of the beds are to the south in this rather complexly folded sequence. Thicker quartzitic sandstones occur at the exposure at the bridge over Murphy Creek. Farther to the west in Murphy Creek a tan-black banded shale sequence occurs in the middle Blakely, with additional sandstone intervals of the lower Blakely exposed farther to the west. The upper Mazarn Shale crops out still farther to the west and is composed of banded greenish gray-black shales and very thin siltstones. Discontinuous sandstone masses, sedimentary pull-aparts, structural boudinage and well developed gently northward dipping cleavage occurs in the Blakely Sandstone. Two partially weathered lamprophyre igneous dikes of probable early upper Cretaceous age cut the upper Blakely sequence to the east of the bridge. A trail leads northward along the east bank of Murphy Creek to an abandoned "gold-silver" tunnel. The sandstone in the Blakely appear to be thinning upward sequences and this likely represents a low-energy sedimentary regime of submarine channels in a midfan depositional environment. A source area to the northeast is suggested. The bioclastic limestone lenses in the lower Womble Shale probably represents submarine sediment slurries derived from local and, in part, extrabasinal sources that existed along the northern flank of the Ouachita trough. Prof. J. Keith Rigby of Brigham Young University recently examined a sample of the Womble limestone containing sponge spicules from this site and he states:

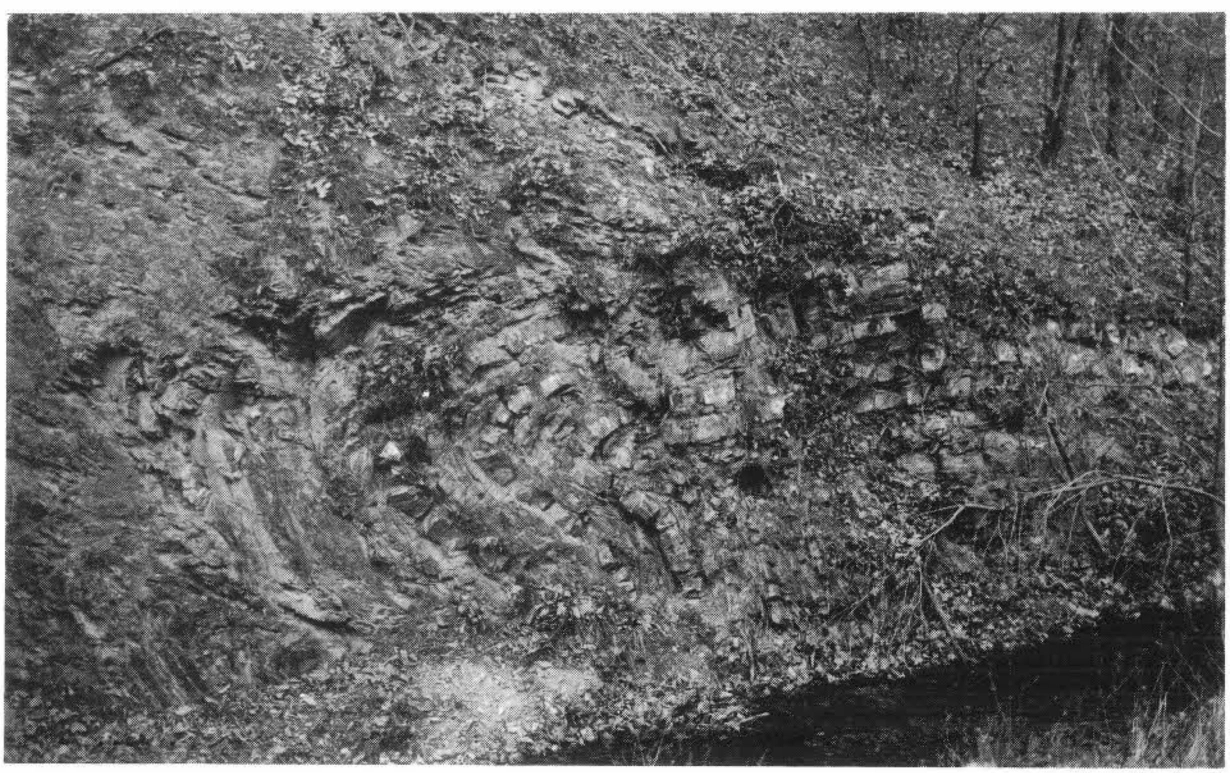
> "The long monactines all clustered together are typical of root tufts in the hexactinellids. The spicules were originally opaline silica and have been replaced in part by calcium carbonate and chalcedony. I suspect that the tufts were probably formed in place and may represent deep-water sponges. Had the tufts been transported far, I think they would have been broken apart."

Recent studies by Repetski (in Ketner, 1980) indicate that the lower Womble is middle Ordovician age. Markham (1972) has shown that the Womble contains bioclastic limestone intervals and slurried masses at several places in the region. Indeed there are intervals of olistostromes or sedimentary melange in the Womble throughout much of the Ouachita region. In the eastern core area near Benton the upper Womble contains some lenticular channel-like layers of phosphatic subgraywacke and conglomerate. These beds become finer grained to the south suggesting a northern source. Honess (1923, p. 62–63) describes some similar argillaceous brownish-green sandstones in the Broken Bow area of Oklahoma. Some bottom marks, load features, and minor graded bedding are present in these rocks.

Continue on U. S. Hwy. 270.

Figure 47 - Stop 24. Southward inclined folds in the Bigfork Chert at a quarry south of Crystal Springs are developed in interbedded chert (gray) and decalcified, punky, silty chert (white).

Figure 48 - Stop 25. Southward inclined folds and interbedded thin quartzitic sandstones and shales of the Blakely Sandstone on the north side of U. S. Hwy. 270.



122.8 **STOP 26 – RECUMBENT FOLDS AND LIMESTONES OF THE COLLIER SHALE AT BRIDGE OVER MURPHY CREEK (Plate 32 and Figure 49).**

These exposures of micritic to pelletoidal, thin to massive bedded limestone, some gray shale, and black chert of the upper Collier Shale occur about 0.2 miles east of the Monte Cristo Rock Shop along Murphy Creek. Graded bedding and other features indicate that the top of the beds are to the south. Thus these isoclinal folds are overturned or recumbent to the south. Strain has created well-developed cleavage, flowage of shale and other rock in the fold hinges, and boudinage in some beds. Small pellets and oolites occur in the more massive limestone to the south of the bridge and are a good marker for the Collier Shale throughout the region. Some of these more massive limestones in the area contain intervals composed of chert clasts with other fragments (including some plagioclase feldspar). Wise (1964) indicates some biologic features in some thin limestones of the Collier south of Mount Ida, Arkansas which were originally thought to represent algal structures but now are considered to be trace fossils. At first inspection the folds in this area appear to be relatively straightforward. But, our studies have proved otherwise and this has been confirmed by a thesis investigation by Paul Soustek of Southern Illinois University (1979). There are several epochs of folding, the earliest of which may have been caused by soft-sediment deformation. The faulting is equally complex. Small hydrothermal quartz-calcite veins fill the fractures in the Collier. Repetski and Ethington (1977, p. 95) obtained conodonts from the limestone intervals south of this bridge and from other localities in the area, as well as the Broken Bow area of Oklahoma, that confirm early Ordovician (Tremadocian) age rather than Cambrian for the Collier. They state that the presence of *Cordylodus angulatus* Pander serves to establish the early Ordovician age. They further state that thisspeciesis joined by other distinctive elements and include both simple cones and multidenticulate forms. These include: *Paldotus bassleri* Furnish; *Loxodus bransoni* Furnish; *Acanthodus lineatus* (Furnish); *"Oistodus" triangularis* Furnish; and *Chosonodina herfurthi* Muller. This fauna was designated "Fauna C" in North American studies, thus making the Collier correlative with the Mackenzie Hill Formation of the Arbuckle Mountains and the Oneota Dolomite of the Upper Mississippi Valley.

In the Broken Bow area of Oklahoma Pitt (1955) named a sequence of shales, thin limestones, and sandstones that he considered older than the Collier Shale the Lukfata Sandstone. Repetski and Ethington (1977, p. 96–97) on the basis of conodonts showed that this section is younger than the Collier and thus confirmed our opinion that the section was inverted.

In an effort to better understand the Ordovician limestones in the Ouachita Mountains of Arkansas samples from most of them have been submitted by Stone for chemical analysis and the preliminary results are shown in Table 1 in the Appendix.

123.2 **STOP 27 – FLAT–LYING SEQUENCE OF CRYSTAL MOUNTAIN SANDSTONE NORTHWEST OF MONTE CRISTO (Plate 32 and Figure 50).**

A sequence of nearly flat-lying, interbedded, thin to thick, fine to

Figure 49 - Stop 26. Isoclinal recumbent folds in thin beds of micritic limestone and shale of the Collier Shale a short distance north of Murphy Creek bridge on U. S. Hwy. 270.

Figure 50 - Stop 27. Upright quartzitic sandstones and shales with dissecting hydrothermal quartz veins in the Crystal Mountain Sandstone on U. S. Hwy. 270.

medium-grained orthoquartzites and buff to gray banded shales occurs on the south side of U. S. Hwy. 270 a short distance northwest of the Monte Cristo Rock Shop. The high hills in all directions are formed by the massive sandstone intervals of the Crystal Mountain Sandstone. Some small cross-laminations, minor grading of beds, and other features confirm that the rocks are indeed upright. Sandstone sequences appear to thin and fine upward suggesting that these intervals are submarine fan channels. Portions of some beds were once likely calcareous but have since been leached by weathering. Small hydrothermal quartz veins fill joints in the strata and clear quartz crystals are numerous here as well as throughout this region in the Crystal Mountain Sandstone. This exposure appears to be near the center of a small anticlinal flexure on the limb of a larger synclinal fold. However, the Crystal Mountain Sandstone dips under the Collier in all directions. The contact, therefore, is a thrust fault which makes this exposure a structural window.

At the other Crystal Mountain exposures in the area, particularly near the base of the formation, there are some intervals of thin, gray micritic limestone and thin to thick conglomerate composed of small to large clasts of limestone, sandstone, chert, and other materials. It is our belief that these rocks represent low-energy, proximal turbidites and, locally, slurries and slides from foreland facies to the north. It is suggested that they are submarine midfan deposits. In another opinion Davies and Williamson (1977) state that the Crystal Mountain and Blakely Formations were deposited in a shallow-marine basin which has a provenance for most of the sandstones to the south of the North American continent.

No diagnostic fossils have been collected from the Crystal Mountain Sandstone, but it is likely that conodonts will be found in the thin limestones. Crystal Mountain is placed in the lower Ordovician as a result of its stratigraphic position.

Continue west on U. S. Hwy. 270.

125.6 Additional folded sequences of limestone of the upper Collier Shale are exposed along the northeast side of the roadcut on U. S. Hwy. 270.

125.7 Approximate trace of a large, low dipping thrust fault with the Collier Shale exposed to the south and the Blakely Sandstone to the north.

126.6 A very complexly folded sequence of weathered calcareous sandstone and shale in the lower Womble Shale is exposed here. A fault is exposed in the small excavation on the north side of the road and is dissected by small milky quartz veins. Note that most of the folds trend to the northeast.

Our ideas on the deposition of the Ordovician rocks in the Ouachita Mountains are summarized below.

> Stone, Charles G., and Haley, Boyd R., 1981, DEEP–WATER DEPOSITION OF ORDOVICIAN STRATA IN THE OUACHITA MOUNTAINS, ARKANSAS AND OKLAHOMA: South Central GSA Meeting, April 13, 14, at San Antonio, Texas.

Early workers in the Ouachita Mountains placed the Ordovician strata in deltaic and restricted shallow-water marine depositional environments. Subsequent investigators generally followed this regime until the early 1950's when concepts of deep-water marine depositional environments were applied to portions of the Ordovician through middle Pennsylvanian rocks. Recent workers in the Ouachita Mountains may be grouped into two general categories concerning models for Ordovician deposition: (1) all the rocks were deposited in deep-water marine environment; or (2) all or most of the rocks were deposited in deltaic or shallow-water marine environments.

During our studies over the past decade we have not found any indigenous shallow-water marine sedimentary structures, invertebrate fossils, or trace fossils in Ordovician rocks of the Ouachita Mountains. However, there are lithic units with bottom marks, trace fossils, and other features considered to be of deep-water marine origin. Numerous thin-bedded, dense, blue-gray limestone are thought to represent *in situ* deep-water marine deposits formed above the carbonate compensation depth. Lithologies and features that have been misinterpreted as being shallow-water marine origin include: (a) cross-laminations; (b) cleavage refraction in sandstones; (c) slump and slurry intervals containing flowage structures and superposed erratic blocks; and (d) transported bioclastic, oolitic, and pelletoidal limestones.

We conclude that all Ordovician strata in the Ouachita Mountains from the early Ordovician Collier through the late Ordovician Polk Creek Formations are proto-Ouachita bathyal platform or trough deposits and represent either: (1) indigenous pelagic or hemipelagic deposits; or (2) turbidity or bottom current submarine fan and related facies, combined with episodes of slump and slurry detachments all derived from "northerly" flanking shelf, slope, and submarine ridge sources.

126.7 Turn north on road to Mountain Harbor Resort.

129.2 Mountain Harbor Resort.

END OF SECOND DAY

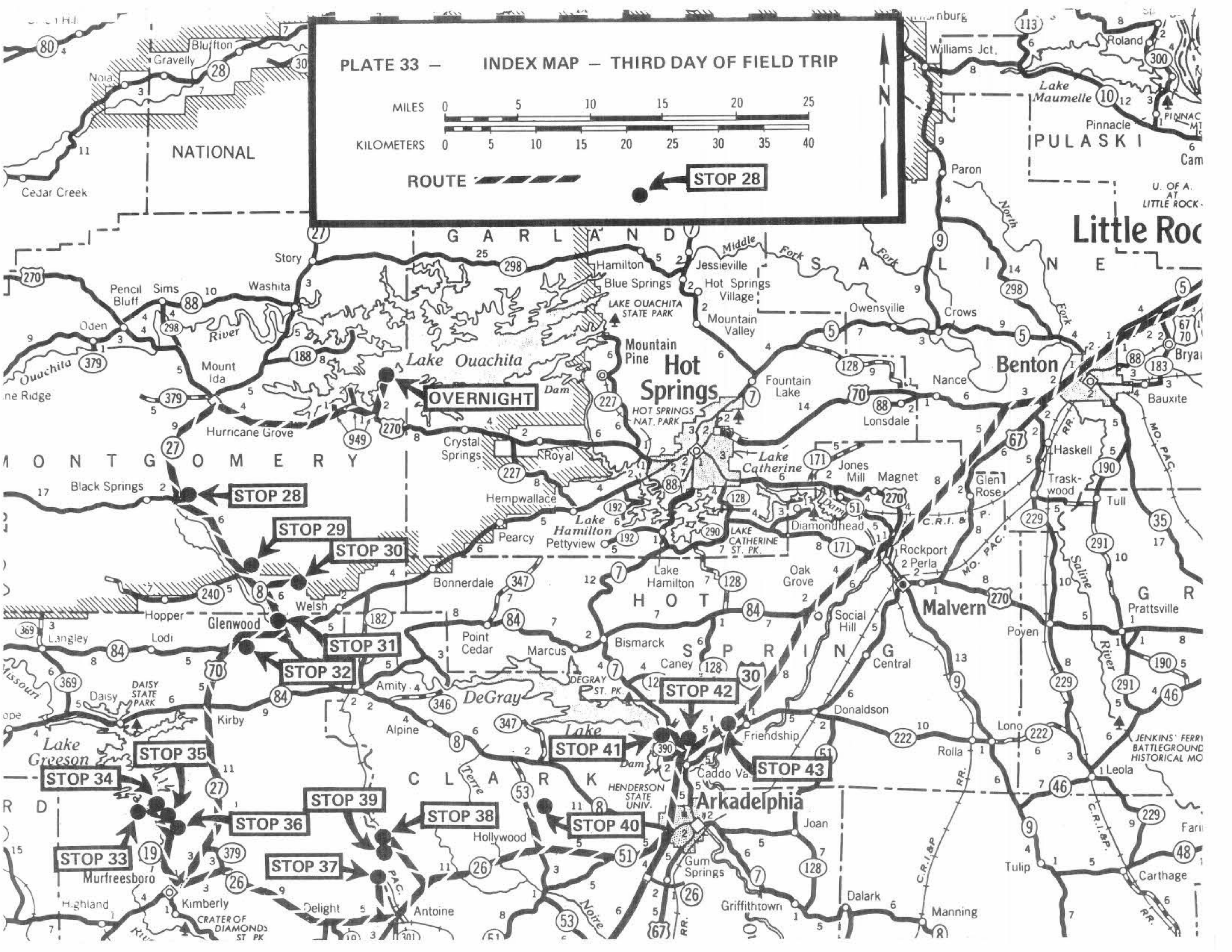


PLATE 33 — INDEX MAP — THIRD DAY OF FIELD TRIP
MILES 0 5 10 15 20 25
KILOMETERS 0 5 10 15 20 25 30 35 40
ROUTE
STOP 28
N
GARLAND
SALINE
MONTGOMERY
HOT SPRING
CLARK
PULASKI
NATIONAL
Little Roc
U. OF A. AT LITTLE ROCK
Hot Springs
HOT SPRINGS NAT. PARK
Benton
Malvern
Arkadelphia
HENDERSON STATE UNIV.
Lake Ouachita
LAKE OUACHITA STATE PARK
Lake Hamilton
Lake Catherine
LAKE CATHERINE ST. PK.
DeGray Lake
DEGRAY ST. PK.
Lake Greeson
DAISY STATE PARK
CRATER OF DIAMONDS ST PK
JENKINS' FERRY BATTLEGROUND HISTORICAL MO
OVERNIGHT
STOP 28
STOP 29
STOP 30
STOP 31
STOP 32
STOP 33
STOP 34
STOP 35
STOP 36
STOP 37
STOP 38
STOP 39
STOP 40
STOP 41
STOP 42
STOP 43
Mount Ida
Glenwood
Murfreesboro
Kimberly
Delight
Antoine
Amity
Caddo Valley
Friendship
Mountain Pine
Story
Washita
Hurricane Grove
Black Springs
Welsh
Hopper
Langley
Lodi
Daisy
Kirby
Alpine
Point Cedar
Marcus
Bismarck
Caney
Hollywood
Joan
Gum Springs
Griffithtown
Dalark
Manning
Donaldson
Rolla
Lono
Leola
Tulip
Carthage
Central
Social Hill
Oak Grove
Lake Hamilton
Rockport
Perla
Diamondhead
Magnet
Jones Mill
Lonsdale
Fountain Lake
Mountain Valley
Hot Springs Village
Jessieville
Hamilton
Blue Springs
Crystal Springs
Royal
Hempwallace
Pearcy
Pettyview
Bonnerdale
Owensville
Crows
Paron
Williams Jct.
Roland
Pinnacle
Lake Maumelle
Nance
Haskell
Traskwood
Glen Rose
Tull
Poyen
Prattsville
Bauxite
Bryant
Pencil Bluff
Sims
Oden
Cedar Creek
Nola
Gravelly
Bluffton
Highland
Saline River
Ouachita River
Missouri
Terre Noire
North Fork
Middle Fork
MO. PAC.
C.R.I.&P.

ROAD LOG – THIRD DAY
CENTRAL AND SOUTHERN OUACHITA MOUNTAINS, ARKANSAS

Mount Ida, Norman, Caddo Gap, Glenwood, Kirby, Murfreesboro, Delight, Antoine, Arkadelphia, Malvern, Benton, Little Rock (Plate 33).

MILEAGE	DESCRIPTION
0.0	Start at Mountain Harbor Resort and return to U. S. Hwy. 270.
2.5	Turn west on U. S. Hwy. 270.
13.1	Turn south on Arkansas Hwy. 27 at Mount Ida, Arkansas.

The middle and lower Ordovician Womble Shale, Mazarn Shale, Crystal Mountain Sandstone, and Collier Shale occur in complexly folded and thrust faulted sequences in this central core area of the Ouachita Mountains. The following comments are by George Viele (1973).

> Between Mount Ida and Norman, Arkansas fold attitudes are fairly constant. Axial surfaces are moderately inclined or recumbent and they exhibit gentle warping. The fold hinges consistently plunge toward the west or southwest parallel to the trends and plunges shown by the map pattern. Rotation directions are consistently toward the south. The only problems occur in places such as about 1½ miles north of Stop 28, where if our top and bottom calls are correct, the rotation direction suggests an overturned, northward moving limb. This is not completely anomalous, for we suggest initial movement toward the north, and at later stops we shall see definite proof for it. Tentatively the name Crystal Mountain trend is applied to these folds. The bearings of fold hinges in the Crystal Mountains are the same but the axial surfaces appear to be much steeper. Only more work will reveal whether this represents the effect of thick sandstones in the stratigraphic section or if the steep axial surfaces are related to a later phase of folding.

21.0 **STOP 28 – TYPICAL SEQUENCES OF UPPER MAZARN SHALE NORTH OF NORMAN (Plate 34 and Figure 51).**

The exposure on the east side of Arkansas Hwy. 27 contains interbedded banded green and black shale, laminated fine-grained gray siltstone, and minor lenses of fine-grained brownish-gray quartzitic sandstone in the upper part of the Mazarn Shale. Small southward inclined folds with shallow northward dipping cleavage and some structural boudinage characterize the sequence. The southward overturning of the folds is confirmed by graded bedding, small cross laminations, and a few bottom marks (top of the beds are to the south). It is likely that the siltstones and sandstones are formed by fairly weak turbidity and marine currents causing grading of the silt and clay fractions. Trace fossils are fairly numerous in some intervals and along with other data suggest a deep-water origin. Small milky quartz veins fill fractures in the rock. As the vegetation on the ridge shows, cedar trees seem to prefer the Mazarn Shale.

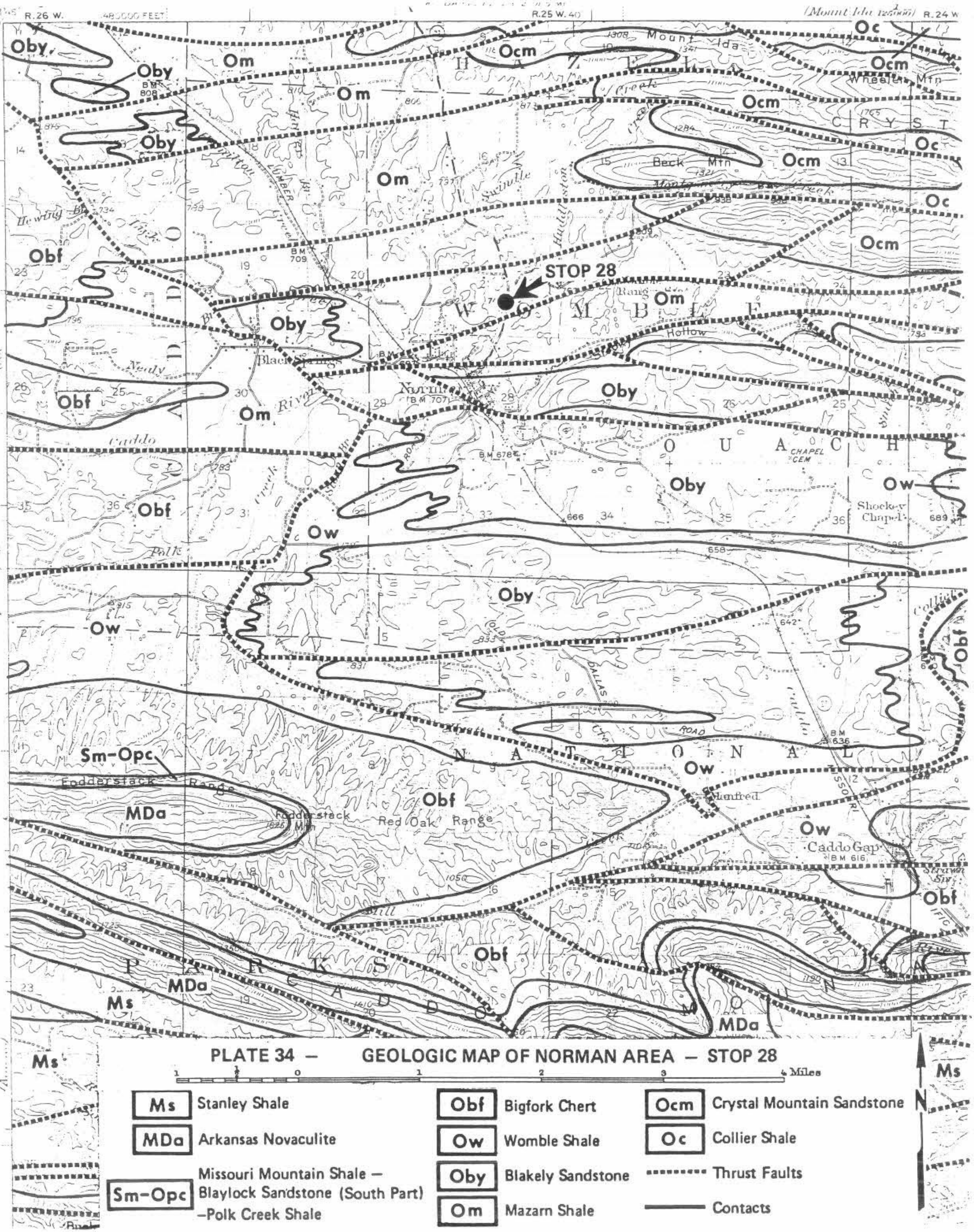


PLATE 34 — GEOLOGIC MAP OF NORMAN AREA — STOP 28

Some intervals of bluish-gray, micritic limestone, gray sandy conglomeratic limestone and in places thin intervals of black chert are found in the lower Mazarn Shale north of this area as well as locally in the upper Mazarn.

It is thought that the Mazarn represents relatively quiet early trough deposition with minor fine clastics and some sedimentary slump and slurry masses being brought in from sources to the north or northeast.

Denison et al., (1977, p. 37) reports a number of Devonian ages (358 to 378 m. y.) from some of the metasedimentary rocks in the Mazarn Shale to the west in the Broken Bow uplift of Oklahoma. It is further suggested that these age determinations indicate metamorphic-igneous activity during Devonian times in the Ouachita fold belt. The bulk of their age determinations from Collier and Mazarn surface samples and from subsurface samples of the deep Vierson and Cochran No. 25-1 Weyerhaeuser Well are early Pennsylvanian to early Permian, the time of major tectonic episodes in the Ouachita Mountains.

21.4 City limits of Norman, Arkansas; formerly known as Womble. The name of the town was changed when Mr. Womble moved. The following comments are extracted from George Viele (1973).

> Fold patterns start to change south of Norman, Arkansas. Most axial surfaces are moderately inclined and dip southeastward, though about a third of those measured in the area between Norman and Caddo Gap dip gently to the northwest.They appear to be gently warped about a northeast-southwest axis. Fold hinges consistently plunge eastward toward the Mazarn synclinorium though reclined hinges plunging south-southeast become more numerous toward the south. Indeed, the outcrops of novaculite at Caddo Gap provide the best examples of superposed folding in the western Ouachita Mountains. On the geologic map a downdip view of the Arkansas Novaculite-Stanley contact shows S rotations, but at Caddo Gap a Z rotation has been superposed on the earlier folds. Axial surfaces of the S folds have been folded back toward the south. A reclined system has been noted in several localities almost as far west as the Oklahoma State Line.

In recent years proposals involving subduction, rifting, megashear, and other tectonic processes have been advanced by investigators to explain the structure of the Ouachita Mountains (Viele, 1973, 1976, and 1979; Keller and Cebull, 1973; Morris, 1974; King, 1975; Wickham, Roeder, and Briggs, 1976; Thomas, 1977; and Arbenz, 1980). A study of those papers provides additional insights into the complex structural geology of the Ouachita Mountains. Arbenz presents some of his concepts on the origin of the Ouachita system in the following abstract.

> Arbenz, J. K., 1980, FRESH LOOK AT SOME OUACHITA PROBLEMS: Presented at Annual Meeting, Denver Colorado, Am. Assoc. Petroleum Geologists Bull., v. 64, No. 5.
>
> Numerous new geologic and geophysical data collected in recent

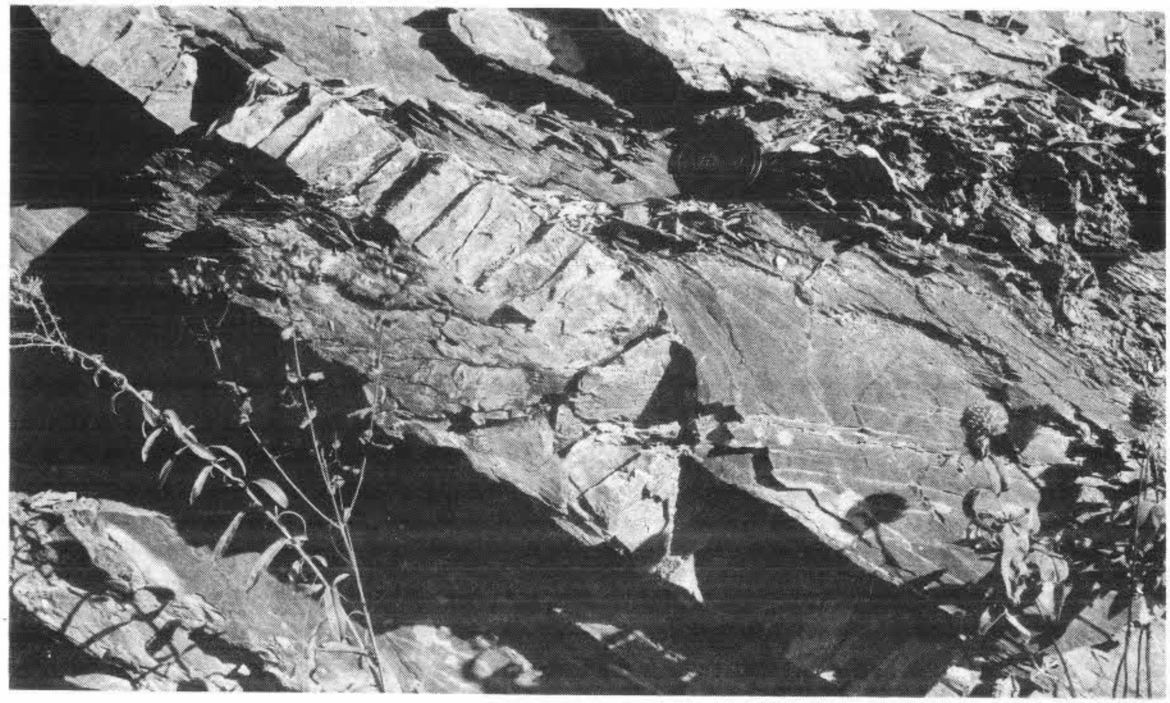


Figure 51 - Stop 28. Closeup showing thin layers of banded shale and siltstone with a small southward inclined fold exhibiting cleavage and internal crowding in the fold hinge from a roadcut in the upper Mazarn Shale on Arkansas Hwy. 27 north of Norman, Arkansas.

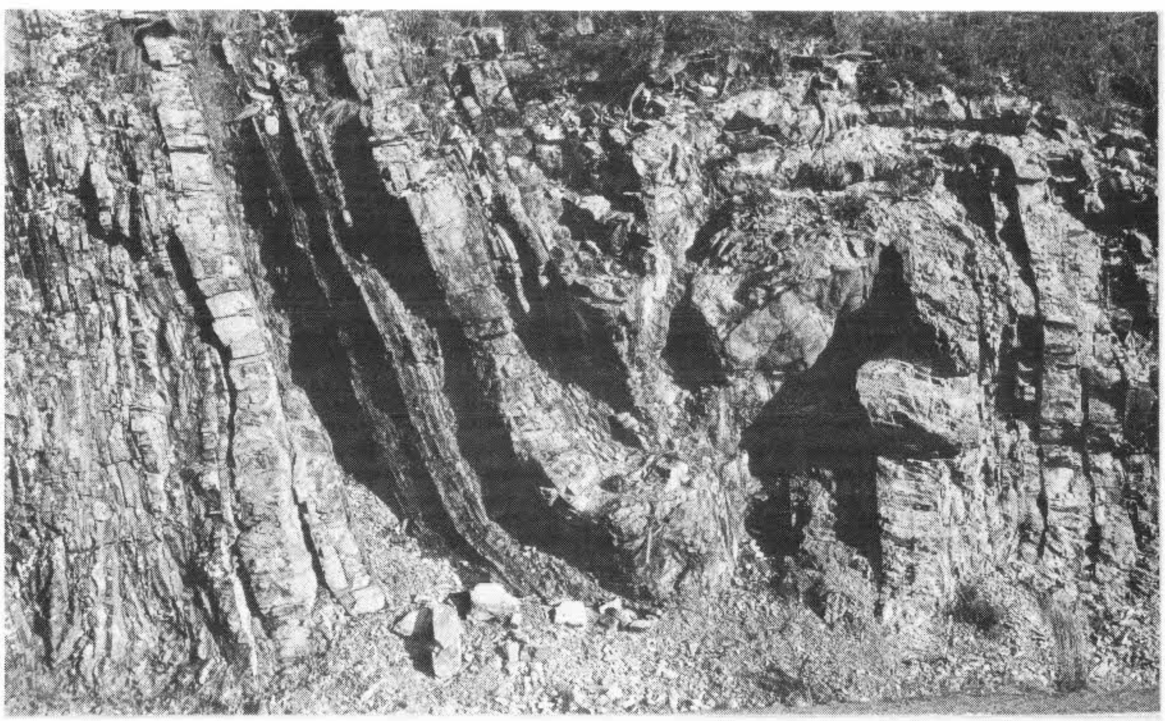


Figure 52 - Stop 29. Steeply reclined folds with small faults in thick to thin intervals of very dense novaculites and some thin shales in the lower part of the Lower Division of the Arkansas Novaculite at the north end of the Caddo Gap section on Arkansas Hwy. 27.

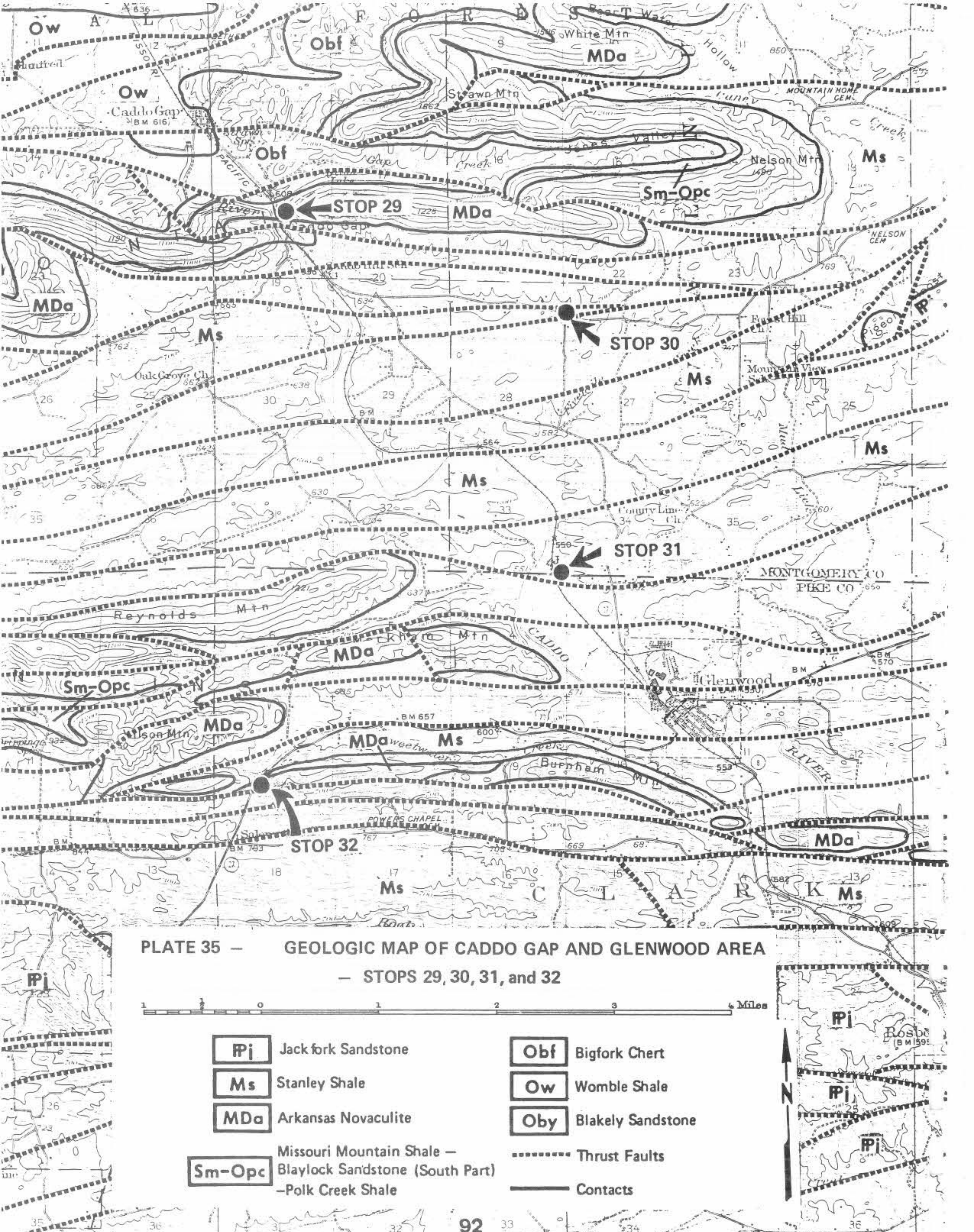


PLATE 35 — GEOLOGIC MAP OF CADDO GAP AND GLENWOOD AREA — STOPS 29, 30, 31, and 32

IPj	Jackfork Sandstone	Obf	Bigfork Chert
Ms	Stanley Shale	Ow	Womble Shale
MDa	Arkansas Novaculite	Oby	Blakely Sandstone
Sm-Opc	Missouri Mountain Shale — Blaylock Sandstone (South Part) —Polk Creek Shale	▪▪▪▪▪▪▪	Thrust Faults
		▬▬▬	Contacts

years in the Ouachita province by industry, government, and academic institutions allow an updated synthesis of events that shaped the southern margin of North America in the Paleozoic.

Some new key observations include: (1) radiometric data indicate both Devonian and late Paleozoic metamorphic events affected the core areas of the Ouachita Mountains; (2) long-suspected pre-Desmoinesian orogenic uplift that supplied detritus into the foreland basins of the Ouachita system is well displayed on seismic data and has been confirmed by the drill. Weakly deformed Desmoinesian and younger, shallow marine to continental successor basin sediments overlie with angular unconformity the folded and thrusted Ouachita facies rocks beneath the Gulf Coastal Plain as far south as the Sabine uplift; (3) high-quality field work, especially in Arkansas, has yielded ample data that supports a polyphase deformation in the core areas of the Ouachita Mountains. Movements consisted of at least one north-vergent thrust and fold phase primarily of Pennsylvanian age. Initial folding and thrusting were followed (probably in Permain time) by a south-vergent overturning of previous geometries, additional folding and thrusting, and the development of north-dipping cleavage; and (4) plate tectonic reconstructions of the opening and closing of the Iapetus Ocean and the formation and breakup of Pangea have added to the understanding of the events that led to the origin of the Ouachita system. Nevertheless, big data gaps remain.

27.5 City limits, Caddo Gap, Arkansas.

28.8 **STOP 29 – CLASSIC SECTION OF ARKANSAS NOVACULITE AT CADDO GAP (Plate 35 and Figures 52, 53).**

Legend has it that in 1541 Hernando DeSoto's party was attacked here by the Tula Indians who rolled boulders down the steep slopes on them.

The sequence beginning at the north end of the roadcut is: olive tan to maroon shale and a thin chert sandstone conglomerate bed of the upper Missouri Mountain Shale; massive, dense, white to light gray, highly jointed, sometimes sandy in the basal portions, novaculite and chert of the Lower Division of the Arkansas Novaculite; black shale, gray chert and some gray novaculite of the Middle Division of the Arkansas Novaculite; thin bedded to massive, cream to white, and, in part, tripolitic novaculite of the Upper Division of the Arkansas Novaculite; gray chert, greenish-black shale, quartzitic sandstone and a thin chert sandstone conglomerate bed of the Hot Springs Member of the basal Stanley Shale; and greenish-black shale and graywacke of the lower Stanley Shale. Many other good exposures of the rocks occur along the highway, railroad and Caddo River in the area. Based on the study of conodonts at this site Hass (1951) placed the Mississippian-Devonian boundary some 27 feet below the top of the Middle Division. Structurally the rocks are rather severely deformed at this site. There are numerous steeply reclined fold hinges and possibly another system with flatter hinges. A tear fault is present along the southern margin of the Stop and likely affected the fold rotations. Jay Zimmerman and David Evansin are presently studying in detail the rocks at Caddo Gap and they should provide additional data on the structure and stratigraphy.

To most investigators novaculite is a chemically pure microcrystalline variety of chert and typically breaks with a conchoidal or subconchoidal fracture. Lowe (1977, p. 136) shows that two distinct populations of detrital quartz grains occur within the massive white novaculite. One is a fine quartz that is distributed through the novaculite and likely represents a cyclic introduction of aeolian detritus into the basin of deposition. The other is made up of well-rounded, highly spherical, medium to coarse-grained sandstone in thin beds within the lower 70 feet of the Lower Division of the Arkansas Novaculite and uppermost Missouri Mountain Shale. He postulates that this sand may indicate a shelf contribution from the north by rapid sedimentation processes such as turbidity currents. In the Middle Division of the Arkansas Novaculite, Lowe (1977, p. 138) describes thin alternating chert and shale beds with some chert beds containing coarser grains. Where they do, grading and current structures are common. He suggests that these appear to be fine turbidity current sequences and indicates the presence of C and D intervals of the Bouma sequence. Sholes (1977, p. 139) indicates that the novaculite beds are spiculitic and pelletal, whereas the chert is primarily Radiolaria-bearing.

Keller et al., (1977, p. 834) in scanning electron microscopic studies of the Arkansas Novaculite suggests that the term novaculite be restricted to the polygonal triple point texture caused by low-rank thermal metamorphism. Present SEM studies of many additional samples from various Paleozoic Formations in the Ouachita Mountains by Keller and Stone indicate the coarsest polygonal triple point texture occurs near Little Rock, Arkansas, with another area of fairly coarse texture in the Broken Bow area of Oklahoma. At Caddo Gap polygonal triple point texture is very fine to absent.

Tripoli used primarily for abrasive products has been mined from the Upper Division near Hot Springs, Arkansas to the east and in the Cossatot Mountains to the southwest. Novaculite is also extensively quarried, primarily near Hot Springs, for several types of the highest quality whetstone. Holbrook and Stone (1979) indicate that novaculite constitutes a tremendous resource of high-purity silica (99+%) in the central and southern Ouachita Mountains of Arkansas and Oklahoma (see Plates 36, 37). Manganese often occurs in the Lower Division of the Arkansas Novaculite in this area and farther to the west and likely was derived from leaching of the novaculite. Some limited mining operations for the small manganese veins and pockets have taken place in this area and westward into McCurtain County, Oklahoma. Investigations by Kidwell (1977) have disclosed a suite of rare iron phosphate minerals in some abandoned manganese mines in the Arkansas Novaculite, 10 to 35 miles west of here.

29.7 Turn east on Forest Service Road 226.

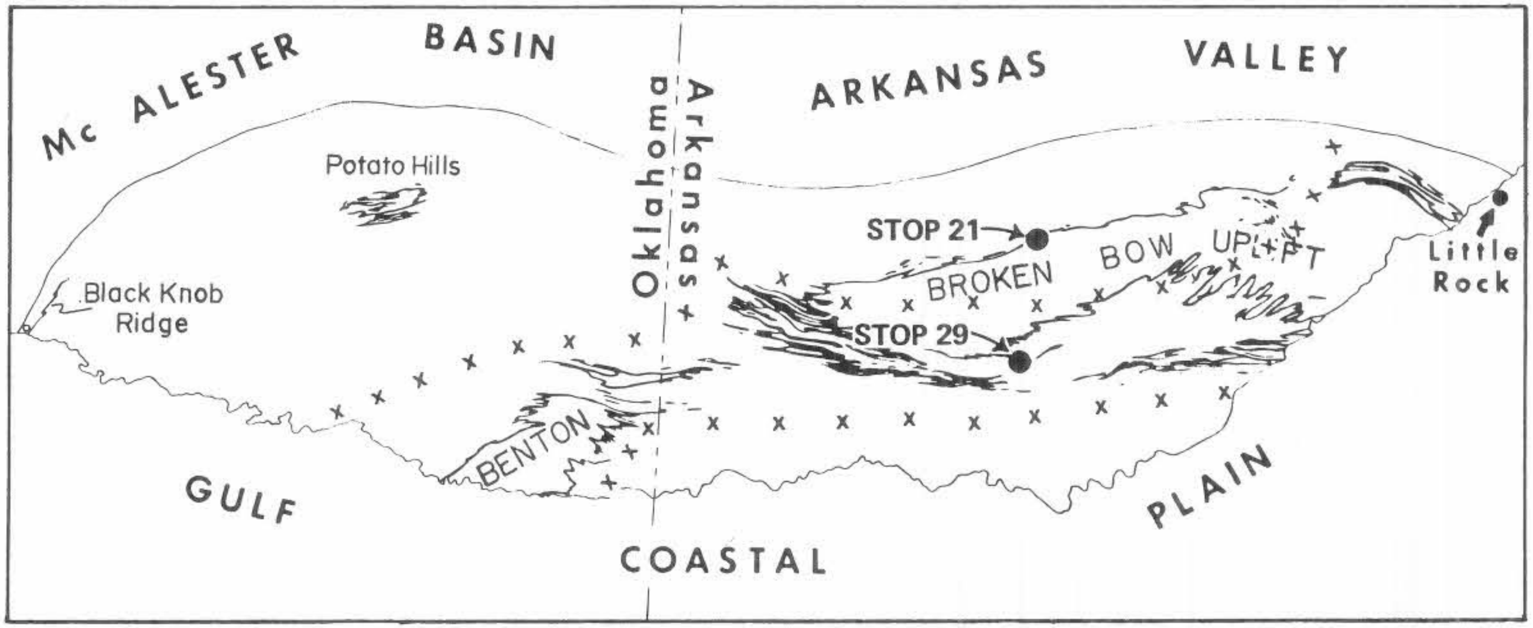


PLATE 36 – MAP OF OUACHITA MOUNTAINS SHOWING OUTCROP OF THE ARKANSAS NOVACULITE (black area and lines) IN ARKANSAS AND OKLAHOMA. THICK SHALE–FREE PORTIONS OF THE NOVACULITE ARE WITHIN AREA OUTLINED BY X's.

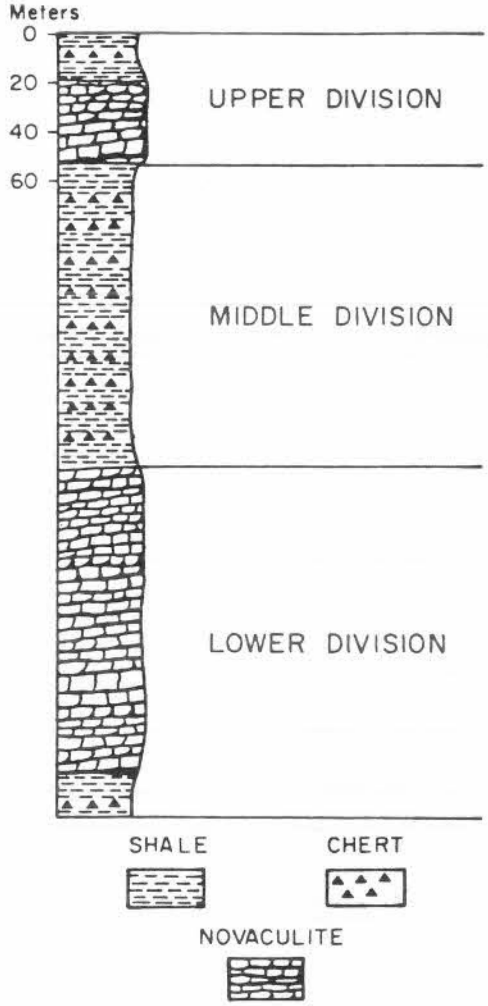


PLATE 37 – IDEALIZED COLUMNAR SECTION OF THE ARKANSAS NOVACULITE SHOWING TYPICAL CENTRAL AND SOUTHERN OUACHITA MOUNTAIN FACIES.

38.6 **STOP 30 – LOWER STANLEY SHALE IN THE BIRD AND SON SLATE GRANULE PIT (Plate 35 and Figure 54).**

We wish to thank Hurcil Cowart and other members of his staff for permission to visit the site! **Please be careful** – and wear your hard hats!

Sheared shale and/or slate in the lower Stanley Shale is being mined and processed from this pit for roofing granules and as a filler. Most of the rocks are upright and are dipping rather steeply to the south. They consist of black shale or slate, black chert, with thin siltstone and graywacke. There are several thrust faults cutting the sequence and the fault zones exhibit numerous slickenside surfaces coated with dickite. The faulting has repeatedly shoved one sequence northward over another and some faults are, in part, slightly backfolded to the south. Small folds are formed in the chert interval on the east side of the pit. The thin, graded, sandstone and siltstone layers

Figure 53 - Stop 29. Vertical sequence of Arkansas Novaculite with decalcified (?) massive novaculite containing secondary manganese blebs at the top of the Lower Division (to the left), overlain by thin, often graded, chert and shale of the Middle Division near the middle of the Caddo Gap section on Arkansas Hwy. 27.

Figure 54 - Stop 30. A view of the Bird and Son Slate Granule Pit developed in sheared and faulted shale with some siltstone, graywacke and chert in the middle portion of the lower Stanley Shale north of Glenwood.

are locally bottom-marked, thicken and coarsen upward and are believed to represent lobe sequences of an outer submarine fan or basin plain environment of deposition. These sandstones were likely derived from sources to the south and southeast. The sands were built out initially to the north and northwest as large deltas and deep-water submarine fans and subsequently directed by turbidity currents westward down the Ouachita trough. Close inspection of the clastic units shows that both structural boudinage and sedimentary pull-aparts are present. Two generations of cleavage are present and dip steeply to the north. The weathered Stanley Shale at the top of the pit shows characteristic greenish-brown color. Small quartz veins with pyrite and calcite (some dog-tooth variety) fill fractures in the sandstone.

The middle and lower Stanley Shale are contained in the Tenmile Creek Formation of the lower Stanley Group in the Ouachita Mountains of Oklahoma. Both in Arkansas and Oklahoma there are chert intervals in the Stanley Shale that represent reliable markers. The Battiest (Ba-teest') chert interval near the middle of the lower Stanley Shale is particularly definitive in portions of eastern Oklahoma. Due to the many structural complexities in this area and throughout the region, we are presently unable to make an exact correlation of the cherts in this pit with units elsewhere.

Deposits of bedded barite occur locally in the Fancy Hill District to the west and Pigeon Roost District to the east in the lower Stanley Shale. Brobst and Ward (1965), R. Zimmermann (1966), Hanor (1977), and others ascribe a primary sedimentary origin for the barite; Scull (1958) and others consider the barite a hydrothermal deposit and relate it to the Mesozoic intrusives. We are of the opinion that the barite is of sedimentary origin.

Return to Junction of Arkansas Hwy. 27.

33.4 Turn south on Arkansas Hwy. 27.

37.1 **STOP 31 – GRAYWACKE IN THE LOWER STANLEY SHALE NORTH OF GLENWOOD (Plate 35).**

This exposre of vertically dipping (bottom to north), interbedded graywacke and shale is in the lower Stanley Shale. This is an opportunity to examine the deep weathering that takes place in this region. At the top of the exposure the sandstones are brown in color and the shale is olive, whereas at the base, the sandstones are gray and the shales are gray-black. Other features exposed here are: graded bedding, cross-laminations, probable debris flows, and some soft-sediment deformation. These rocks show both thinning and thickening upward sequences and probably represent outer submarine fan deposits. It is thought that these deposits had a source area to the south or southeast. Small quartz veins fill the fractures, notably in the sandstones, and some cavities contain quartz crystals. A few of the quartz crystals are water-bubble or negative types.

38.5 Turn west on U. S. Hwy. 70B and Arkansas Hwy. 27 at Glenwood, Arkansas.

38.8 Turn west on U. S. Hwy. 70 and Arkansas Hwy. 27 and proceed across the Caddo River.

40.0 Continue west on U. S. Hwy. 70 and Arkansas Hwy. 27.

43.5 **STOP 32 – MIDDLE AND UPPER DIVISIONS OF THE ARKANSAS NOVACULITE AND LOWER STANLEY SHALE IN THE EASTERN COSSATOT MOUNTAINS (Plate 35).**

This exposure on the east side of U. S. Hwy. 70 and Arkansas Hwy. 27 displays from north to south; shale, tuffaceous (?) siltstone, chert, and minor conglomerate of the lowermost Stanley Shale; weathered intervals of thin-bedded tripolitic novaculite of the Upper Division of the Arkansas Novaculite; black conodont-bearing siliceous shale and chert of the Middle Division of the Arkansas Novaculite; a fault zone; and, at the south end, graywacke and shales of the lower Stanley Shale. It is thought that this sequence in the eastern Cossatot Mountains shows the transition from the earlier thin trough deposits to the later thick turbidite-flysch facies. These rocks contain folds that are very tight and upright or slightly inclined to the north and fault planes that dip to the south. The lower Stanley sandstones are often tuffaceous, but the acidic volcaniclastic beds of the Hatton Tuff lentil which are prominent to the west and southwest have not been identified in this area. The thin tuffaceous (?) siltstone of the lower Stanley Shale likely represents outer submarine fan or basin plain facies. The following abstract by Niem presents some of the present concepts on the lower Stanley deposition.

Niem, Alan R., 1976, PATTERNS OF FLYSCH DEPOSITION AND DEEP–SEA FANS IN THE LOWER STANLEY GROUP (MISSISSIPPIAN), OUACHITA MOUNTAINS, OKLAHOMA AND ARKANSAS: Jour. Sed. Petrology, v. 46, no. 3, p. 633–646.

A southern proximal and northern distal flysch facies are recognized in Mississippian lower Stanley strata over an area of 5000 sq. mi. in the Ouachita Mountains of Oklahoma and Arkansas. Four widespread tuffs, each with distinctive lithologies, are interbedded with deep-marine turbidite sandstones and shales and serve as key units for detailed correlation of eight sections 500 to 1500 ft. thick.

The lower Stanley flysch is an ancient analog to one or more modern deep-sea fans and adjacent basin deposits. The lithologic character, sedimentary structures, bedding styles, fan-like geometry, ratio of sandstones to shale, and stratigraphic relationships of proximal and distal facies of the lower Stanley Group are similar to middle and outer margins of modern deep-sea fans and associated basin sediments off the coast of western North America.

A proximal turbidite facies (probably a channeled suprafan) was deposited in the Hot Springs area of Arkansas at the same time a deep-water shale-rich facies accumulated in the southern and central Ouachitas of Oklahoma. During later Stanley time

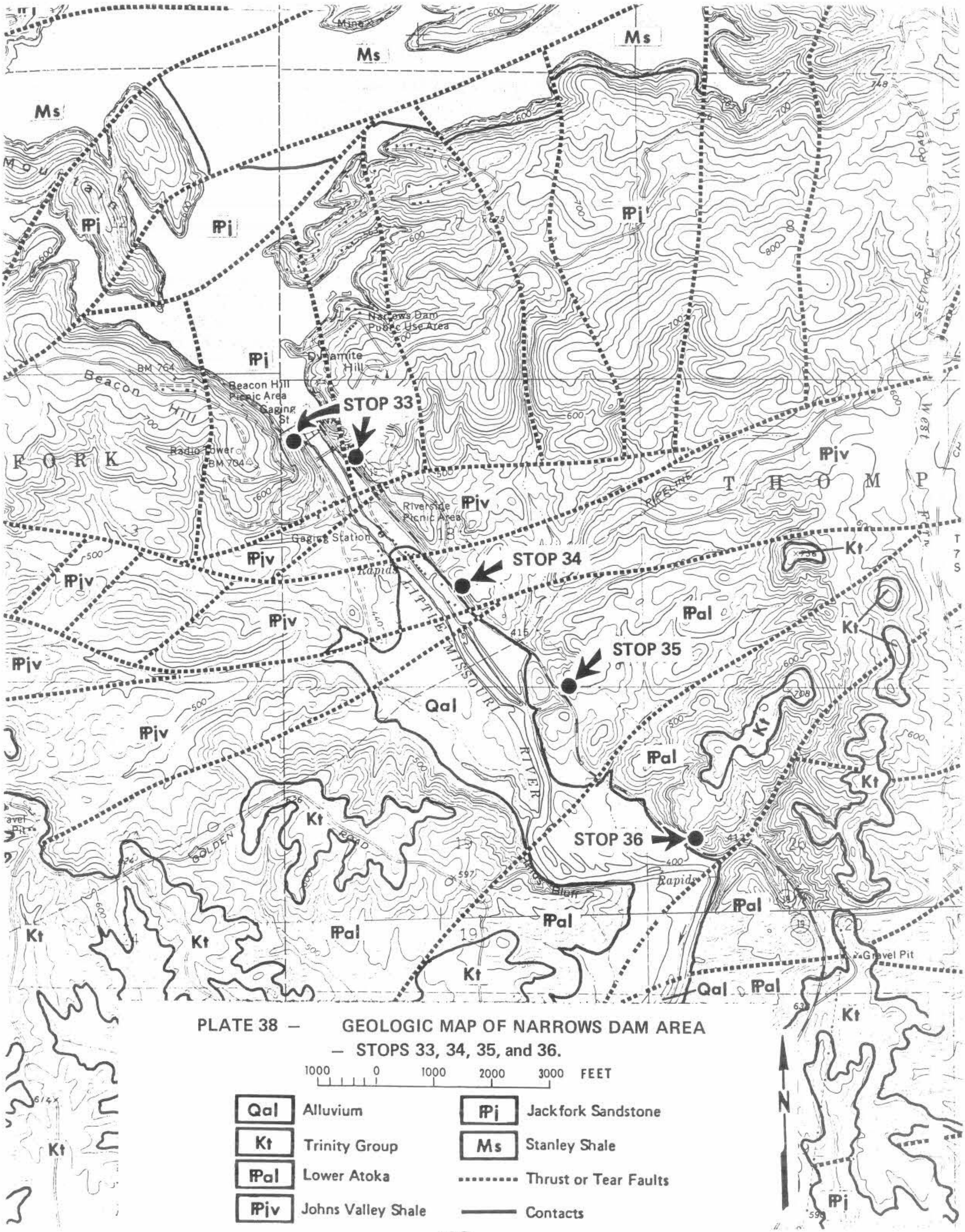


PLATE 38 — GEOLOGIC MAP OF NARROWS DAM AREA — STOPS 33, 34, 35, and 36.

a proximal flysch facies prograded over the shale-rich facies of the southern Ouachitas of Oklahoma and represents deposition of a middle fan facies over an outer fan and basin plain facies. This proximal facies laterally changes to a distal flysch facies of apparent outer fan and basin plain deposition in the central Ouachitas of Oklahoma. The source area for lower Stanley strata was to the south-southeast, probably a northeastern continuation of the buried upper plate of the Luling thrust of Texas.

Hass (1950, p. 1578; 1953, p. 72) describes a collection of conodonts 75–145 feet above the base of the Stanley in shales at several locations and stated that they were Meramecian in age. These same conodonts were examined by J. W. Huddle (in Gordon and Stone, 1977, p. 77) and he recognized them as an early Chesterian assemblage. The Hatton Tuff lentil and some bedded barite deposits were associated with these shales in some instances. The basal Stanley Shale (sandstone, conglomerates and shales of the Hot Springs Sandstone Member) is late Meramecian age according to Gordon and Stone (1977, p. 76–77).

In this Cossatot Mountain subprovince the underlying Blaylock Sandstone of Silurian age is about 1000 feet thick and consists of thin interbedded sandstone, siltstone and shale with many flysch-like characteristics including abundant probable deep-water trace fossils. The Blaylock is not present as a mappable unit in the central and northern Ouachita Mountains. The source of nearly all the clastics for the pre-Hatton Tuff units in the Ouachita Mountains was the North American craton.

48.6 Continue south on Arkansas Hwy. 27 at Kirby, Arkansas.

60.8 Continue west on Arkansas Hwys. 26 and 27.

61.3 Turn west on Arkansas Hwy. 19 in northern Murfreesboro, Arkansas.

67.8 **STOP 33 – UPPER JACKFORK SANDSTONE AND LOWER JOHNS VALLEY SHALE AT NARROWS DAM (Plate 38 and Figures 55, 56).**

We wish to thank Tom Fugitt and Joe Chaney of the U. S. Corps of Engineers for permitting us to have access to the exposures along the base of Narrows Dam.

At this Stop we are in the Athens Plateau subprovince of the southernmost Ouachita Mountains. The rocks are folded less intensely than they are to the north. There are numerous broad synclines and narrow, tight, often slightly inclined anticlines, all of which are cut by major thrust faults and smaller tear faults. Until quite recently this basic description fit the geology for all of this region. However in the antimony district some 25 miles to the west, north of DeQueen, Arkansas, Haley and Stone (Geologic Map in Howard, 1979) mapped a major decollement in the Stanley Shale in the Cossatot River area.

The rocks exposed along the access road on the west side of the dam dip steeply to the south and are composed of interbedded thick to thin quartzitic to subgraywacke sandstone and black shale in the upper portion of the Jackfork Sandstone. A sedimentary slurry or debris flow forms a conspicuous interval at the base of the dam and is composed of sandstone and shale clasts with iron carbonate concretions in a contorted shale matrix. In the vicinity of the gate and in the river bed below there are small folds that plunge steeply southwest and are cut by small tear faults. Bottom marks are numerous at the base of some beds and indicate a paleocurrent directed to the west. Convolute bedding, load features and soft-sediment slump structures are present in many intervals. Small sandstone dikes begin in some sandstones and cut across shale intervals. These dikes likely represent injections formed during diagenesis. Plant fossils are common in the siltstone "blue beds" that occur at the top of many sandstones. There is fining and thinning upward of most sandstone sequences. Rocks at this Stop were likely deposited in the middle or outer submarine fan environment.

Traces of cinnabar occur with dickite on the slickensides in the small fault zones. This mineralization probably took place during very late Paleozoic tectonism or possibly early Mesozoic rifting and igneous intrusion. There are many abandoned mercury mines in this area. The following abstract by Clardy and Bush provides some additional data on these deposits.

> Clardy, B. F., and Bush, W. V., 1976, MERCURY DISTRICT OF SOUTHWEST ARKANSAS: Arkansas Geological Commision Information Circular 23, 57 p.
>
> Cinnabar was discovered in southwestern Arkansas in 1930. Mining began in 1931 and mercury was produced each year through 1944. Production through this period was approximately 1500 76–pound flasks. Mining has been negligible since 1974.
>
> Surface rocks in the mercury district are sandstones, shales and siltstones of the Mississippian and Pennsylvanian Systems; and gravel, clay, sand, and limestone of the Cretaceous System. The Paleozoic rocks have been folded and faulted into steeply dipping generally east-west trending ridges and valleys. In places, the Paleozoic rocks are covered by gently dipping Cretaceous strata.
>
> Cinnabar and other primary minerals were deposited from aqueous solutions rising through the fractured Paleozoic rocks. The majority of ore deposits are associated with the larger faults in the area and generally occur in the overthrusted fault blocks within a mile of the fault traces. Prospecting along these major trends has been by examination of outcrops, pitting, trenching, core drilling, and some geochemical evaluation. Future exploration in the district should begin in the areas of major faulting.

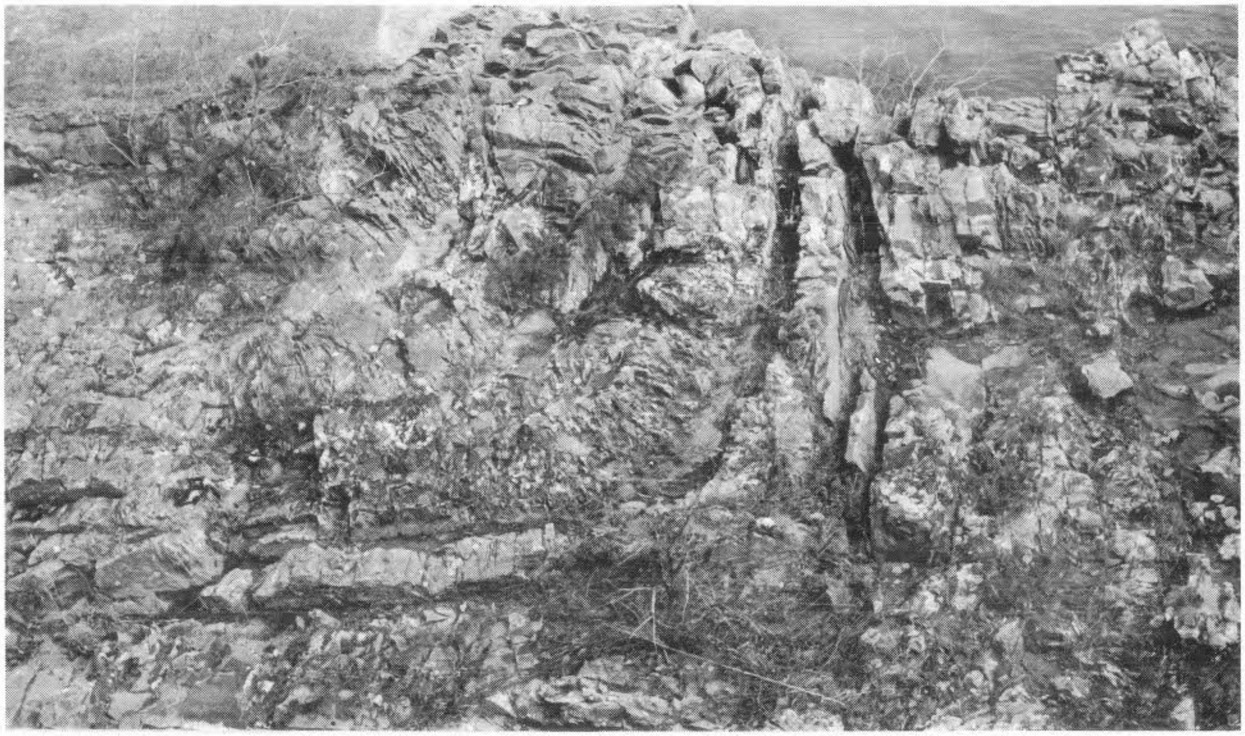


Figure 55 - Stop 33. An overhead view of a steeply southwestward plunging fold with extensive fracturing and minor faults in thin to thick quartzitic sandstones and shales of the upper Jackfork Sandstone in the Little Missouri River bed on the west side of Narrows Dam.

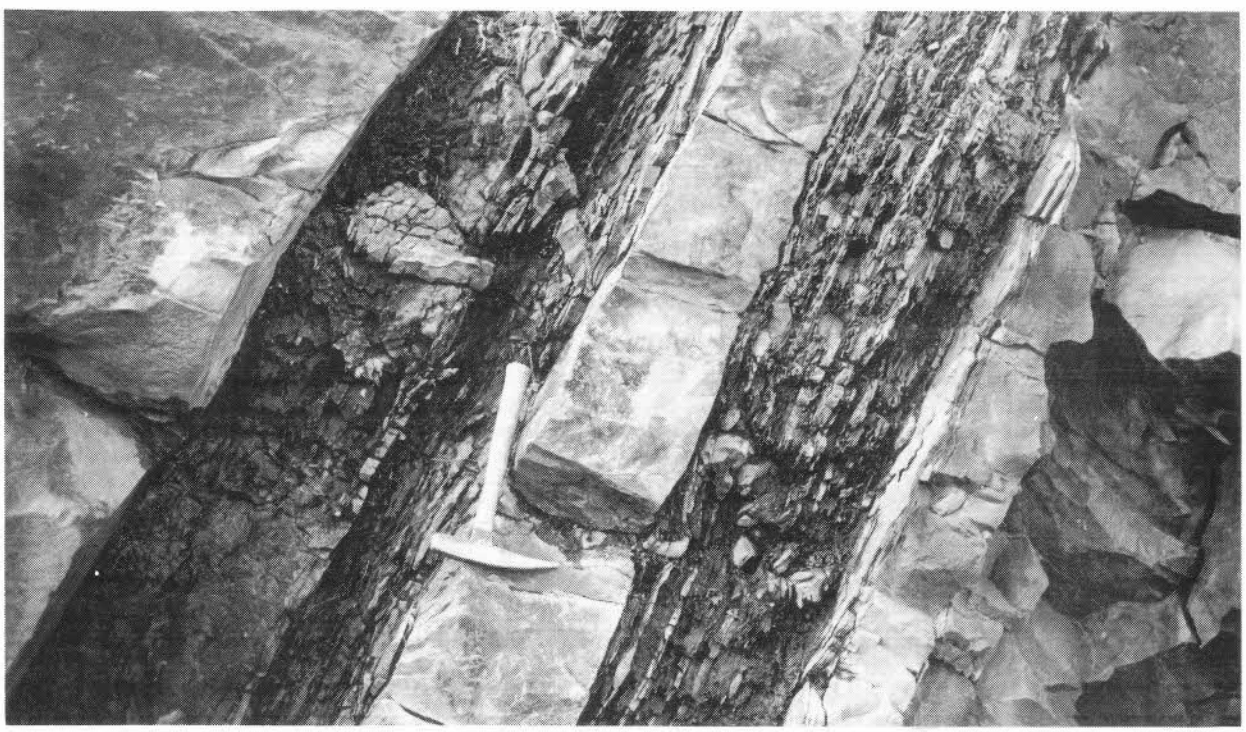


Figure 56 - Stop 33. Closeup of southward dipping, interbedded, quartzitic sandstone, siltstone and shale with a small crinkled sandstone "injection" dike in the upper Jackfork Sandstone in the roadcut on the west side of Narrows Dam.

Proceed to the east side of bridge over the Little Missouri River. The exposures, from north to south, begin with steeply dipping massive quartzitic sandstone beds near the top of the Jackfork Sandstone. Across from the Rest Area, there is silty clay shale and thin beds of micaceous subgraywacke that represents the lower part of the Johns Valley Shale. More Johns Valley sandstone beds are exposed along the roadcut to the southeast. Small tear faults and associated folds are present at places in these rocks. The Johns Valley also contains soft-sedimentary slump masses and intervals at this site.

68.4 **STOP 34 – EXOTIC INTERVAL IN THE JOHNS VALLEY SHALE SOUTHEAST OF NARROWS DAM (Plate 38 and Figure 57).**

This exposure on the northeast side of Arkansas Hwy. 19 is in steeply southward dipping, olive-gray, silty shales and micaceous sandstone of the lower Johns Valley Shale. Bottom marks, graded bedding, convolute structures and other features are common in the sandstones. There are exotic blocks, lenses and boulders of subgraywacke, plant-bearing graywacke, lutite, and silty graywacke containing fossiliferous limonitic clay nodules in the silty shale interval.

The following fauna was obtained from these nodules by Walthall (1967, p. 517).

Ostracoda
- *Amphissites rugosus* Girty
- *Amphissites* cf. *A. confluens* Bradfield
- *Amphissites rothi* Bradfield
- *Amphissites nodosus* Roth
- *Amphissites* sp.
- *Bairdia* sp.
- *Bythocypris* sp.
- *Healdia* aff. *H. concinna* Delo
- *Monoceratina ardmorensis* Harlton
- *Paraparchites guthreyi* Bradfield
- *Paraparchites* sp.
- *Seminolites* cf. S. *pushmatahensis* Harlton

Foraminifera
- *Endothyra* (?) sp.
- *Endothyrinella minuta* Waters
- *Spirilliana* sp.

Gastropoda
- *Stroebus* sp. (neontic)
- *Bellerophon* sp. (neontic)

Pelecypoda
- *Nuculana* sp. (neontic)

The more continuous sandstones and shale at the top of this exposure were included by Walthall (1967, p. 517–519) in the lower Atoka Formation. He noted that, locally, an invertebrate mold fauna (Honess mold fauna) of late Morrowan age occurred near the base of these beds. This interval and approximately 1500 feet of additional overlying sandstone and shale are included by Haley et al., (1976) in the middle and upper Johns Valley Shale. This evaluation was based, in part, on work in the frontal Ouachita Mountains near Aly, Arkansas where some 1900 feet of strata was placed in the Johns Valley Shale. Walthall (1967, p. 518) states that the ostracod fauna from correlative beds appears to be identical with those collected in the exotic blocks in the Johns Valley, and thus both are considered equivalent with the Gene Autry Shale of Oklahoma and are early Morrowan age.

These generally fining and thinning upwards sandstone sequences, also contain rocks derived by mass movements, are considered middle submarine fan channel deposits. We concur with Walthall and Bowsher (1966), Walthall (1967) and Gordon and Stone (1977) that these clastic exotics of the Johns Valley Shale in the southern Ouachita Mountains are likely derived by submarine slumping from a tectonically active belt containing, in part, shelf facies to the south of the Athens Plateau. The Johns Valley Shale reflects a time of extreme instability in the Ouachita trough!

68.8 **STOP 35 – DEFORMED SHALES OF THE LOWER ATOKA FORMATION SOUTHEAST OF NARROWS DAM (Plate 38).**

This exposure in the lower Atoka Formation on Arkansas Hwy. 19 contains contorted beds and masses of black clay shale (weathered to light brown at the top) and lesser amounts of micaceous brown siltstone and sandstone with some small iron carbonate and a few chert concretions. Numerous faults dissect the rocks in this area and slickensides coated with dickite are rather common. Some lenticular masses of siltstone and sandstone occur in the shale. The sandstone at the north end of the roadcut contains numerous plant fragments.

It is thought that this section of lower Atoka represents a olistolithic sedimentary slumped interval (wildflysch) that was derived from sources to the south. It was later tectonically imprinted by late Pennsylvanian and younger spasms of the Ouachita orogeny. While this interval resembles the Johns Valley Shale it is stratigraphically about 2500 feet above this unit.

69.6 **STOP 36 – THICK LOWER ATOKA SANDSTONES SOUTH OF NARROWS DAM (Plate 38 and Figure 58).**

This exposure on the north side of Arkansas Hwy. 19 occurs in a steeply southward dipping sequence of interbedded gray shale and thick brown subgraywacke of the lower Atoka Formation. A complete section of the lower Atoka is not exposed in the Athens Plateau but more than 6500 feet of friable subgraywacke and gray clay shale occur at various places in the region. Many intervals of the Atoka are removed by faults or concealed by boulder beds, gravel, or clay of the Lower and Upper Cretaceous Formations.

At this site the Atoka contains a massive channel sandstone sequence

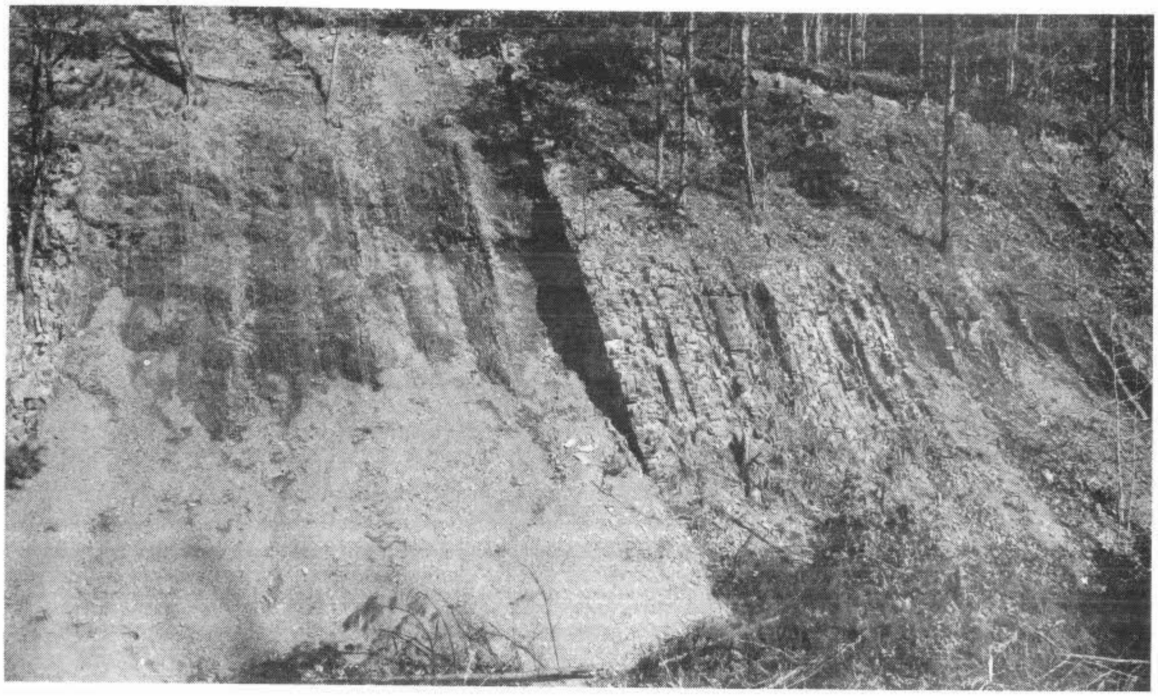


Figure 57 - Stop 34. Steeply southward dipping clay shales (to left) overlain by a thinning and fining upwards sequence of thin-bedded micaceous subgraywacke in the lower Johns Valley Shale southeast of Narrows Dam on Arkansas Hwy. 19.

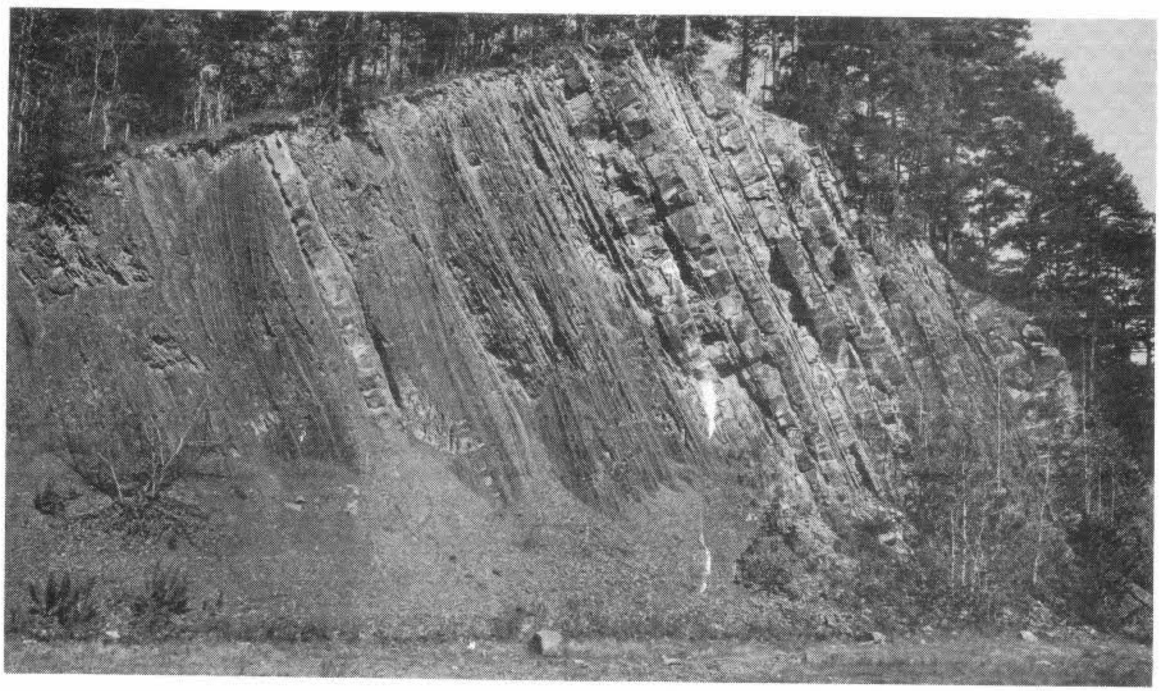


Figure 58 - Stop 36. Sequence of southward dipping beds of silty shale and thin to thick subgraywacke representing, for the most part, middle submarine fan channels in the lower Atoka Formation southeast of Narrows Dam on Arkansas Hwy. 19.

overlain by shale and siltstone intervals and two higher but smaller channel sequences. Flute marks, drag grooves, cross-laminations, ripple marks, convolute structures, and other sedimentary features occur in the sandstone beds. A paleocurrent towards the west is indicated. The channels and the thick sandstone interval appear to cut into the underlying rock a few feet and contain some large scours and internal slumps.

It is thought that these thinning and fining upward channel sequences represent deep-water submarine midfan environments of deposition with a source area primarily to the south or southeast. At approximately this interval at locations in adjoining areas an invertebrate mold fauna occurs in a decalcified, limonitic, brown sandstone that locally contains some granules of quartz. Gray-black chert beds with sponge spicules are also present in places. Walthall (1967, p. 519) indicates that palynomorphs are present in the shale but were not recovered because of the high fixation of the carbon.

72.6 The Jackfork Sandstone exposed here protrudes though the Pike Gravel of the Trinity Group (Lower Cretaceous).

74.1 Continue east on Arkansas Hwys. 19, 26, and 27.

74.6 Proceed east on Arkansas Hwy. 26.

89.7 Turn north on dirt road – 26,000 (Weyerhaeuser Company Road). Do not attempt to make this trip except **in good weather!**

93.8 **STOP 37 – THICK SANDSTONES OF THE LOWER ATOKA FORMATION AT ANTOINE RIVER QUARRY (Plate 39 and Figures 59, 60).**

This abandoned quarry on the west side of the Antoine River in the lower Atoka Formation contains southward dipping, massive, brown subgraywacke, gray-black shale and minor iron carbonate beds and concretions. There is at least 6500 feet of interbedded subgraywacke and shale of the lower Atoka Formation exposed along the west side of the Antoine River in this area. It is not known if other Atokan or younger rocks were once present in the Athens Plateau. In the subsurface of the west Gulf Coastal Plain to the south, Vernon (1971), Woods and Addington (1973) and Meyerhoff (1973) indicate that there are nearly flat-lying, gently deformed, shallow-marine deposits of late Pennsylvanian and Permian age overlying severely folded and faulted older Carboniferous rocks.

The thick bedded fining and thinning upward sandstones at the quarry seem to comprise several channels or individual channel migrations that cut a few feet into the underlying units. The thin as well as some of the thicker sandstones commonly exhibit graded bedding, bottom marks, cross-laminations, convolute bedding and other features. The thicker sandstones also exhibit some large scour, load, and ball and pillow features. A paleocurrent to the west is generally indicated. Some of the siltstone "blue beds" contain plant fossil fragments. Locally a few sandstones contain molds of invertebrate

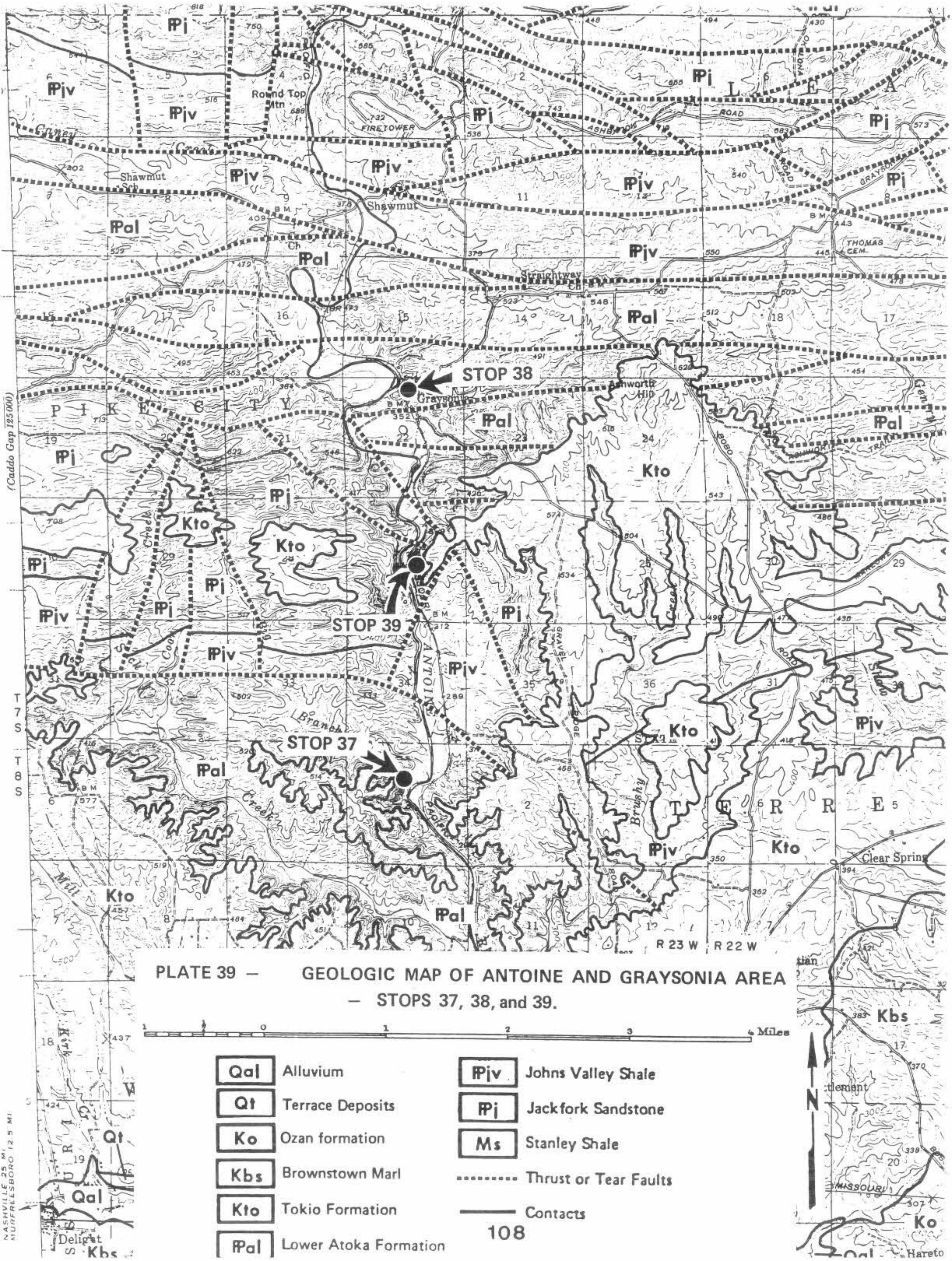


PLATE 39 — GEOLOGIC MAP OF ANTOINE AND GRAYSONIA AREA — STOPS 37, 38, and 39.

Figure 59 - Stop 37. Thick interval of southward dipping subgraywacke and lesser amounts of silty shale representing middle submarine fan channels in the lower Atoka Formation at an abandoned quarry on the west bank of the Antoine River.

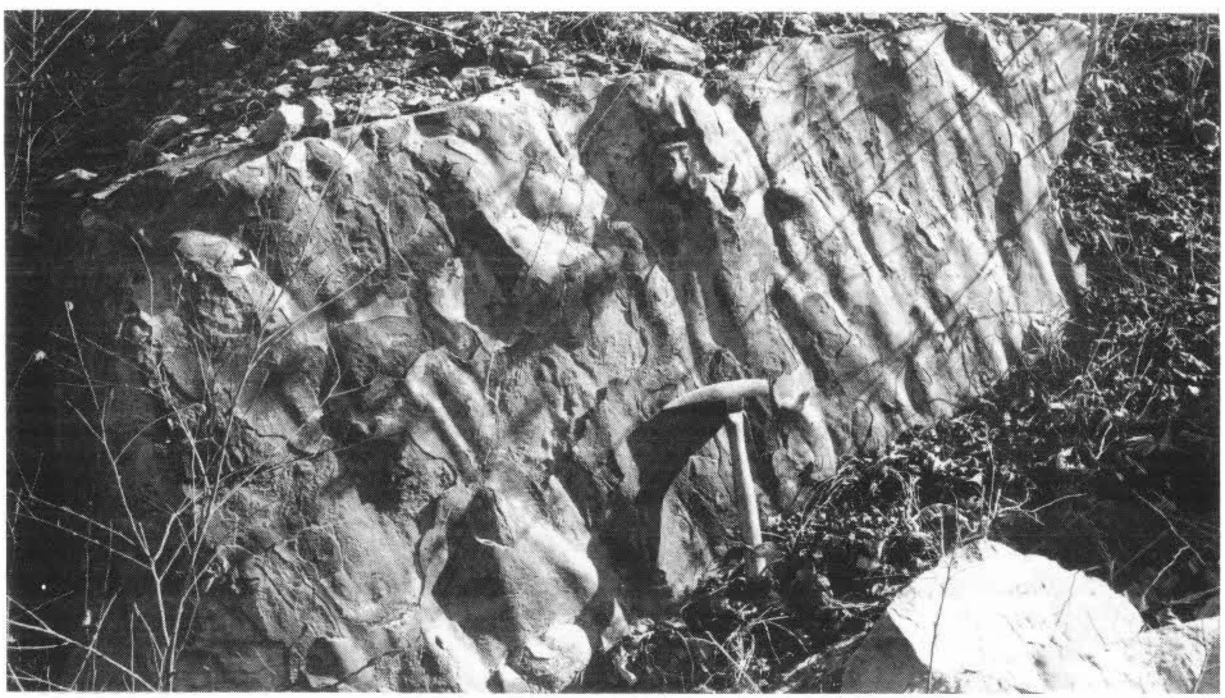


Figure 60 - Stop 37. Bottom marks (mostly flute molds) showing paleocurrent flow (from top to bottom) on a loose boulder of subgraywacke from the lower Atoka Formation at an abandoned quarry on the west bank of the Antoine River.

fossil fragments. A small tear fault cuts the interval and has slickensides with dickite.

It is thought that these thick sandstones represent midfan submarine channel sequences derived from a source to the south or southeast.

Overall in this portion of the Ouachita Mountains there is a comparative lack of intense shearing and folding in the rocks. There are a number of plausible reasons for the decline in deformation, two of these are: (1) less stacking and loading of the strata; and, (2) less intense tectonism.

Return to Arkansas Hwy. 26.

97.8 Turn east on Arkansas Hwy. 26 and proceed through Antoine, Arkansas.

99.4 Antoine, Arkansas.

101.7 Turn north on Bobo Road (Weyerhaeuser Company Road).

104.8 Turn west on Marlow Road (Weyerhaeuser Company Road).

105.9 Turn north on Park Trail (Weyerhaeuser Company Road).

110.2 Turn south on unnumbered road to the abandoned timber town of Graysonia.

111.0 **STOP 38 -- "CHAOTIC" SEQUENCES IN THE LOWER ATOKA FORMATION AT GRAYSONIA, ARKANSAS (Plate 39 and Figures 61, 62, 63).**

These chaotic-appearing and exotic-bearing sequences with masses and beds of subgraywacke, gray clay shale, and iron carbonate beds and concretions occur in the lower Atoka Formation along the Missouri Pacific Railroad tracks at the abandoned timber town of Graysonia, Arkansas.

The outcrop contains soft-sediment slumped, contorted, and tectonically faulted intervals. The beds and masses are upright, inclined, reclined, and recumbent at various places along the exposure. This chaotic-appearing sequence is believed to have developed as a result of the following series of events: (1) initial debris flows and slurries during deposition; (2) cycles of slumping and sliding during and shortly after deposition; (3) further downslope mass movements; and, (4) subsequent folding and faulting during various epochs of the Ouachita orogeny. Walthall (1967, p. 518–519) also interpreted these deposits as largely composed of exotic beds and olistostromes that were rather intensely folded and faulted. He notes further that the depositional masses were commonly folded as they rolled downslope.

Bottom marks, ripple marks, graded bedding, cross-laminations, dish and pillar, structures, convolute structures, and other features are numerous and help to indicate the initial top and bottom of many beds. Except in a few cases where the intervals are more continuous, the sedimentological data is not adequate in determining the "true" top and bottom of the respective beds or sequences because of the combination of both "chaotic" sedimentary

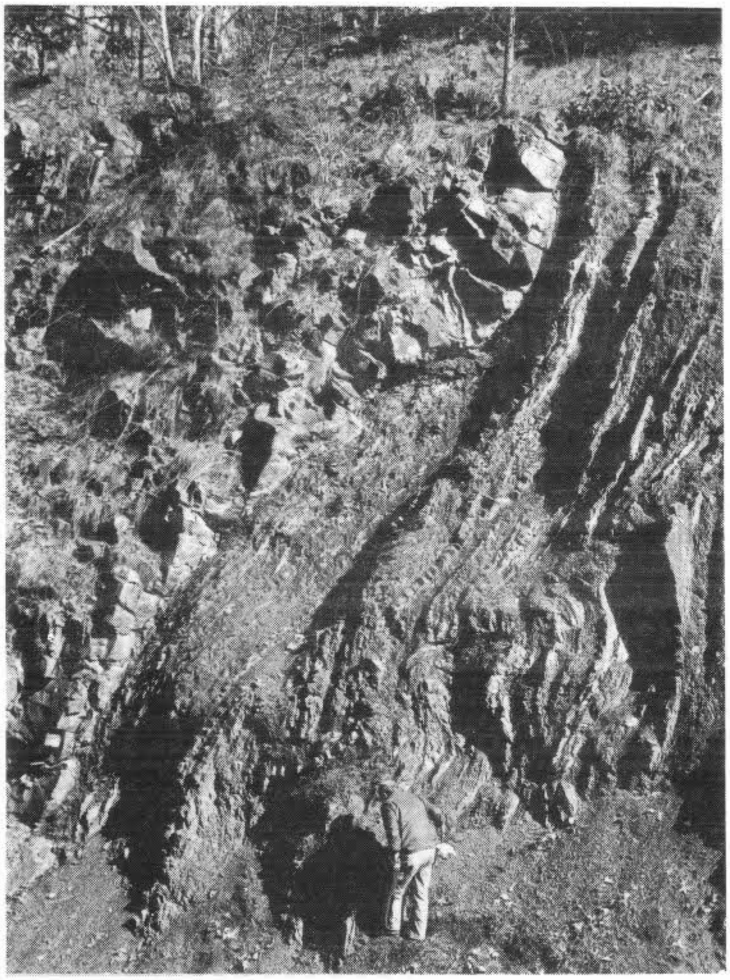


Figure 61 - Stop 38. Thick to thin bedded, soft-sediment slumped and contorted interval with some tectonically generated faults in northward dipping shale and silty sandstone of the lower Atoka Formation at Graysonia Railroad cut.

Figure 62 - Stop 38. Shales, silty sandstones and iron carbonate layers in the lower Atoka Formation at Graysonia Railroad cut show soft-sediment contortions, pull-aparts, recumbent folds, "glumps" and flowage features with some later tectonic faulting and deformation.

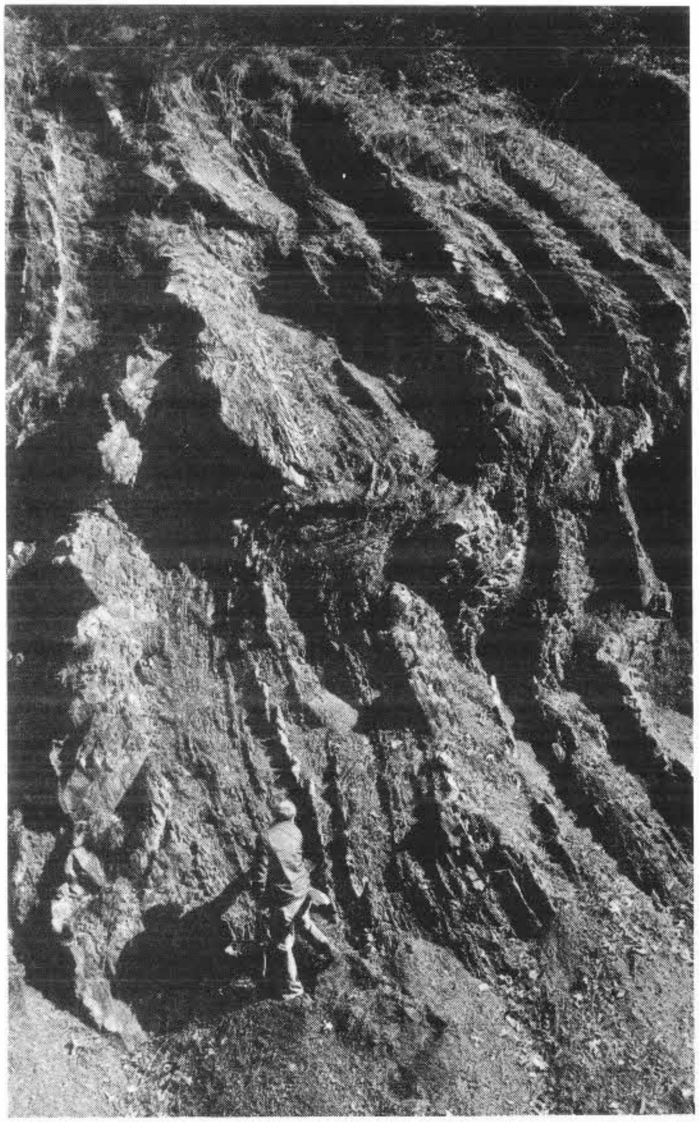


Figure 63 - Stop 38. Interval of steeply dipping, soft-sediment contorted and tectonically faulted and folded silty sandstones, shales, and iron carbonate layers in the lower Atoka Formation at Graysonia Railroad cut.

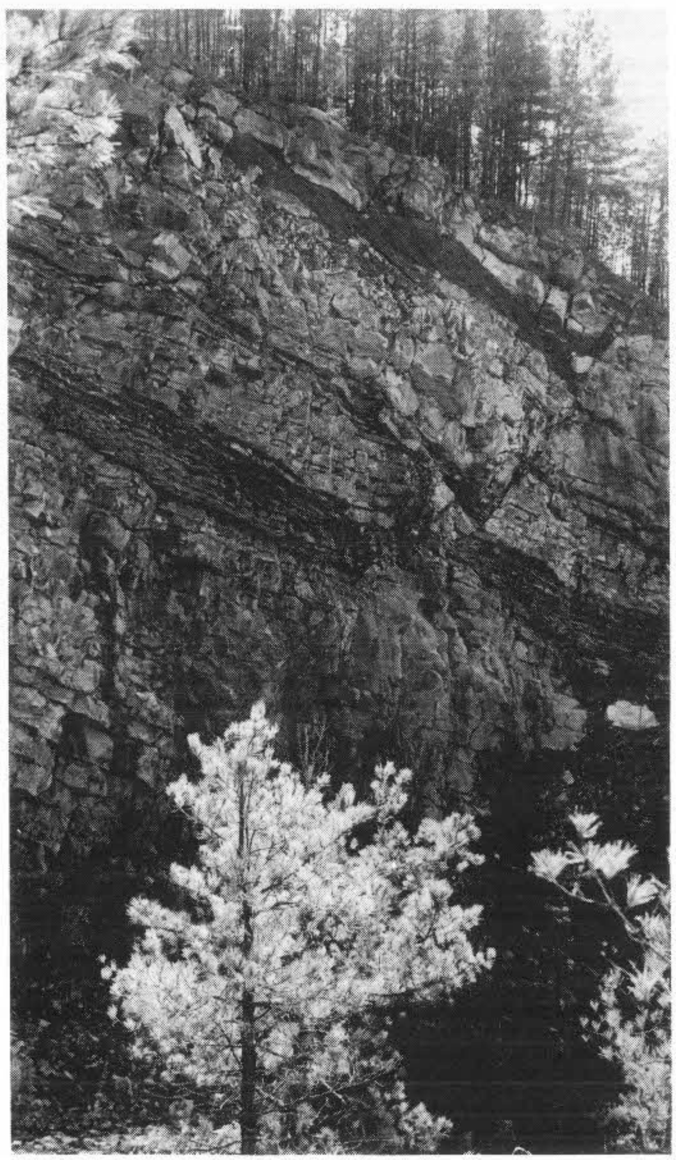


Figure 64 - Stop 39. Several thinning upward fan channel sequences composed of massive quartzitic sandstone and shale in the middle Jackfork Sandstone cut by a tear or high-angle reverse fault at the abandoned Weyerhaeuser quarry on the east side of the Antoine River.

and later structural complexities. Furthermore many paleocurrent readings are likely in error. Balled, and pull-apart sedimentary structures are common in some sandstone beds. A few sandstone olistoliths show fracturing and subsequent healing that occurred prior to the major compressional deformation. Flowage of shale into the fold hinges is also considered a feature that occurred mostly during slumping. Small thrust faults dissect the rock and are marked by slickensides coated with dickite, calcite and some quartz. This sequence in many ways resembles the Johns Valley Shale, but it is a few thousand feet above the presently mapped base of the lower Atoka Formation (Haley, et al., 1976). We conclude that these rocks represent an extensive development of submarine slumping in a high energy depositional regime and were derived from a source area to the south.

The question is posed whether the interval represents a submarine slump-sedimentary deformation sequence with generally later tectonic imprint or a subduction-suture zone?

Return towards Arkansas Hwy. 26.

111.7 Turn east on Park Trail.

113.3 Turn west on Marlow Trail.

114.8 Turn southwest on Quarry Road.

116.1 **STOP 39 – JACKFORK SANDSTONE IN ABANDONED WEYERHAEUSER COMPANY QUARRY NORTH OF ANTOINE, ARKANSAS (Plate 39 and Figure 64).**

This abandoned Weyerhaeuser quarry for rock aggregate on the east side of the Antoine River and Missouri Pacific railroad tracks exposes about 150 feet of southward dipping, interbedded massive quartzitic sandstones, siltstones and thin gray-black shales of the middle Jackfork Sandstone. These rocks commonly exhibit Bouma sequences, graded bedding, bottom marks, load structures, trace fossils and other features that are indicative of flysch deposition. Concretions and thin beds of iron carbonate occur in some of the shales and siltstones. Thin siltstones "blue beds" formed by debris flows occur above many of the sandstones and contain carbonized plant fragments and some pyrite.

There are least five major thinning and fining upward sandstone fan channels exposed in the walls and floor of the quarry. This sequence of turbidites represents east to west transport of sediment probably in the middle submarine fan depositional environment.

Several high-angle faults dissect the section and exhibit both vertical and horizontal (tear) movements. Near the faults small quartz veins fill fractures in the rock. Dickite occurs on the slickenside surfaces and in the thin gouge intervals. Mercury ores were previously mined a few miles to the north and northeast of this area from cinnabar-bearing veins in, or near fault

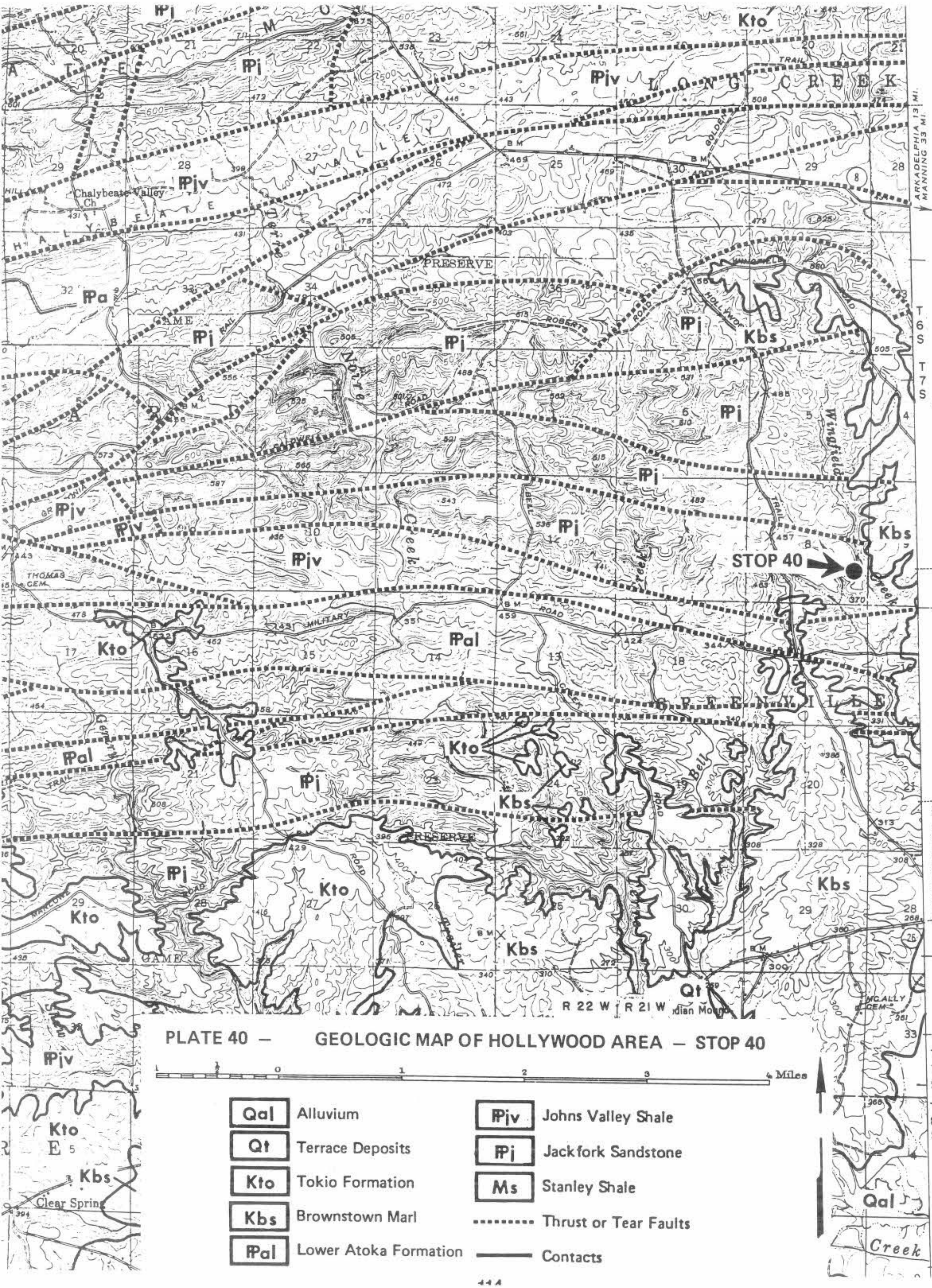


PLATE 40 — GEOLOGIC MAP OF HOLLYWOOD AREA — STOP 40

zones in the Jackfork and Stanley Formations.

Return to Marlow Road.

117.5 Proceed east on Marlow Road.

119.0 Turn south on Park Trail.

121.4 Continue south on Bobo Road.

122.8 Turn east on Arkansas Hwy. 26.

132.6 Hollywood, Arkansas. Turn north on Arkansas Hwy. 53.

135.4 Turn right on Matts Road. Gravel from the upper Cretaceous age Brownstown Marl was obtained from small pits in this area for use on local roadbeds.

136.0 **STOP 40 – UPPER JACKFORK SANDSTONE AT HOLLYWOOD QUARRY (Plate 40 and Figures 65, 66, 67, 68).**

We wish to thank Scott McGeorge and Don Bolling of the Pine Bluff Sand and Gravel Company for permission to enter the site.

This large quarry which is sporadically operated for rock aggregate is developed in a gently westward dipping sequence of massive quartzitic sandstone, siltstone, and some gray-black shale in the upper Jackfork Sandstone near the axis of an anticline. The lower portions of the lower massive sandstone locally contains beds with granules. Concretions and beds of iron carbonate occur in some of the shales and siltstones. The tops of some sandstone and thin siltstone "blue beds" contain plant fragments. Scours mark several cycles in the 15 foot thick granule-bearing interval. The granules are composed of quartz and minor metaquartzite. Numerous sedimentary features occur throughout the interval and include graded bedding, Bouma sequences, bottom marks, ripple marks, scour structures, and convolute and load features. Small sandstone "injection" dikes fill early formed fractures in some beds. Trace fossils, probably of the Nereites deep-water type, are numerous in and along some of the beds.

One major and two minor fining and thinning upward sandstone sequences are present and indicate probable middle submarine fan channel deposition. A source to the east-southeast is suggested by the lithic types and sedimentary features. See Plate 41 for our generalized model postulated for the Jackfork Sandstone deposition in Arkansas and surrounding areas.

Several east-northeast trending high-angle "reverse" faults cut the rock. Upon close inspection they are found to have a greater horizontal component of displacement than vertical and thus are better classified as tear faults. Slickensides with minor quartz, calcite and dickite occur in the fault zone.

Return to Hollywood, Arkansas.

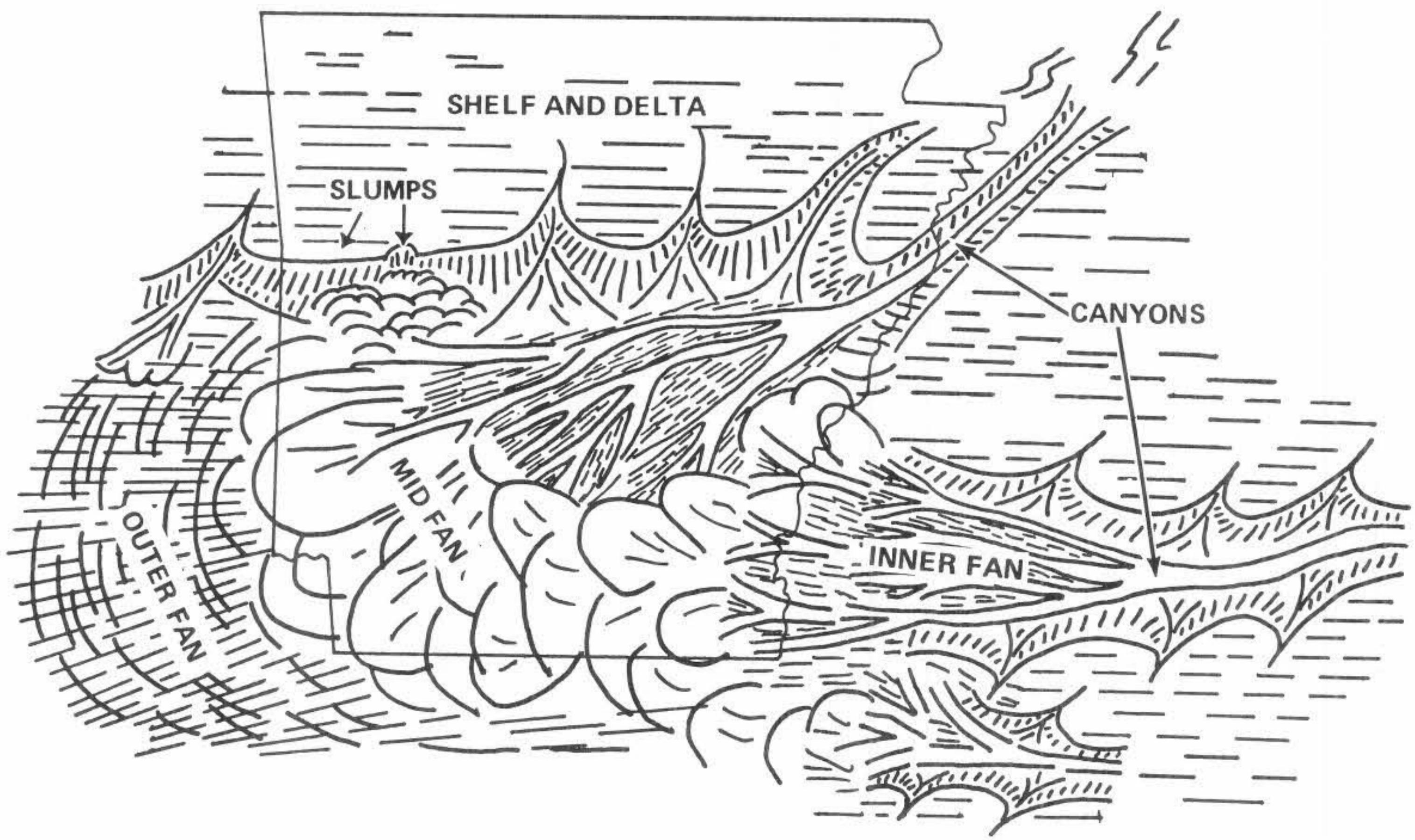


PLATE 41 – MAP DIAGRAMMATICALLY SHOWING THE DEPOSITIONAL FACIES OF THE JACKFORK SANDSTONE AND EQUIVALENT ROCKS IN ARKANSAS.

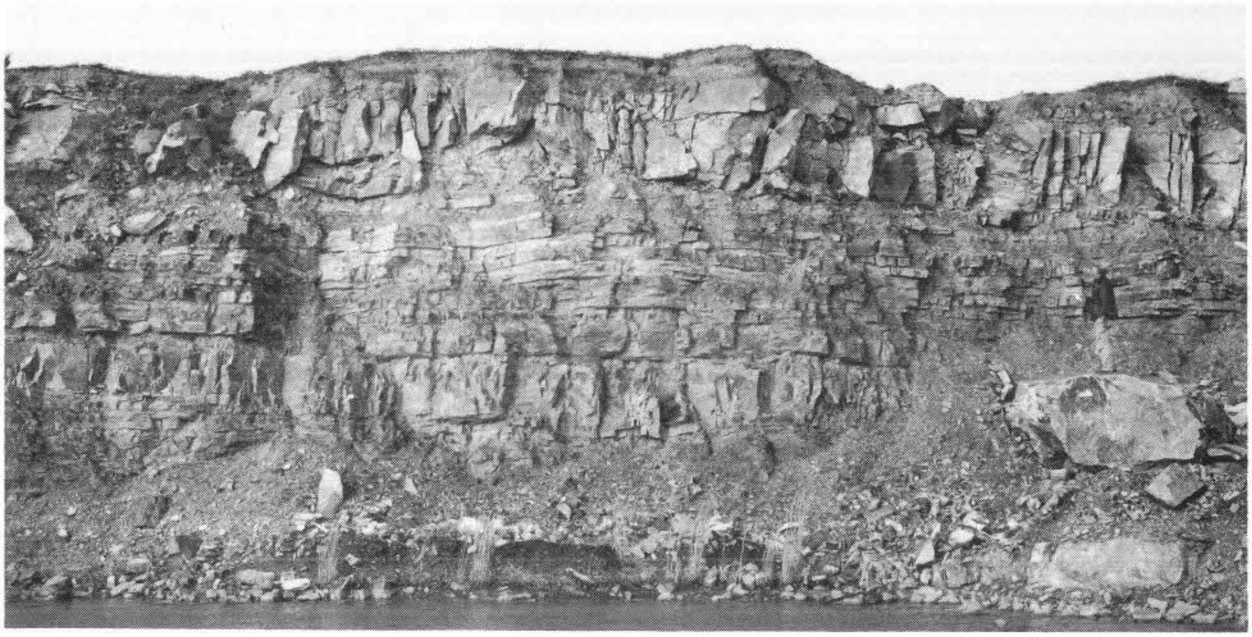
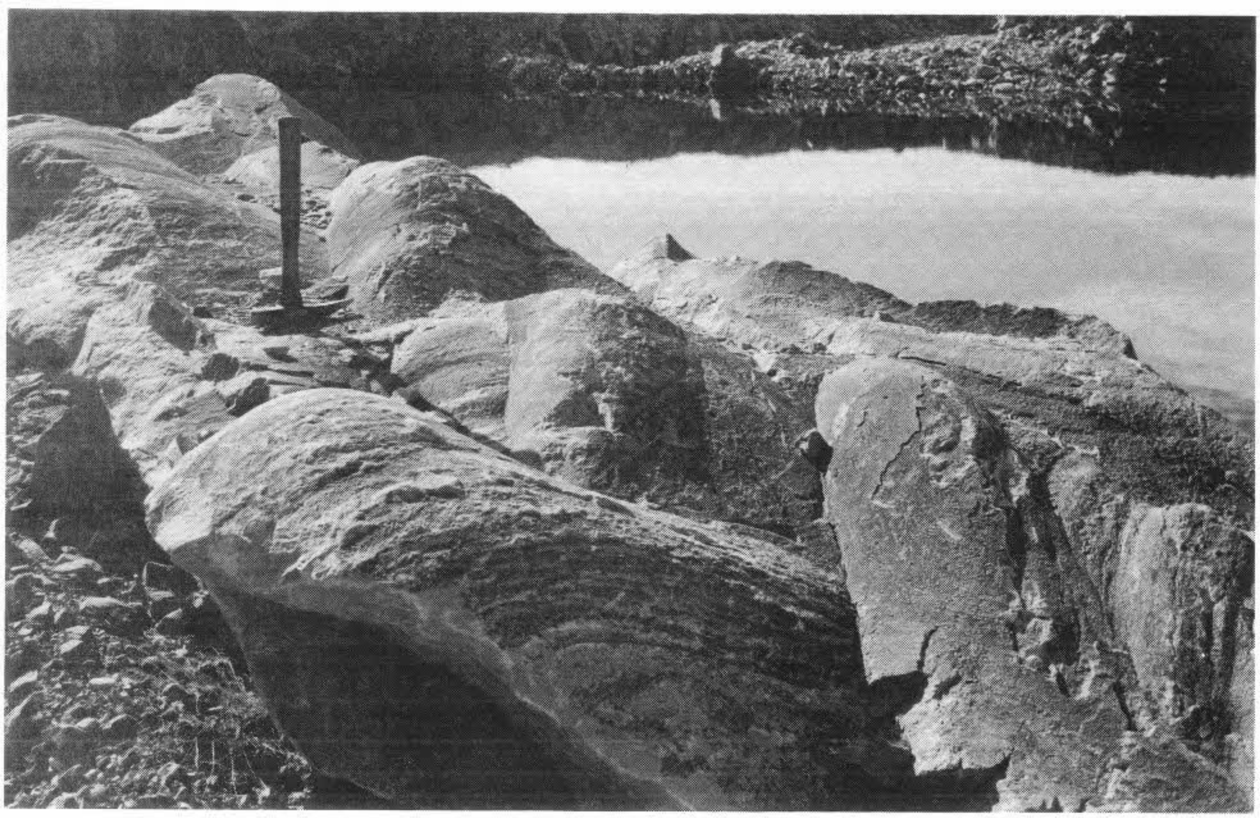


Figure 65 - Stop 40. Thinning and fining upward sequences of quartzitic sandstone and shale representing middle submarine fan channel facies in the upper Jackfork Sandstone at the Hollywood quarry. Note the sharp contacts at the base of the massive channel sandstones.

Figure 66 - Stop 40. Impression of the fossil plant Lepidodendron on the top of a sandstone bed in the upper Jackfork Sandstone at the Hollywood quarry.

Figure 67 - Stop 40. Small sandstone "injection" dikes filling early formed fractures at the top of a sandstone bed in the upper Jackfork Sandstone at the Hollywood quarry.

Figure 68 - Stop 40. A loose boulder in the upper Jackfork Sandstone at Hollywood quarry displays large scour features on the base of a granule-bearing fan channel sandstone.



139.4 Hollywood, Arkansas. Turn left on Arkansas Hwy. 26 to Arkadelphia, Arkansas.

145.1 Proceed east on Arkansas Hwys. 8, 26 and 51.

145.4 Turn northeast on Interstate Hwy. 30.

150.0 Turn north on Arkansas Hwy. 7 at Exit 78.

152.9 Turn west on road to DeGray Dam.

153.6 **STOP 41 – NOTABLE SEQUENCE OF MIDDLE AND UPPER JACKFORK SANDSTONE AT LAKE DE GRAY SPILLWAY (Plate 42 and Figures 69, 70, 71, 72).**

Park at Lake DeGray access area and walk to the east and then to the south across the one thousand foot sequence of southward dipping, fine-grained quartzitic sandstone, subgraywacke, gray siltstone, and black shale in the middle and upper Jackfork Sandstone. The sandstones contain Bouma sequences, graded bedding, load structures, dish and pillar structures, bottom marks, ripple marks, broad scours, clay balls and other features. Slurry and slump intervals of probable intraformational origin are present and one unusual zone contains small sandstone cobbles, chert pebbles, iron carbonate concretions, clay balls and other lithologies in a shale matrix. Sandstone olistoliths "glumps and gloops" occur in a few intervals, especially in the shale sequences below the upper more massive sandstone at the south end of the spillway. Coalified plant fragments are quite common in some of the debris flow deposits represented by the siltstone "blue beds". A few invertebrate fossil remains can be found at various places along the exposure.

At the south end of the spillway there are at least 15 cycles of granule or "grit" deposition in a 200 foot sequence. These "grit" beds are commonly graded and have some small to rather large scour features. The granules are composed of quartz and metaquartzite.

The north end of the spillway contains mostly thinning upward sandstone sequences and are thought to represent middle submarine fan channel deposits. Near the middle of the spillway there are several thickening and coarsening upward fan lobe sequences. At least one thickening upward proceeds into a thinning upward dying lobe sequence. These intervals in the middle of the spillway represent a thick regressive or prograding section of outer fan lobe or possibly midfan interchannel deposits. The exposures at the south end of the spillway represent thinning upward, high-energy, probable middle fan channels. It is thought that these deposits were supplied from deltas and through submarine canyons down the slopes from two major areas: (1) to the northeast (Illinois Basin); and, (2) to the east (southern Appalachians).

Some small tear faults cut the rocks and contain milky quartz, dickite and traces of cinnabar. In this southern Ouachita Mountain area pervasive shearing, cleavage, boudinage and other structural deformation features are

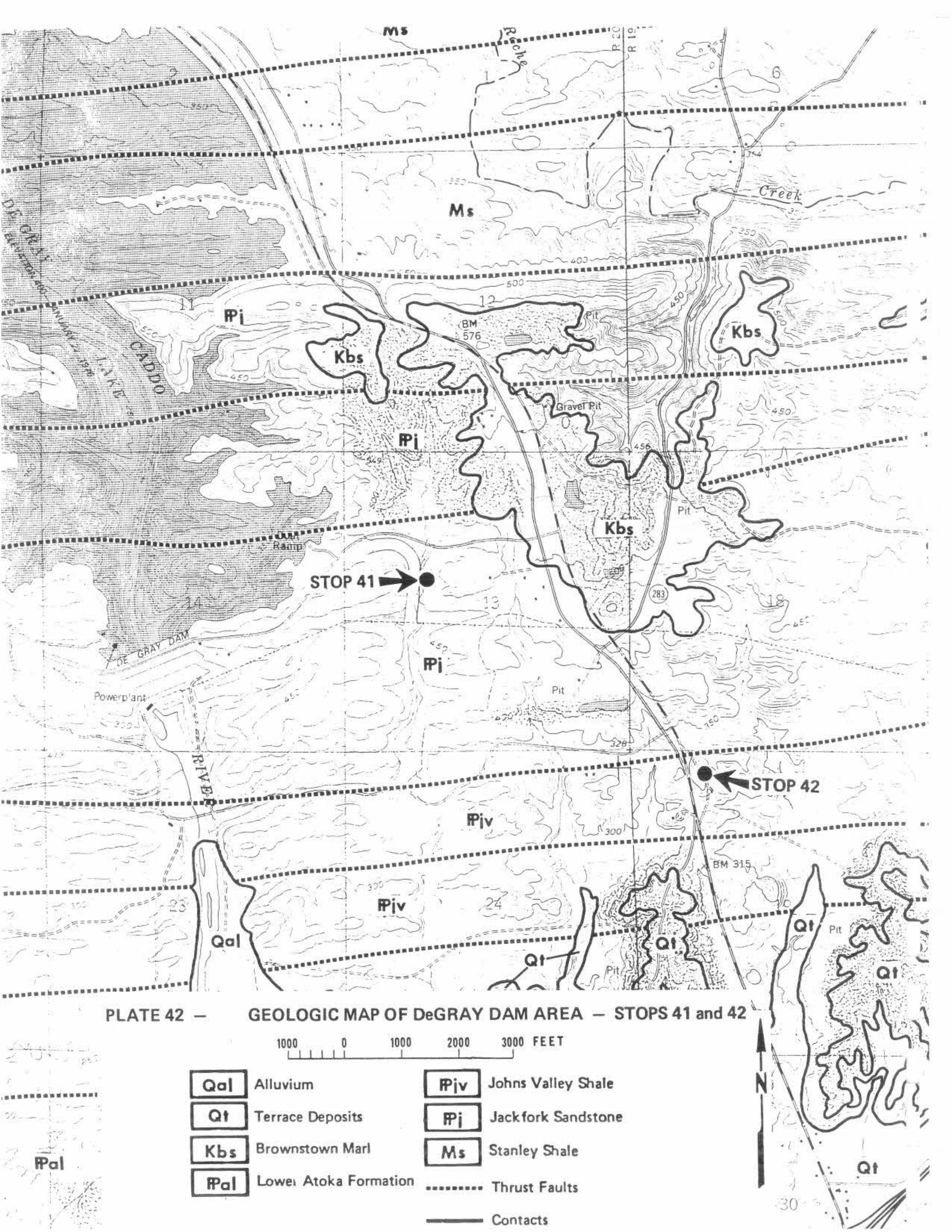


PLATE 42 — GEOLOGIC MAP OF DeGRAY DAM AREA — STOPS 41 and 42

absent. Viele (1973) notes that along the northern margin of the Ouachita Mountains there is evidence for northern tectonic transport. Here on the south side there is evidence for the same direction of movement. However, in the lower Paleozoics, we have abundant evidence of southward movement. This is but one of the many Ouachita problems.

In recent years the DeGray spillway cut has served as one of many educational geologic stops for groups interested in flysch and submarine fan deposition. Plates 43A, 43B and 44 are extracted from a report by R. C. Morris (1977) who performed a detailed sedimentological study of the units at this exposure. Some additional deep-sea fan models and concepts have been applied to these rock units by a number of workers, including Lock in the following abstract.

> Lock, Brian E., 1979, OUTER DEEP--SEA FAN DEPOSITIONAL LOBE SEQUENCE FROM JACKFORK GROUP OF SOUTHERN ARKANSAS: Gulf Coast Assoc. Geol. Soc. and SEPM Regional Meeting Abs., in Am. Assoc. Petroleum Geols. Bulletin, v. 63, no. 9.
>
> Sediments accumulating on the lower parts of the continental slope and the adjacent rise have been shown to contain significant organic materials and are regarded as important prospective hydrocarbon source beds. It is likely that future technological developments will result in important production from these environments. A search for stratigraphic traps will require an understanding of depositional processes on deep-sea fans gained partly from study of ancient examples exposed on land. The Carboniferous sequences of the Ouachita Mountains of Oklahoma and Arkansas provide an outstanding opportunity for examination of sediments from these environments.
>
> The outcrops of Jackfork Group turbidites (Pennsylvanian) exposed in the walls of the spillway at DeGray Dam, Arkansas have been described by R. C. Morris. This sequence shows a rhythmic alternation between turbidite units with high sandstone/shale ratios (facies C of E. Mutti and F. Ricci-Lucchi) and units with low sandstone/shale ratios (facies D). Facies C is interpreted as material deposited on active sand lobes, and facies D consists of lobe-fringe and interlobe sediments. A pattern of frequent lobe shifting can be recognized analogous to the way the main distributary system switches from side to side of the delta. Individual lobes range in thickness from 3 to 70 m, with a mean of about 25 m. This association is characteristic of the outer fan environment of A. Bouma and T. Nilson.
>
> The upper part of the DeGray section contains massive sandstones and pebbly sandstones interpreted as deposits of a major distributary channel. It is possible that buildup of the fan sediments had brought the area into the middle fan environment by this time.

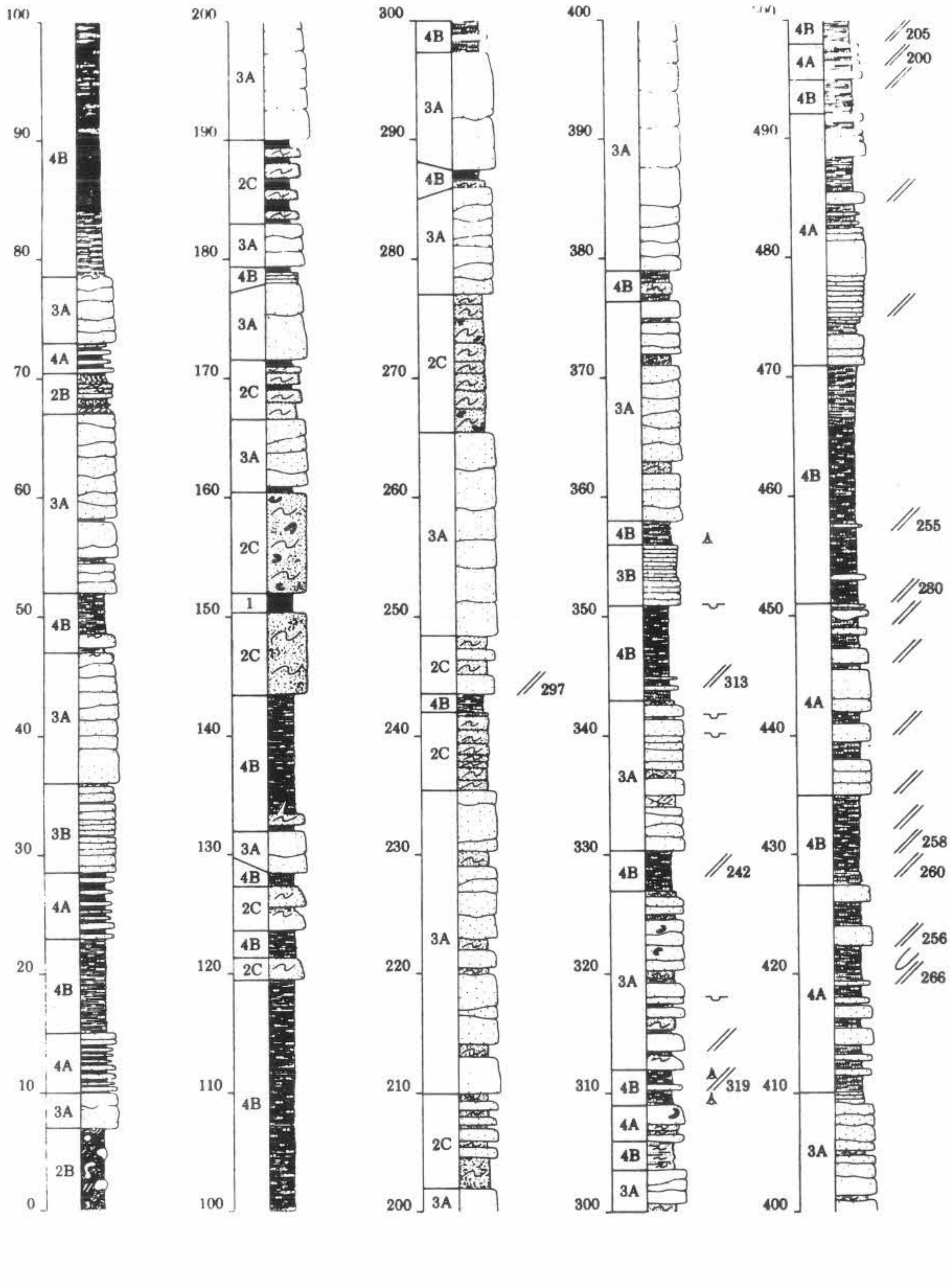


PLATE 43 A — **PARTIAL STRATIGRAPHIC SECTION OF UPPER JACKFORK ROCKS EXPOSED ALONG THE SPILLWAY AT DE GRAY DAM, SEC. 14, T. 6 S., R. 20 W.** Numbers at left of each column are feet above bed where study began — see Plate 43B on p. 124 for legend. (From R. C. Morris).

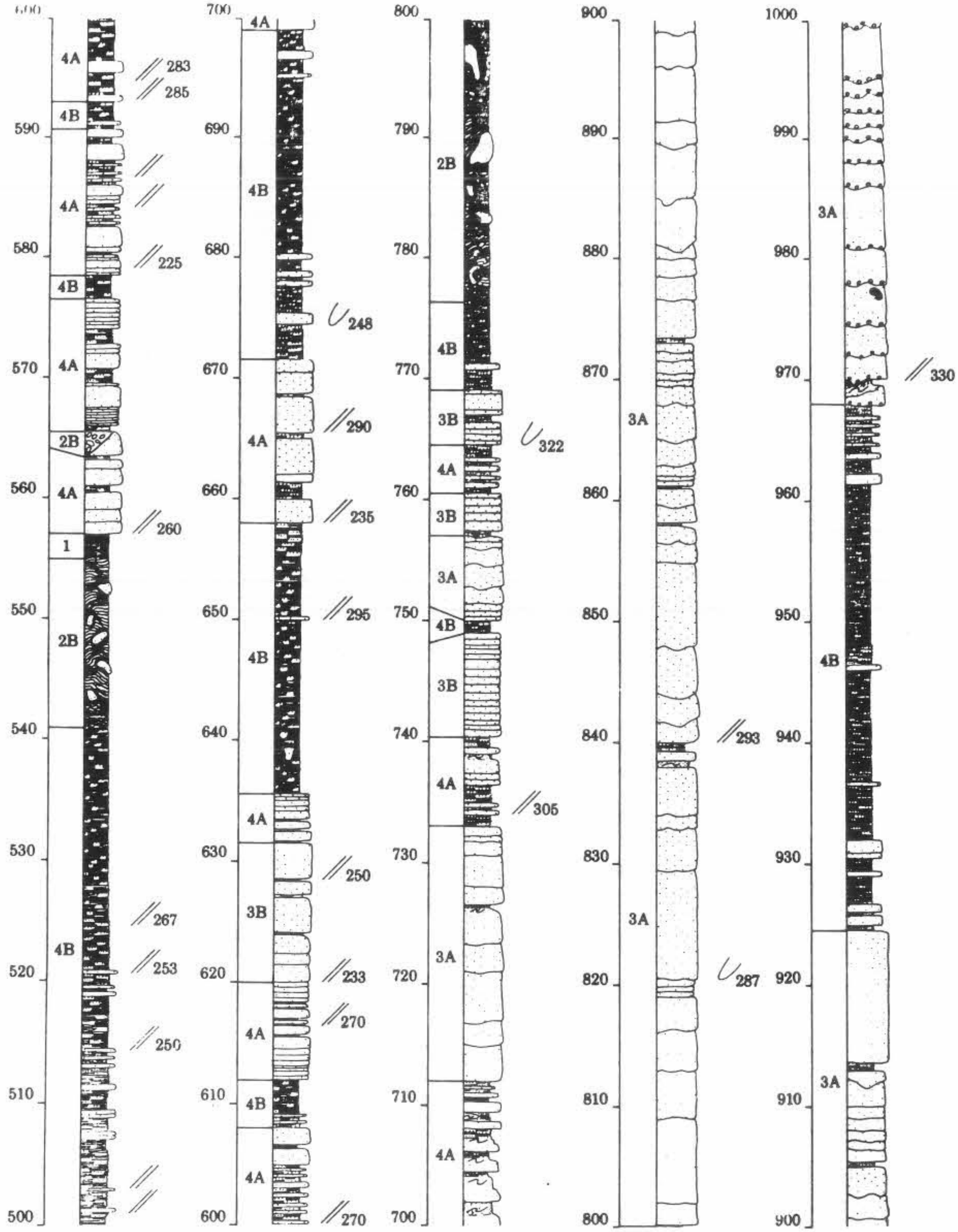
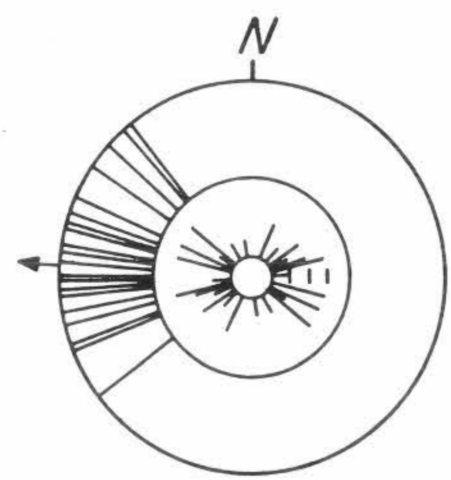


PLATE 43 A – (Continued)

LEGEND

Sandstone	SS, slurried	Cross stratification
	SS, pebbly	
Shale	SS, sparse shale chips	Rubble bedding
Sandstone & Shale		Contorted stratification
Siltstone & Shale		Graded bedding
Mudstone		Load structure
Sharp scoured contact		Flute cast with orientation (200)
Sharp flat contact		Tool cast with observed or inferred down - current orientation (310)
Transitional contact		

PLATE 43 B – LEGEND FOR LITHOLOGIES, BEDDING CONTACTS AND SEDIMENTARY STRUCTURES IN THE DE GRAY SPILLWAY STRATIGRAPHIC SECTION. (From R. C. Morris).



LOC. 21, T 6 S, R 20 W

$N = 44, \bar{X} = 274°$

PLATE 44 – PALEOCURRENT DIAGRAM OF SOLE MARKS FROM UPPER JACKFORK SANDSTONES IN THE SPILLWAY AREA. Inner circle indicates data with current trend only (length of lines correspond with number of readings); outer circle includes current directions from prods or flutes. Arrow indicates mean current direction as determined from all major or inferred down-current directions. Letter N indicates north. (From R. C. Morris).

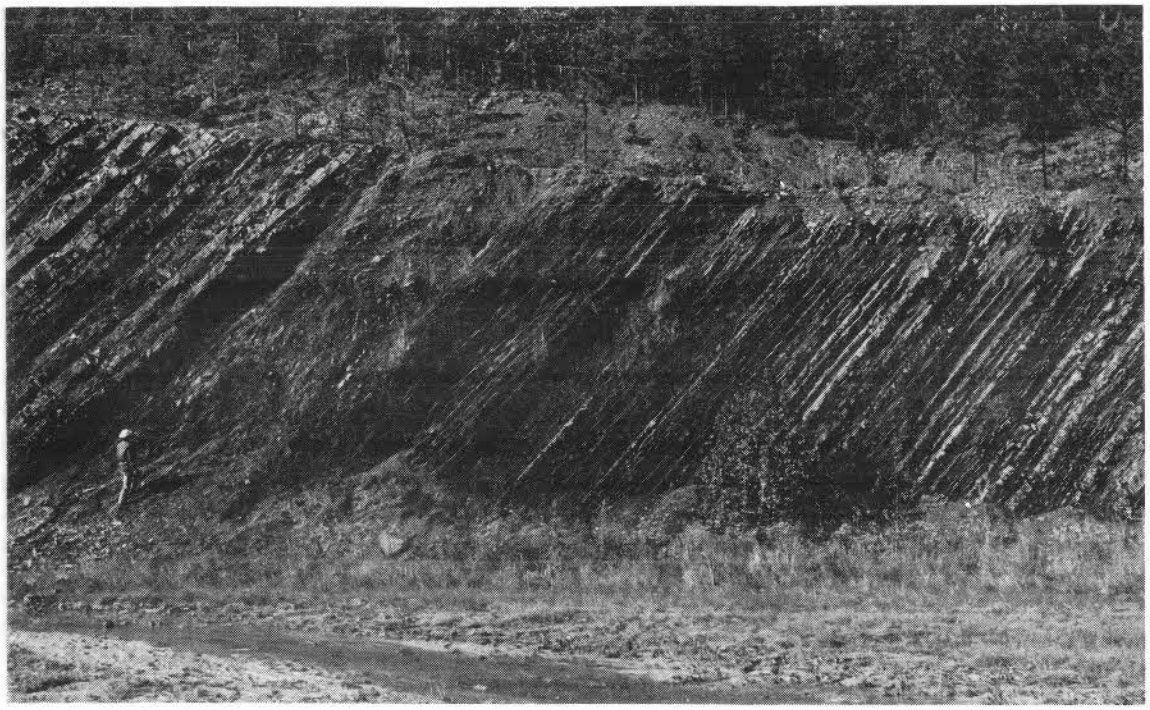


Figure 69 - Stop 41. An exposure of the upper Jackfork Sandstone near the middle of the DeGray spillway cut. The interbedded sandstones and shales exhibit both thickening and thinning upward sequences. A cobble-bearing slurried interval is present where the figure is standing. These deposits represent either submarine outer fan lobe or possibly midfan interchannel facies.

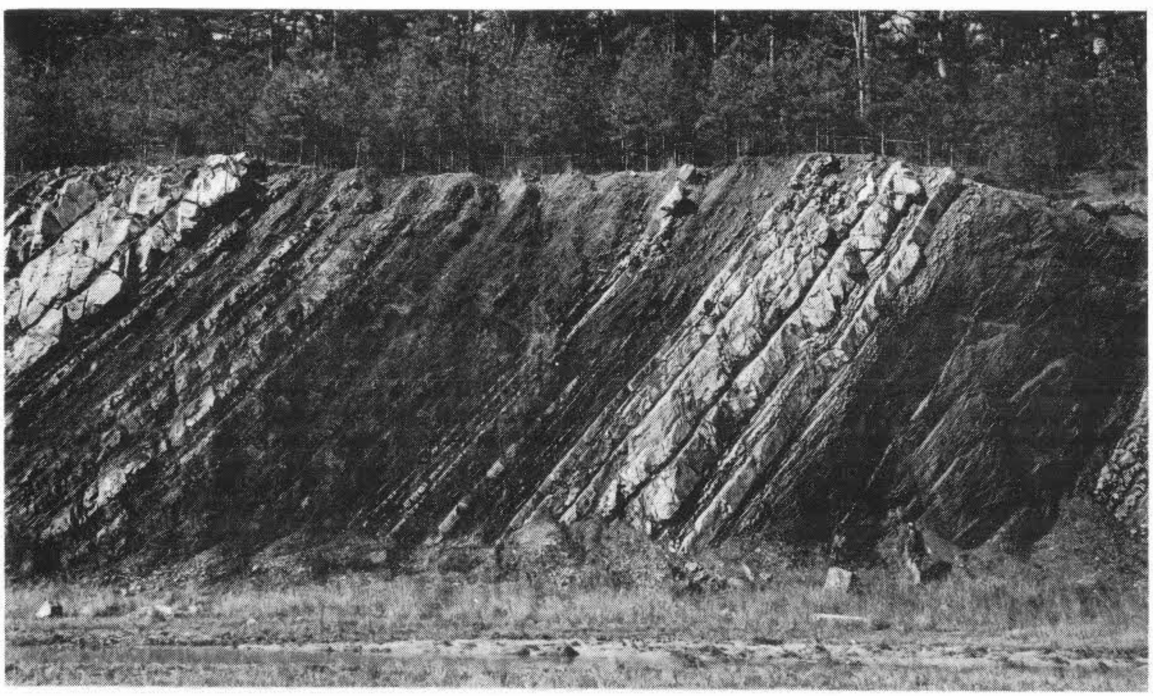
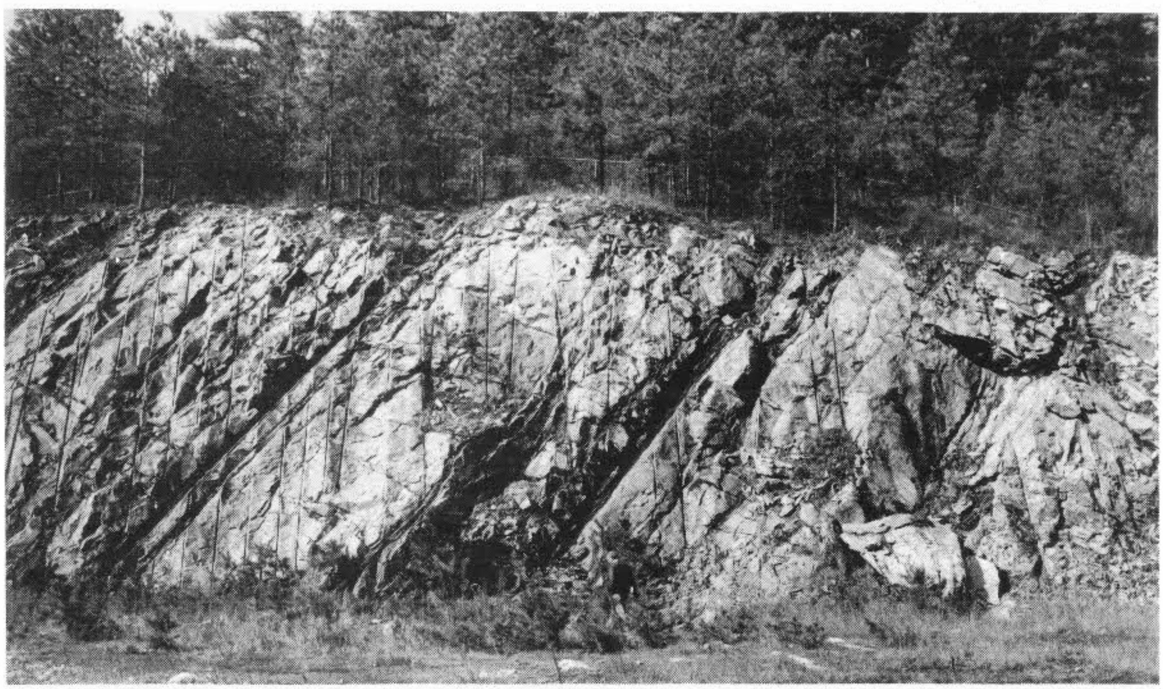


Figure 70 - Stop 41. Several thinning and fining upward intervals of southward dipping, quartzitic sandstone and shale representing probable middle submarine fan channels in the upper Jackfork Sandstone near the middle of the DeGray spillway cut.

Figure 71 - Stop 41. Parallel laminated granule-bearing "grit" interval in the upper Jackfork Sandstone at the south end of the DeGray spillway cut. The granules are composed, for the most part, of rounded quartz and metaquartzite.

Figure 72 - Stop 41. An interval of quartzitic sandstone formed by three probable middle submarine fan channels or three cycles or pulses of a single migrating channel in the upper Jackfork Sandstone at the south end of the DeGray spillway cut.



Many of the critical characteristics of these sediments would be recognizable on well logs, and the DeGray section is a good example of one association that might be drilled on the continental rise.

Return to Arknsas Hwy. 7.

154.4 Turn south on Arkansas Hwy. 7.

155.3 **STOP 42 – JOHNS VALLEY SHALE NORTH OF ARKADELPHIA, ARKANSAS (Plate 42).**

This exposure on the side road about 100 yards southeast of Arkansas Hwy. 7 is in southward dipping lower Johns Valley Shale. The north end of the roadcut is a few hundred feet from the apparent contact with the underlying Jackfork Sandstone, but there is a thrust fault between the two units. At the north end the rocks consist of several thinning and fining upward sequences of brown, silty, micaceous subgraywacke with some thin beds of siltstone and silty gray shale. Near the middle of the roadcut there are contorted and rubbly sandstone sequences, some with sandstone, chert, and other exotic clasts that, for the most part, represent sedimentary slumps. It is our belief that the slumping of these rocks was from the south to the north. There are also some later tectonic faults dissecting these slumped beds that have slickensides and dickite. At the south end of the exposure there are many thin bedded intervals of sandstone and shale. Bottom marks, Bouma sequences, graded bedding, ball and pillow structure, and other features are common. Trace fossils are present and appear to be of a deep-water type.

It is postulated that the lower part of the Johns Valley at this Stop represents submarine midfan channel deposits, and it is overlain by submarine slumped and rubble intervals that are both local and extrabasinal. The south end of the exposure contains sequences that thicken upwards and probably are midfan lobe or interchannel deposits.

Return to Interstate Hwy. 30.

157.8 Turn east on Interstate Hwy. 30.

160.7 **STOP 43 – SUBMARINE FAN CHANNELS IN UPPER JACKFORK SANDSTONE AT MILE POST 81 NEAR FRIENDSHIP, ARKANSAS (Plate 45 and Figures 73, 74).**

This exposure consists of southward dipping, weakly deformed, intervals of interbedded, light gray, fine-grained quartzitic sandstone with some granule-bearing sandstone (near the top), blue-gray, plant-bearing siltstones "blue beds" and lesser quantities of gray-black shale of the upper Jackfork Sandstone. Along this exposure there are at least eight major, well exposed fan channel sequences that range in thickness from about 15 to over 125 feet. Each sequence is characterized by thinning of beds and fining of grain size

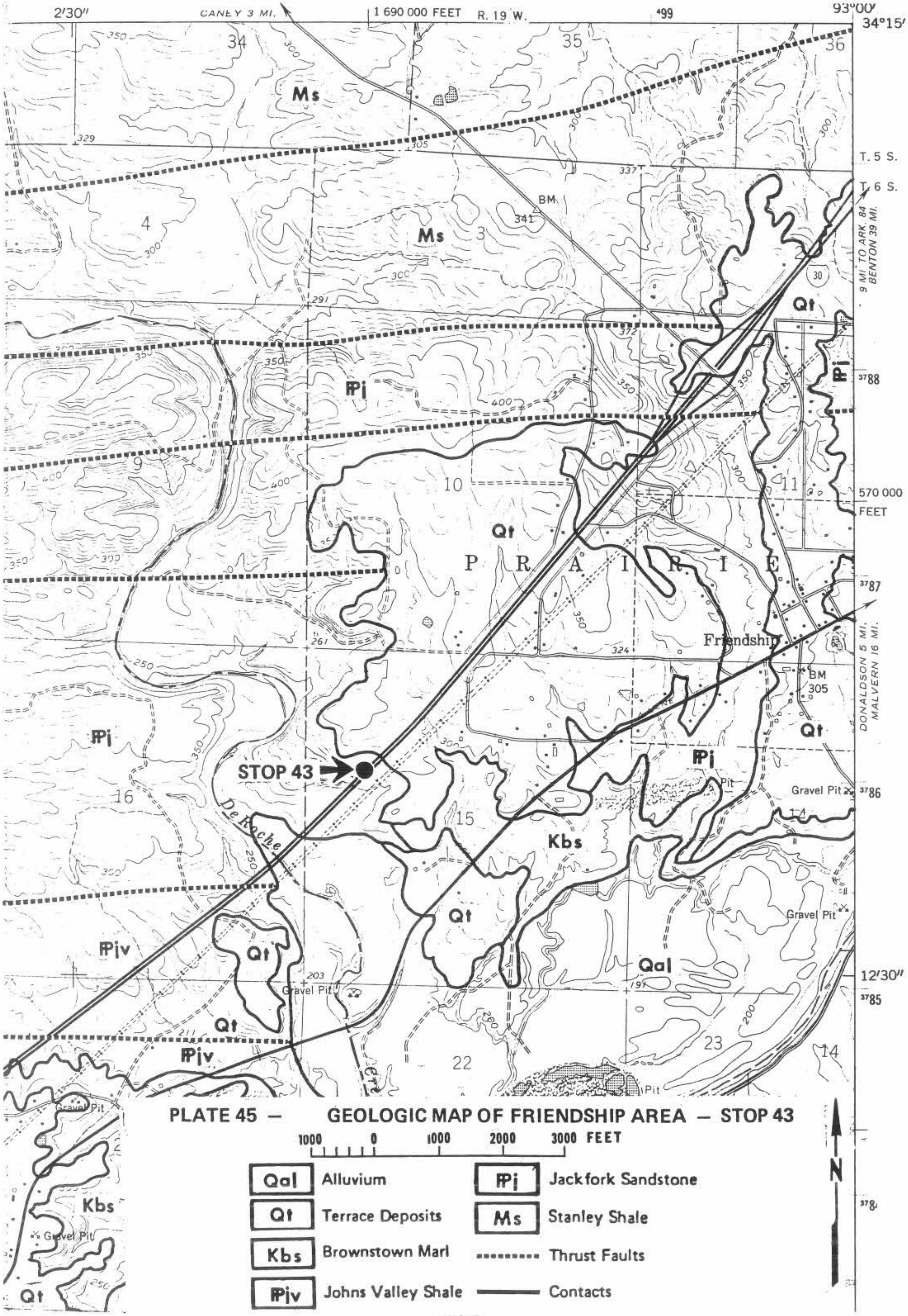


PLATE 45 — GEOLOGIC MAP OF FRIENDSHIP AREA — STOP 43

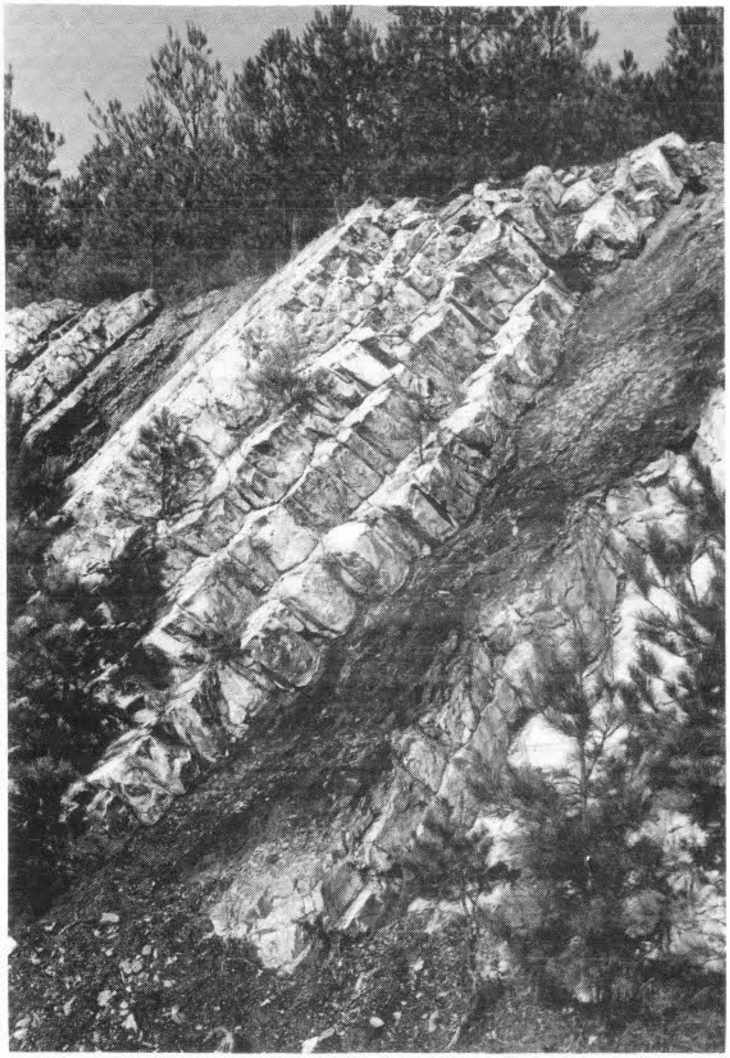


Figure 73 - Stop 43. Graded and fining upward, massive to thin, quartzitic sandstone, siltstone and shale of a probable middle submarine fan channel in the upper Jackfork Sandstone at Milepost 81 on Interstate Hwy. 30 near Friendship, Arkansas.

Figure 74 - Stop 43. The upper Jackfork Sandstone at Milepost 81 on Interstate Hwy. 30 near Friendship, Arkansas, shows southward dipping, interbedded quartzitic sandstone, siltstone and shale. There is a thinning upward fan channel on the right, a possible thickening upward fan lobe near the middle and a very massive sandstone of a large fan channel on the left.

upward. The channels appear to be entrenched only a few feet into the underlying rock. Between channel sequences 5 and 6 a thickening upward fan lobe sequence is present. There seems to be little difference in the channels here and those at the south end of the DeGray spillway in the upper Jackfork. However, both of the channel sequences contain more shale and are less entrenched than those at the Big Rock quarry some 60 miles to the northeast at North Little Rock (Stop 1).

These rocks contain Bouma sequences, bottom marks, load structures, convolute bedding, water expulsions, internal slurries, ripple marks and other features. Coalified plant fragments, clay balls, and concretions are abundant in the debris flow siltstone "blue beds" that occur at the top of many sandstones.

Small tear faults cut the interval and are most evident at the southeast end of the exposure where a two-foot wide brecciated fault gouge zone containing dickite and pyrite may be seen.

It is felt that this sequence at Friendship represents a middle fan channel facies derived from two major sources - the northeast and the east, but it is not as proximal as those near Little Rock and slightly more proximal than equivalent rocks at the DeGray spillway.

209.0 Junction of Interstate Hwys. 30 and 430 in southwest Little Rock, Arkansas.

END OF FIELD TRIP

Have a safe and enjoyable trip home and please return again!

APPENDIX

Analyses of Filtrates and Residues from Selected Ordovician Limestones in The Ouachita Mountains, Arkansas

SAMPLE DESCRIPTIONS

1. Collier limestone from roadcut on U. S. Hwy. 270, east of Joplin, Ark., in the SW¼, Sec. 26, T. 2 S., R. 23 W., in Mongtomery County.

   A. Fine-grained limestone.
   B. Coarse-grained limestone.

2. Collier limestone near U. S. Hwy. 270, in Murphy Creek in the NE¼, Sec. 31, T. 2 S., R. 22 W., in western Garland County.

   A. Fine- grained limestone.
   B. Coarse-grained limestone.

3. Womble limestone in Creek at Crystal Springs in the NE¼, Sec. 34, T. 2 S., R. 22 W., in western Garland County. From flaggy to medium beds of limestone in shales.

4. Womble(?) limestone at Big Creek on Arkansas Hwy. 5 in the NW¼, Sec. 28, T. 1 S., R. 16 W., in Saline County.

   A. Fine-grained limestone.
   B. Coarse-grained limestone.

5. Womble limestone from 3 - 10 inch thick medium-grained beds in middle(?) part of unit near center of Sec. 7, T. 2 S., R. 20 W., in Garland County, near Blakely Dam on roadcut (stream).

6. Lower Womble limestones from Mountain Pine Quarry in NW¼, Sec. 34, T. 1 S., R. 20 W., in Garland County.

   A. Dense and fine-grained limestone.
   B. Coarse-grained limestone.

7. Uppermost Mazarn limestone in creek at Blue Springs on Arkansas Hwy. 7 near center Sec. 6, T. 1 S., R. 19 W., in Garland County. From thin and dense beds of limestone.

8. Ditto location - from conglomeratic and sandy limestones in lower Blakely Sandstone.

9. Lower Womble(?) thin and dense limestones from SW SW¼, Sec. 25. T. 1 N., R. 19 W., in Garland County. Near north boundary of Hot Springs Village.

10. Upper Womble thin (4" beds) and dense limestone in Lockers Creek in SW¼, Sec. 29, T. 1 S., R. 18 W., in Garland County, north of Fountain Lake Community.

11. Uppermost Womble thin (2-12" beds) and dense limestone from Arkansas Hwy. 9 roadcut, south of Paron, Ark., in SE¼, Sec. 36, T. 2 N., R. 17 W., in Saline County.

12. Sandy and conglomeratic Blakely limestone(?) from structural window in SE¼, Sec. 14, T. 1 N., R. 18 W., in Saline County (north of Goosepond Mountain).

13. Upper Womble conglomeratic and slurried beds up to 5 feet thick in NW¼, Sec. 4, T. 1 S., R. 17 W., in Saline County, north of Steiner Mountain.

Analyses by Gaston Bell
Arkansas Geological Commission

ANALYSIS OF FILTRATES AND OF RESIDUES OF 1:5 DIGESTIONS OF OUACHITA MOUNTAIN AREA LIMESTONES

A. FILTRATE ANALYSES OF SOLUBLES: (100 g samples digested; filtrate volumes are 1000 ml; components expressed in "grams/liter".)

Components* g/l	Sample Numbers																
	1A	1B	2A	2B	3	4A	4B	5	6A	6B	7	8	9	10	11	12	13
CaO	49.8	50.4	48.9	48.6	32.9	40.1	41.2	44.9	40.6	47.3	39.7	42.8	39.8	49.1	40.6	52.0	40.7
MgO	1.10	1.28	0.59	0.68	1.06	0.64	1.05	0.86	2.18	0.73	0.97	1.01	0.73	0.59	0.56	0.35	2.79
Al_2O_3	Nil	0.02	0.03	0.03	0.80	0.30	0.10	0.59	0.08	0.04	0.20	0.03	0.32	0.04	0.01	0.01	0.01
Fe_2O_3	0.47	0.64	0.40	0.48	2.45	1.68	1.52	3.14	1.64	2.68	0.86	1.98	2.43	0.98	2.54	0.97	1.01
MnO	0.010	0.010	0.020	0.020	0.025	0.025	0.025	0.030	0.010	0.010	0.030	0.030	0.050	0.020	0.030	0.015	0.045
Na_2O	Nil	Nil	Nil	0.010	0.015	Nil	0.020	0.005	0.005	0.010	Nil	Nil	0.010	0.020	Nil	Nil	Nil
K_2O	0.005	0.005	0.005	0.005	0.010	0.015	0.015	0.005	0.010	0.005	0.025	0.005	0.005	0.005	0.005	0.005	0.005
SrO	0.138	0.143	0.104	0.123	0.103	0.072	0.083	0.056	0.059	0.037	0.097	0.027	0.095	0.070	0.059	0.037	0.070
P_2O_5	0.03	0.03	0.03	0.05	0.08	0.02	0.02	0.05	0.04	0.44	0.01	0.09	0.06	0.03	0.06	0.06	0.33
CO_2**	40.4	41.0	39.1	38.9	27.1	32.1	33.5	36.3	34.2	37.9	32.3	34.6	32.0	39.0	32.4	41.2	35.2

Footnotes: * Elements sought but not found: Cu, Pb, Zn, Cd, Ag, Hg, Sb, Co, Ni, Cr, Ga, Ba, Mo, and V.
** Carbon dioxide, CO_2, is a calculated summation of CO_2 combined with CaO, MgO and SrO.

B. RESIDUES FROM DIGEST: (expressed in grams; 100 g samples digested.)

1A	1B	2A	2B	3	4A	4B	5	6A	6B	7	8	9	10	11	12	13
8.0	6.4	10.7	11.1	35.3	24.8	22.4	14.0	20.9	10.6	25.6	19.2	24.3	9.9	23.5	5.1	19.8

C. ANALYSIS OF RESIDUES: (see B)

Components* % of Residue	1A	1B	2A	2B	3	4A	4B	5	6A	6B	7	8	9	10	11	12	13
SiO_2	84.2	86.9	84.6	93.0	80.7	88.4	90.3	79.3	90.0	86.2	90.4	93.5	86.5	79.0	83.3	87.9	93.5
Al_2O_3	8.25	5.67	6.88	2.92	9.63	5.84	5.67	9.97	4.99	2.75	3.78	2.75	8.42	12.7	11.0	5.67	3.09
Fe_2O_3	1.77	1.41	1.86	1.02	3.10	1.36	1.19	1.86	1.32	1.36	1.22	1.87	1.52	1.49	1.64	1.83	1.42
TiO_2**	0.20	0.05	0.05	0.05	0.10	0.05	0.05	0.25	0.05	0.05	Nil	Nil	0.05	0.15	0.15	0.20	0.20
MnO	0.006	0.009	0.008	0.007	0.007	0.009	0.009	0.007	0.009	0.024	0.008	0.013	0.004	0.004	0.004	0.017	0.009
CuO	0.001	0.001	0.001	Nil	Nil	Nil	Nil	0.001	0.001	Nil	Nil	Nil	Nil	0.001	0.001	Nil	Nil
BaO	0.030	0.052	0.111	0.054	0.030	0 026	0.031	0.030	0.029	0.032	0.024	0.034	0.018	0.056	0.027	0.025	0.036
CaO	0.250	0.214	0.143	0.238	0.452	0.238	0.321	0.214	0.155	2.69	0.214	0.143	0.095	0.119	0.083	0.214	0.226
MgO	1.09	1.09	1.10	1.12	1.12	1.11	1.09	1.10	1.10	1.06	1.12	0.69	1.07	1.12	0.65	1.12	0.44
SrO	Nil	Nil	Nil	Nil	Nil	Nil	0.004	Nil	0.001	0.008	Nil	0.001	0.004	0.004	0.004	0.004	0.002
K_2O	0.145	0.071	0.094	0.090	0.070	0.042	0.046	0.075	0.057	0.048	0.065	0.034	0.028	0.028	0.065	0.045	0.024
Na_2O	0.011	0.008	0.009	0.009	0.007	0.005	0.017	0.004	0.006	0.004	0.002	0.006	0.008	0.005	0.004	0.004	0.002
P_2O_5	Nil	Nil	Nil	Nil	0.014	Nil	Nil	0.018	Nil	0.050	0.122	Nil	Nil	Nil	Nil	Nil	Nil
Loss on Ign.	4.02	2.58	5.13	1.48	4.80	2.93	1.30	5.25	2.33	5.69	3.01	0.99	2.25	5.34	3.11	3.02	1.06

Footnotes: * Elements sought but not found: Pb, Zn, Cd, Ag, Hg, Sb, Co, Ni, Cr, Ga, Mo, and V.
** Titania values are derived by visual comparison with TiO_2 color standards without benefit of instrumentation. This was due to a breakdown of the colorimeter and lack of adequate lamp sensitivity on the atomic absorption spectrophotometer.

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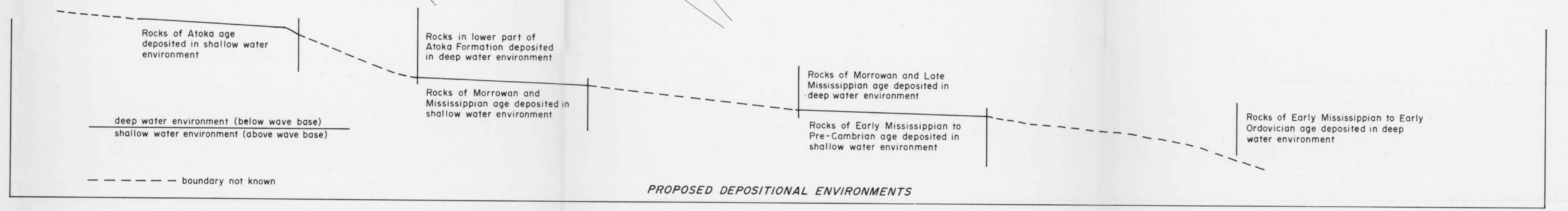

EXPLANATION

Symbol	Rock Units
Ki	Igneous
Kt	Trinity Group
IPau	Upper part of Atoka Formation
IPam	Middle part of Atoka Formation
IPal	Lower part of Atoka Formation
IPjv	Johns Valley Shale
IPj	Jackfork Sandstone
Ms	Stanley Shale
MDa	Arkansas Novaculite
Smb	Missouri Mountain Shale and Blaylock Sandstone
Opb	Polk Creek Shale and Bigfork Chert
Ow	Womble Shale
Ob	Blakely Sandstone
Om	Mazarn Shale
Ocm	Crystal Mountain Sandstone
Oc	Collier Shale

CROSS SECTION ALONG ROUTE OF SECOND DAY ROAD LOG

prepared for

TULSA GEOLOGICAL SOCIETY FIELD TRIP

by

Boyd R. Haley*, Charles G. Stone, and William V. Bush

Arkansas Geological Commission

1977

Scale

1 inch = approximately 2 miles

No vertical exaggeration

* U.S. Geological Survey

YELL
PERRY
SCOTT
NATIONAL
FOREST
MONTGOMERY
GARLAND
SALINE
HOT SPRING
HOWARD
PIKE
Waldron
Plainview
Perryville
Mount Ida
Hot Springs
Lake Catherine
Benton
Malvern
Mount Tabor
Pencil Bluff
Social Hill
Witherspoon

QUATERNARY — Holocene

Qcm — ALLUVIUM—*Both units are equivalent in age. Alluvial deposits in major stream channels or in mappable meanders of major streams—Includes alluvial deposits in natural levees in some areas*

Qso — *Alluvial deposits of local streams or of overbank flow of major streams—In some areas includes deposits in abandoned meanders of major streams*

QUATERNARY — Pleistocene

Qt — TERRACE DEPOSITS—*Alluvial deposits on one or more terrace levels*

Qds — DUNE SAND—*Deposited mostly on terrace deposits of the second level. Younger than some terrace deposits, older than others*

Qss — SILT AND SAND—*Contains lenses of gravel and clay*

Ql — LOESS

Qsg — SAND AND GRAVEL

TERTIARY — Eocene

Tj — JACKSON GROUP

Tc — CLAIBORNE GROUP

Tw — WILCOX GROUP

TERTIARY — Paleocene

MIDWAY GROUP

GULF COASTAL PLAIN

QUATERNARY — Holocene

Qal — ALLUVIUM—*Alluvial deposits of present streams*

QUATERNARY — Pleistocene

Qt — TERRACE DEPOSITS—*Alluvial deposits on one or more terrace levels*

TERTIARY — Eocene

Tj — JACKSON GROUP

Tc — CLAIBORNE GROUP

Tw — WILCOX GROUP

TERTIARY — Paleocene

MIDWAY GROUP

CRETACEOUS — Upper Cretaceous

Kad — ARKADELPHIA MARL

Kn — NACATOCH SAND

SARATOGA CHALK

Km — MARLBROOK MARL

Ka — ANNONA CHALK

Ko — OZAN FORMATION

Kb — BROWNSTOWN MARL

Kto — TOKIO FORMATION

Kw — WOODBINE FORMATION

CRETACEOUS — Lower Cretaceous

Kkg — KIAMICHI FORMATION AND GOODLAND LIMESTONE

Kt — TRINITY GROUP (Kt)

Kde, *De Queen Limestone*

Kdi, *Dierks Limestone*

GULF COASTAL PLAIN, OZARK REGION, AND ARKANSAS VALLEY AND OUACHITA MOUNTAINS REGIONS

CRETACEOUS

Ki — IGNEOUS ROCKS—*Includes undifferentiated rocks of Paleozoic age at Granite Mountain and Murfreesboro*

Acid to intermediate—Nepheline syenite complexes at Magnet Cove and Potash Sulphur Springs, stocks at Granite Mountain and in Saline County, and dikes and sills (principally trachyte, tinguaite, phonolite, some ranging from quartz syenite to diabase)

Basic to ultrabasic—Peridotite or kimberlite pipes (Murfreesboro) and breccias (Benton), and dikes and sills (principally fourchite, ouachitite, and monchiquite)

OUACHITA MOUNTAINS REGION

PALEOZOIC

Pzi — SOAPSTONE-SERPENTINE—*Altered peridotite*

SYMBOLS

CONTACT

NORMAL FAULT

THRUST FAULT—*Also cross fault in some areas, dashed under lake Ouachita to show continuity*

QUATERNARY — Pleistocene and Holocene

Qat — ALLUVIUM AND TERRACE DEPOSITS—*Alluvial deposits of present streams and on one or more terrace levels*

CRETACEOUS(?) TERTIARY

GRAVEL—*Gravel on isolated hills within 40 miles (64 km) of the Mississippi Embayment. Many small deposits to the west not shown*

CRETACEOUS — Upper Cretaceous

Ksc — SAND AND CLAY

Kr — CRETACEOUS ROCKS

PENNSYLVANIAN — Atokan

IPa — ATOKA FORMATION

PENNSYLVANIAN — Morrowan

IPbh — BLOYD SHALE, AND PRAIRIE GROVE MEMBER OF THE HALE FORMATION

IPhc — CANE HILL MEMBER OF THE HALE FORMATION

MISSISSIPPIAN — Chesterian

Mpfb — PITKIN LIMESTONE, FAYETTEVILLE SHALE (INCLUDING THE WEDINGTON SANDSTONE MEMBER), AND BATESVILLE SANDSTONE (INCLUDING THE HINDSVILLE LIMESTONE MEMBER)

MISSISSIPPIAN — Meramecian

Mr — RUDDELL SHALE

Mm — MOOREFIELD FORMATION

MISSISSIPPIAN — Osagean

Mb — BOONE FORMATION

DEVONIAN

CHATTANOOGA SHALE (LOWER MISSISSIPPIAN AND UPPER DEVONIAN), CLIFTY LIMESTONE (MIDDLE DEVONIAN), AND PENTERS CHERT (LOWER DEVONIAN)

SILURIAN

Sisb — LAFFERTY, ST. CLAIR, AND BRASSFIELD LIMESTONES

ORDOVICIAN

Ocj — CASON SHALE AND FERNVALE LIMESTONE (UPPER ORDOVICIAN) AND KIMMSWICK LIMESTONE, PLATTIN LIMESTONE, AND JOACHIM DOLOMITE (MIDDLE ORDOVICIAN)

Ose — ST. PETER SANDSTONE AND EVERTON FORMATION (MIDDLE ORDOVICIAN)

ORDOVICIAN — Lower Ordovician

Op — POWELL DOLOMITE

Ocjc — COTTER AND JEFFERSON CITY DOLOMITES

ARKANSAS VALLEY AND OUACHITA MOUNTAINS REGIONS

QUATERNARY — Holocene

Qal — ALLUVIUM—*Alluvial deposits of present streams*

QUATERNARY — Pleistocene

Qt — TERRACE DEPOSITS—*Alluvial deposits on one or more terrace levels*

PENNSYLVANIAN — Des Moinesian

IPby — BOGGY FORMATION

IPsv — SAVANNA FORMATION

IPma — McALESTER FORMATION

IPhs — HARTSHORNE SANDSTONE

PENNSYLVANIAN — Atokan

IPa — ATOKA FORMATION UNDIVIDED

IPau — *Upper part*

IPam — *Middle part*

IPal — *Lower part*

PENNSYLVANIAN — Morrowan

IPjv — JOHNS VALLEY SHALE

IPj — JACKFORK SANDSTONE

MISSISSIPPIAN

Ms — STANLEY SHALE—*Includes Chickasaw Creek Chert equivalent of Harlton (1938) near top and Hatton Tuff Lentil and Hot Springs Sandstone Member near base*

DEVONIAN MISSISSIPPIAN

MDa — ARKANSAS NOVACULITE—*Includes upper division (Mississippian), middle division (Mississippian and Devonian), and lower division (Devonian)*

SILURIAN

Smb — MISSOURI MOUNTAIN SHALE AND BLAYLOCK SANDSTONE—*The Blaylock Sandstone is present only in the Cross, Cossatot, and Trap Mountains. Missouri Mountain Shale is mapped with Polk Creek Shale and Bigfork Chert in the area between Paron, Saline County, and Little Rock*

ORDOVICIAN

Opb — POLK CREEK SHALE (UPPER ORDOVICIAN) AND BIGFORK CHERT (MIDDLE ORDOVICIAN)

Ow — WOMBLE SHALE (MIDDLE AND LOWER ORDOVICIAN)

ORDOVICIAN — Lower Ordovician

Ob — BLAKELY SANDSTONE

Om — MAZARN SHALE

Ocm — CRYSTAL MOUNTAIN SANDSTONE

COLLIER SHALE

PLATE 46 B — GEOLOGIC COLUMN FOR THE ARKANSAS GEOLOGIC MAP

Geologic Map From Haley et al., 1976