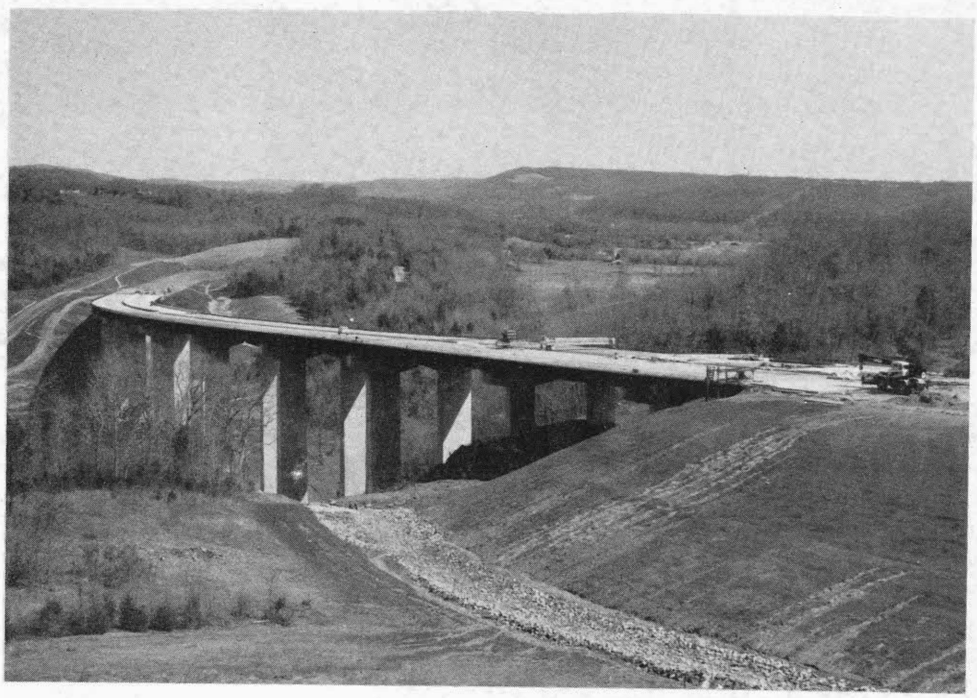
A guidebook to the

HIGHWAY GEOLOGY AT SELECTED SITES IN THE BOSTON MOUNTAINS AND ARKANSAS VALLEY, NORTHWEST ARKANSAS

By

David W. Lumbert and Charles G. Stone



Prepared for the 43rd Highway Geology Symposium

Dr. Sam I. Thornton, Chairman
Fayetteville, Arkansas
August 19-21, 1992

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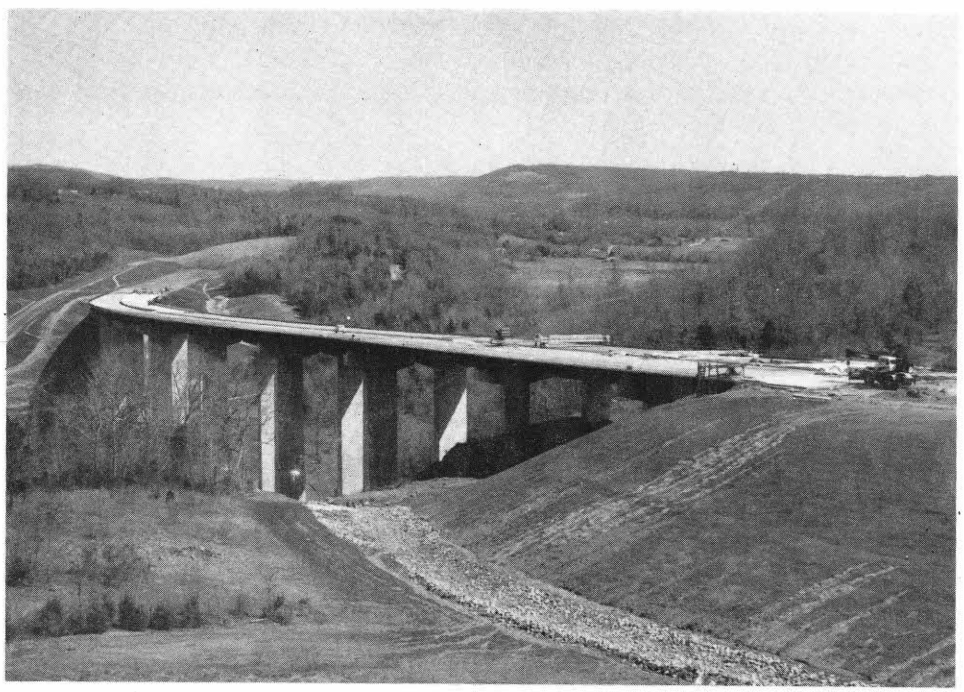

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Reprinted and Revised--September, 1994

INTRODUCTION

This guidebook was prepared for the 43rd Highway Geology Symposium's one-day field trip in northwest Arkansas, August 20, 1992. The primary purpose of the trip is to illustrate the geotechnical conditions encountered at selected sites along the newly "relocated" U.S. Highway 71. To illustrate the wide variety of geotechnical problems encountered in highway construction in this region (including those caused by deep weathering, terrace deposits, alluvium, soils, springs and other features), two additional stops on nearby highways are included.

Rapid population growth and development in northwest Arkansas during the 1960's created excessive traffic demand on the arterial highway system. Congestion along U.S. Highway 71 caused undue delays in north-south traffic, particularly in the Fayetteville-Springdale and Rogers-Bentonville areas.

Construction of the U.S. Highway 71 Bypass at Fayetteville afforded some relief in the congestion; however, diverted through traffic combined with additional traffic generated by rapidly expanding urban development caused the congestion to increase again. To alleviate the congestion, the bypass was upgraded to a fully controlled access four-lane facility with interchanges and grade separations.

This project was followed by construction of a connecting four-lane route for U.S. Highway 71 between Fayetteville and Bentonville.

The Arkansas Highway Commission recognized the need for further improved road facilities in northwest Arkansas and authorized two studies which established a north-south freeway or expressway project for the U.S. Highway 71 relocation between the vicinity of Alma and Fayetteville.

The Relocation Project is a four-lane controlled access facility extending approximately 43 miles from I-40 in Crawford County northward to U.S. Highway 71 Bypass at Fayetteville in Washington County. The project will consist of two twelve-foot lanes in each direction separated by a variable-width median. The right-of-way width will average 300-400 feet. Access will be fully controlled with interchanges and grade separations (overpasses and underpasses) at selected locations.

The design speed for the project is 65 mph. Roadway grades will be limited to 5 percent and maximum horizontal curves will be 5^{o} 30'. The construction on the relocated U.S. Highway 71 started near Alma in January of 1987. Some sections are scheduled for use in early 1995, and the anticipated completion date is the year 2000.

After travelling from Fayetteville to Fort Smith, the field trip proper begins at Fort Smith in the mildly deformed shales and sandstones that underlie the gentle rolling landforms in most of the Arkansas Valley (the Arkoma basin of the petroleum industry). The tour then proceeds north from Alma to Fayetteville, crossing the rugged, highly dissected Boston Mountains (southern Ozarks), which are underlain by nearly horizontally bedded massive sandstones and less competent shales, with some fossiliferous limestones.

We gratefully acknowledge the contributions of Jim Gee and Jake Clements of the Arkansas State Highway and Transportation Department, Division of Materials; Norman F. Williams, George W. Colton, and Norma Lynn Kover of the Arkansas Geological Commission; and Dr. Sam I. Thornton of the Department of Civil Engineering, University of Arkansas. Their assistance in selecting field trip stops and in the preparation of the guidebook were truly invaluable.

GENERAL GEOLOGIC SETTING

(Note: The information included in this section has for the most part been abstracted or adapted from many publications on the area, notably the reports by Zachry and Harris, Brewster and Williams, Hendricks and Parks, Sutherland and Manger, Haley and Hendricks, and Croneis. These publications are listed in the accompanying bibliography.)

The field trip starts in the western part of Arkansas Valley section of the Ouachita province and continues northward across the Boston Mountains section of the Ozark Plateaus province (Figure 1).

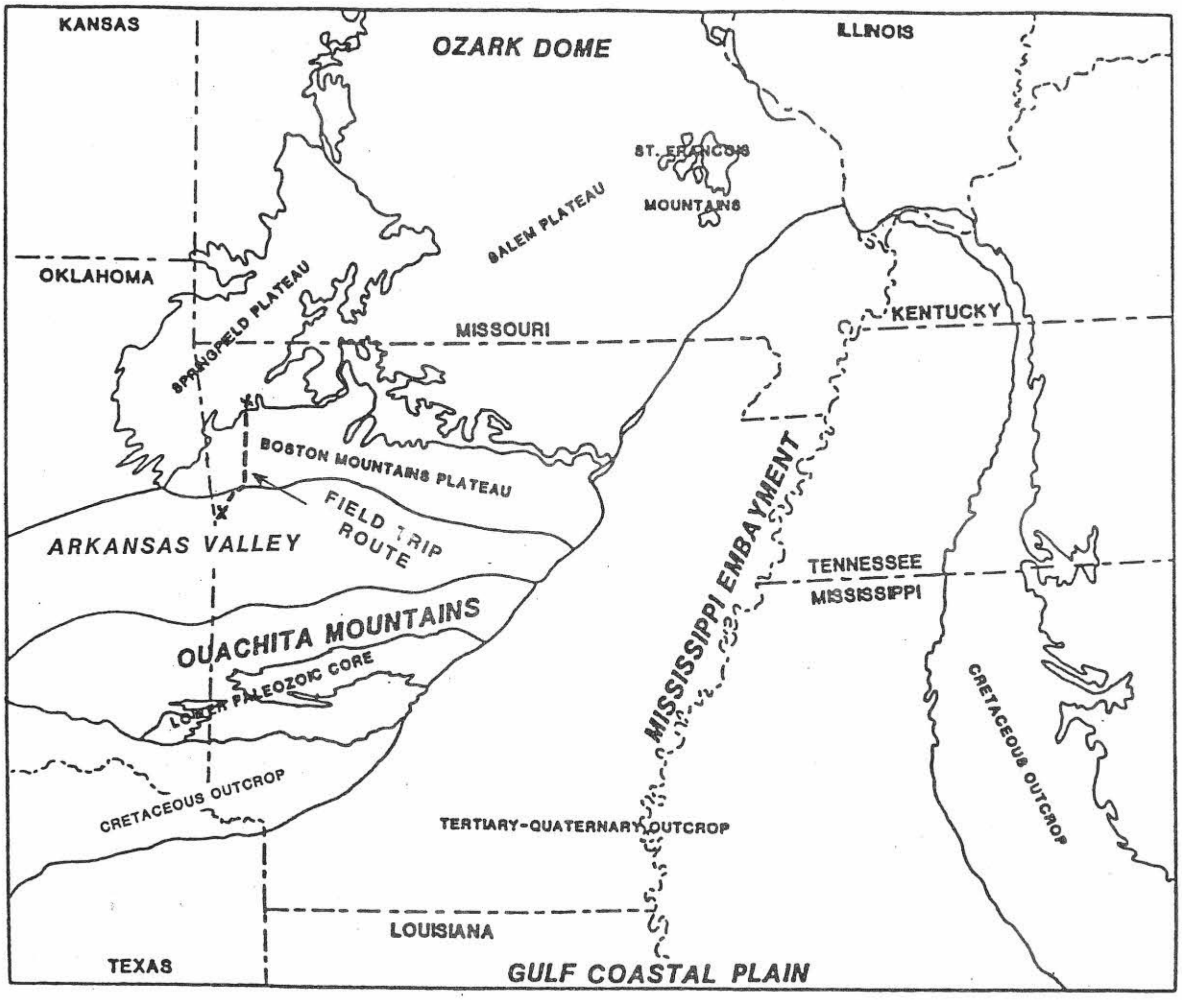

Figure 1. -- *Geologic provinces of Arkansas and nearby areas.*

The exposed stratified rocks in the western part of the Arkansas Valley belong to the Atoka, Hartshorne, and McAlester formations of Early and Middle Pennsylvanian age (Figure 2). They consist mainly of alternating beds of shale and sandstone, but include some coal beds. In this area they increase in thickness from about 7000 feet in the north to about 11,000 feet in the south.

SYSTEM	SERIES	FORMATION		COLUMNAR SECTION	THICKNESS IN FEET	CHARACTER OF ROCKS
PENNSYLVANIAN	DES MOINES		COAL Savanna formation CHARLESTON COAL UNCONFORMITY		450-850	Light-gray to light brownish gray, micaceous, very fine grained to fine-grained sandstone (cross-bedded and ripple-marked; contains plant fossils as well as marine invertebrates) interbedded with medium dark gray shale and siltstone.
			COAL Mc Alester formation COAL LOWER HARTSHORNE COAL		500-1000	Light-gray to light brownish gray, micaceous, very fine grained to fine-grained sandstone (cross-bedded and ripple-marked; contains plant fossils as well as marine invertebrates) interbedded with medium dark gray shale and siltstone.
			Hartshorne sandstone COAL UNCONFORMITY		15-100	Thin-bedded to massive, very light gray, micaceous, very fine to fine-grained sandstone.
	ATOKA		COAL Atoka formation COAL COAL UNCONFORMITY		2,300-10,000	Sandstones and dark to black sandy, micaceous shales. Sandstones usually brown, thin to medium bedded, compact and ripple marked. Massive, cross-bedded sandstone with white quartz pebbles near base.
	MORROW	Bloyd shale	Kessler limestone member		(0-20)	Compact, gray to brown, fossiliferous limestone, locally conglomeratic.
			Woolsey member BALDWIN COAL		(0-45) 0-350	Terrestrial sediments (including the Baldwin coal bed up to 18 inches thick). Conglomerates at top and base locally.
			Brentwood limestone member		(0-100)	One, two or three limestone beds, each 3 to 10 feet thick with interbedded shales. Limestones impure, fossiliferous, and locally cross-bedded.
		Hale formation	Prairie Grove member		(60-200) 60-250	Gray, limy, fine to medium-grained sandstone, fossiliferous oolitic limestone, and, locally, a basal conglomerate.
			Cane Hill member UNCONFORMITY		(0-65)	Shale, siltstone, and fine-grained sandstone. Locally limy. Basal conglomerate.
MISSISSIPPIAN	UPPER		Pitkin limestone UNCONFORMITY ?		0-200	Massive, gray, fossiliferous limestone.
		Fayetteville shale	Wedington sandstone member		(0-55)	Gray to brown sandstone, in part calcareous; and massive and cross bedded in places.
					10-350	Black, carbonaceous, pyritic, fissile shale with clay ironstone concretions. Thin, dark limestones locally.
		Batesville sandstone			0-75?	Gray to brown, calcareous sandstone, weathering to brown or buff, porous sandstone.
			Hindsville limestone member		(0-50?)	Gray, fossiliferous, bituminous limestone, in part oolitic with thin sandstone beds.
			Ruddell shale		?	(Not definitely known to be present in western Arkansas) Gray, fissile clay shale in north central Arkansas.
			Moorefield formation UNCONFORMITY		0-30?	Outcrops tentatively assigned to this formation are gray, glauconitic, fine to medium crystalline limestone.
	LOWER	Boone formation			50-400	Massive, gray, crystalline, fossiliferous limestone with much nodular and bedded chert.
			St. Joe limestone member UNCONFORMITY ?		(10-100)	Thin-bedded, non-cherty, gray to reddish-brown, crinoidal limestone.

Figure 2. -- *Columnar section of rocks exposed in northwestern Arkansas.*

Gravel-and silty sand-capped terraces were formed by the Arkansas River and some of its tributaries during Pleistocene time at several levels above the present river. Alluvium was deposited in wide areas along the Arkansas River and its major tributaries, and in narrower areas along the smaller streams.

Normal faults are abundant in the northern part of the Arkansas Valley -- and in the adjacent southern Boston Mountains --, and vaguely defined folds with flank dips of from two to five degrees are present. More intensely deformed folds, commonly with associated thrust faults, appear successively to the south toward the Ouachita orogenic belt.

The northern part of the Arkansas Valley area developed as a structural feature in middle Atoka (Pennsylvanian) time as an extensional stress field broke the shelf into generally east-trending normal faults with extensive down-to-the-south and lesser down-to-the north displacement (Figure 3). Subsidence caused by the faults accommodated over 25,000 feet of Atoka strata in the southern part of the basin adjacent to the Ouachita Mountains. Approximately 2700 feet of lower Atoka rocks overlie the Morrowan (Pennsylvanian) section immediately south of Frog Bayou (Stop 3), and up to 1500 feet are present in the Boston Mountains to the north.

The Boston Mountains section is a dissected highland that extends from north-central Arkansas to northeastern Oklahoma (Figure 1). Elevations in Arkansas range from 800 to 1000 feet in the valleys up to around 2400 feet on the mountains. The hilltops are flat, and the valleys are generally steep-sided and have relatively narrow floodplains. Carboniferous strata in the Boston Mountains are essentially flat lying and deformation is mainly confined to widely spaced fault zones. Regional dip is to the south at approximately one-third of a degree. The boundary between the mountains and the Arkansas Valley section to the south is the Mulberry fault north of Alma, across which down-to-the-south displacement ranges from 2000 to 2500 feet.

The Boston Mountains are bounded to the north by the successively lower Springfield and Salem plateaus and to the south by the Arkansas Valley section, a peripheral foreland basin associated with the Ouachita orogenic belt in west-central Arkansas and east-central Oklahoma (Figure 1). Paleozoic sedimentary rocks of Mississippian age crop out in the floor and lower valley walls of deeply incised streams. The hilltops and most of the valley walls are underlain by strata of Pennsylvanian age (Figure 2). Carboniferous rocks of the Boston Mountains overlie a Paleozoic sequence that ranges in age from Cambrian to Devonian and has a thickness of 2000 to 2500 feet. Rocks ranging from Lower Ordovician to Devonian are exposed, along with some Carboniferous rocks, on the Springfield and Salem plateaus to the north.

A brief description of the Carboniferous formations and Quaternary deposits exposed along the route of this field trip follows (Figure 2).

MISSISSIPPIAN SYSTEM

Fayetteville Shale (10-350')

Most of this formation is a black carbonaceous fissile clay shale in which clay ironstone concretions are numerous. Locally a thin highly fossiliferous limestone occurs near the base in northwestern Arkansas.

In the upper part of the Fayetteville Shale is a sandstone member, the Wedington, which reaches a thickness of 200 feet, but commonly is less than 50 feet thick. The rock is dense, hard, light gray to brown, fine-grained and generally thin-bedded. Locally, however, it may be massive, especially where the sandstone is flaggy.

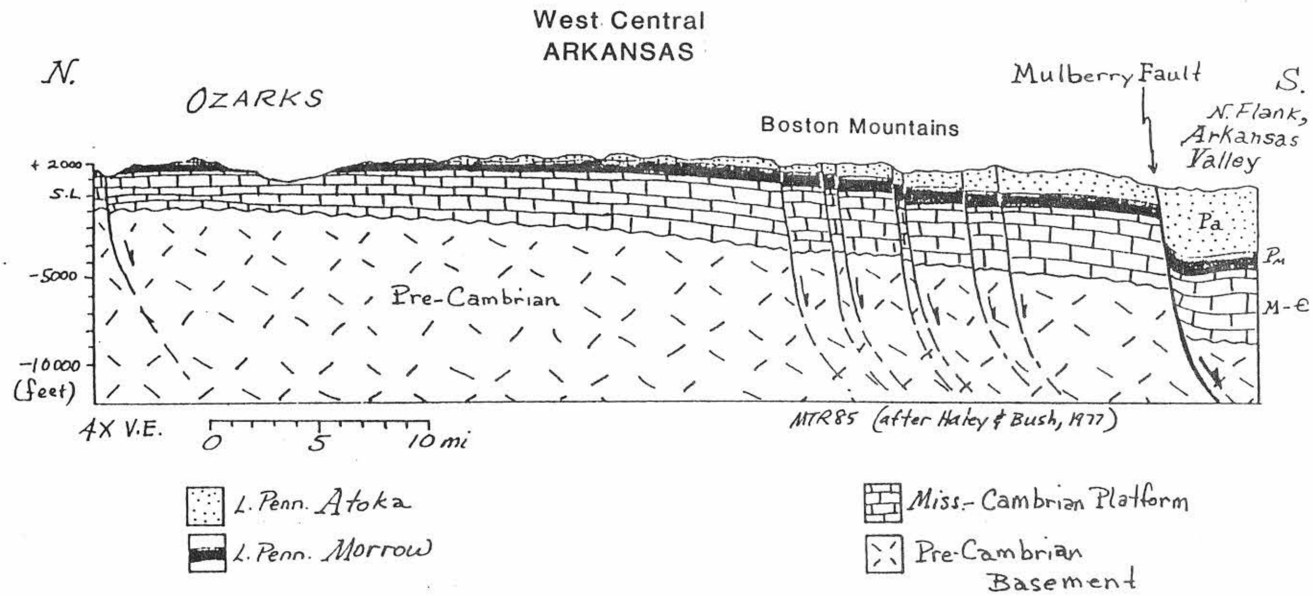

Figure 3. -- *Generalized geologic cross-section across northwest Arkansas. (Adapted from M.T. Roberts).*

Where the Batesville Sandstone is present, it is conformably overlain by the Fayetteville Shale. Elsewhere the Fayetteville lies upon the Boone, except for a few localities where it rests on the Hindsville Limestone Member of the Batesville. The Fayetteville is overlain by the Pitkin Limestone, probably disconformably. Where the Pitkin was removed by pre-Pennsylvanian erosion, the Fayetteville is overlain by some part of the Morrow Group.

Pitkin Limestone (0-200')

The Pitkin Limestone is the uppermost formation of Mississippian age in northwestern Arkansas. It outcrops from near Batesville in Arkansas on the east to near Muskogee in northeastern Oklahoma. Typically the Pitkin consists of massive beds of compact, bluish-gray limestone which in places is ferruginous and porous. Locally it may be sandy enough to show indistinct cross-bedding on weathered surfaces. Its outcrop is usually a vertical cliff with large blocks of the undermined limestone lying on the slope below. Most of the rock is fossiliferous, bryozoans, corals, crinoids, and brachiopods being especially numerous.

The Pitkin rests disconformably on the Fayetteville Shale and is overlain by the Hale Formation with disconformity, as shown by the irregular upper surface of the Pitkin and a conglomerate at the base of the Hale.

PENNSYLVANIAN SYSTEM

Hale Formation (60-250')

The Hale Formation is the lowermost of the Pennsylvanian formations of northern Arkansas. It extends from eastern Oklahoma along the Boston Mountain escarpment to the vicinity of Batesville. Its thickness in northwestern Arkansas probably averages about 150 feet. The formation consists of a shale-rich member below and a sandstone-dominated member above.

The lowermost part of the formation is a basal conglomerate composed of a ferruginous limestone matrix containing pebbles of limestone, sandstone, and cement.

Above the basal conglomerate is a black clay shale with thin ripple-marked sandstones. This shale is normally followed by a sandstone section including thin and massive beds. Above these sandstones is a black fissile clay shale which in places contains much sandstone and sandy shale. The upper part of the formation is characteristically a series of massive, brown, cross-bedded, calcareous sandstones which develop a cavernous surface on weathering. Lenses and beds of limestone occur throughout the sandstone and in places are as much as 50 feet thick.

The Hale is unconformable on the Pitkin, and north of the edge of the Pitkin, the unconformity truncates successively older beds, finally bringing the Hale to rest upon the lower part of the Fayetteville Shale. Where the overlying Bloyd is present, its contact with the Hale is conformable. In some areas the Bloyd was removed by erosion and the Hale is overlain by the Atoka Formation.

Bloyd Shale (0-350')

The Bloyd Shale is best developed in the western part of the Boston Mountains in Arkansas where it is 200 feet thick. It thins to the north, east, and west but extends westward to the vicinity of Muskogee, Oklahoma and eastward into Independence County, Arkansas.

The formation consists of shale and two limestone members. The lower part is a black fissile clay shale 5 to 20 feet thick. Above the shale is the Brentwood Limestone Member, composed of one, two, or three limestone beds, each 3 to 10 feet thick, separated by shales. The limestones are impure, very fossiliferous, vary from fine-grained to crystalline, and are locally cross-bedded.

Above the Brentwood is a black carbonaceous shale in which a thin coal bed occurs. Above the coal-bearing shale is the Kessler Limestone Member. It resembles the Brentwood in general appearance, but is thinner, darker in color, locally conglomeratic and weathers into thin shaly plates. The shale above the Kessler resembles the Fayetteville Shale but is somewhat more sandy.

The Bloyd is conformable with the underlying Hale Formation and is overlain by the Atoka Formation with a slight angular unconformity.

Atoka Formation (2300-10,000')

Rocks of Atoka age are exposed in Arkansas from the Boston Mountains escarpment southward across the Arkansas Valley to the Ouachita Mountains. They extend from the Coastal Plain westward into Oklahoma.

The Atoka Formation is the most widespread formation in Arkansas. It was named for the town of Atoka, Oklahoma, near which it is well exposed. The formation ranges in thickness from about 2300 feet in the Boston Mountains to about 10,000 feet in the central Arkansas Valley section.

The Atoka consists predominantly of shale with lesser amounts of interbedded sandstone. The shale is mostly black, carbonaceous, micaceous, sandy, and splintery. The sandstone beds are white or light gray and coarse grained, or massive to gray or brownish and very fine-grained. All the sandstone is micaceous. Channel sandstones are rather frequently found and there is considerable lateral gradation of sandstone to shale.

Conglomerates are prominent in exposures in the Ozark region, and coal beds are found at several stratigraphic positions in the Atoka formation, but they are usually thin and of limited extent.

The Atoka is underlain by the Bloyd Shale with a slight angular unconformity and is unconformably overlain by the Hartshorne Sandstone.

Hartshorne Sandstone (15-300')

The Hartshorne Sandstone, named for outcrops near Hartshorne, Oklahoma, is one of the important ridge-forming sandstones of the Arkansas Valley. Its area of outcrop is confined principally to the western part of the Arkansas Valley. The formation typically is less than 100 feet thick, but locally may exceed 300 feet.

The Hartshorne consists of sandstone beds that are coarse-grained, massive and cross-bedded where the formation is thick and generally fine-grained and thin-bedded where it is thin. They are typically light gray to white in color and some are ripple marked. The thicker Hartshorne sequences were probably formed as channel deposits. The formation rarely includes invertebrate remains, but plant fossils are numerous. In some localities fossil forests are found. Minor amounts of gray to black, sandy to silty shale are present in the Hartshorne.

The formation rests unconformably on Atoka rocks, and is overlain conformably by the McAlester Shale.

McAlester Formation (500-1800')

The McAlester Formation was named for exposures near the town of McAlester, Oklahoma. The formation usually has a thickness ranging from 500-1000 feet, but reaches a maximum thickness of about 1800 feet in the Poteau Mountain area south of Fort Smith.

The formation consists mainly of gray, sandy, micacous shale with some dark gray to black, clay shale and discontinous beds of sandstone. Most of the sandstone is buff, fine-grained, argillaceous, and micaceous, but some beds of white, coarse-grained, clean sandstone are found. A number of coal beds are present in the McAlester. The most important coal in Arkansas, the Lower Hartshorne coal, is the lower part of the McAlester. The McAlester is overlain unconformably by the Savanna Formation.

QUATERNARY SYSTEM

Terrace Deposits (0-40')

Alluvial terrace deposits of Pleistocene age occur along the Arkansas River and to a lesser extent along other major streams in the region.

The base of the highest Arkansas River terrace is about 50-60 feet above the present river level. It is restricted to only a few places, primarily because of subsequent periodic reworking by the Arkansas River. The terrace is composed of rounded gravels of sandstone, siltstone, chert, quartz, and minor traces of igneous rock, with interstitial clay and sand.

The lower terrace deposits are widespread along the Arkansas River and generally occur about 20 to 30 feet above the present river level. They are composed of red silty clay with small secondary, brownish-white limestone nodules. Generally, the terrace is very sandy. Pebbles reworked from the high terrace deposits commonly occur near the base.

Alluvium (0-260')

Clay, silt, sand and gravel compose the alluvial deposits of the Arkansas River floodplain. Near Fort Smith, the alluvium averages 70 feet, but may locally exceed 200 feet in thickness.

Soils and Colluvium (0-10')

Throughout much of the Arkansas River Valley and Boston Mountains, soils and colluvial slope-wash debris, usually varying from a few inches to about 10 feet in thickness, cover the Paleozoic formations. These deposits are best developed on the flat-lying valley floors and gentle slopes. On the steeper slopes and hills the deposits contain many locally derived angular to subrounded pebbles and cobbles of siltstone, sandstone, and some limestone. Irregular deep weathering often occurs in the Paleozoic strata beneath the soil and colluvial deposits, and a few cavernous features occur in the Paleozoic limestone units. Some springs are present either at the base of the soil and colluvium or within some of the Paleozoic units. Large-scale mass movement of rock has occurred in several areas. It is most notably developed at Devils Den State Park west of Winslow, where jumbled masses of sandstone covering several acres in size have become detached and slid downslope from the bedrock exposures.

ECONOMIC GEOLOGY

Some of the most prolific gas fields in the state are in the Arkansas Valley area between stops 1 and 2 of the field trip. Most of the gas comes from sandstones in the Atoka Formation, but in several fields Morrowan rocks are important producers. In the Boston Mountains at West Fork and near Brentwood, several small natural gas fields produce from older sandstones. In the Arkansas Valley, significant quantities of high-rank bituminous to semi-anthracite coal have been mined, especially from the Lower Hartshorne coal. Rock aggregate is produced commercially from the Hartshorne Sandstone and the Pitkin Limestone and other formations in the region.

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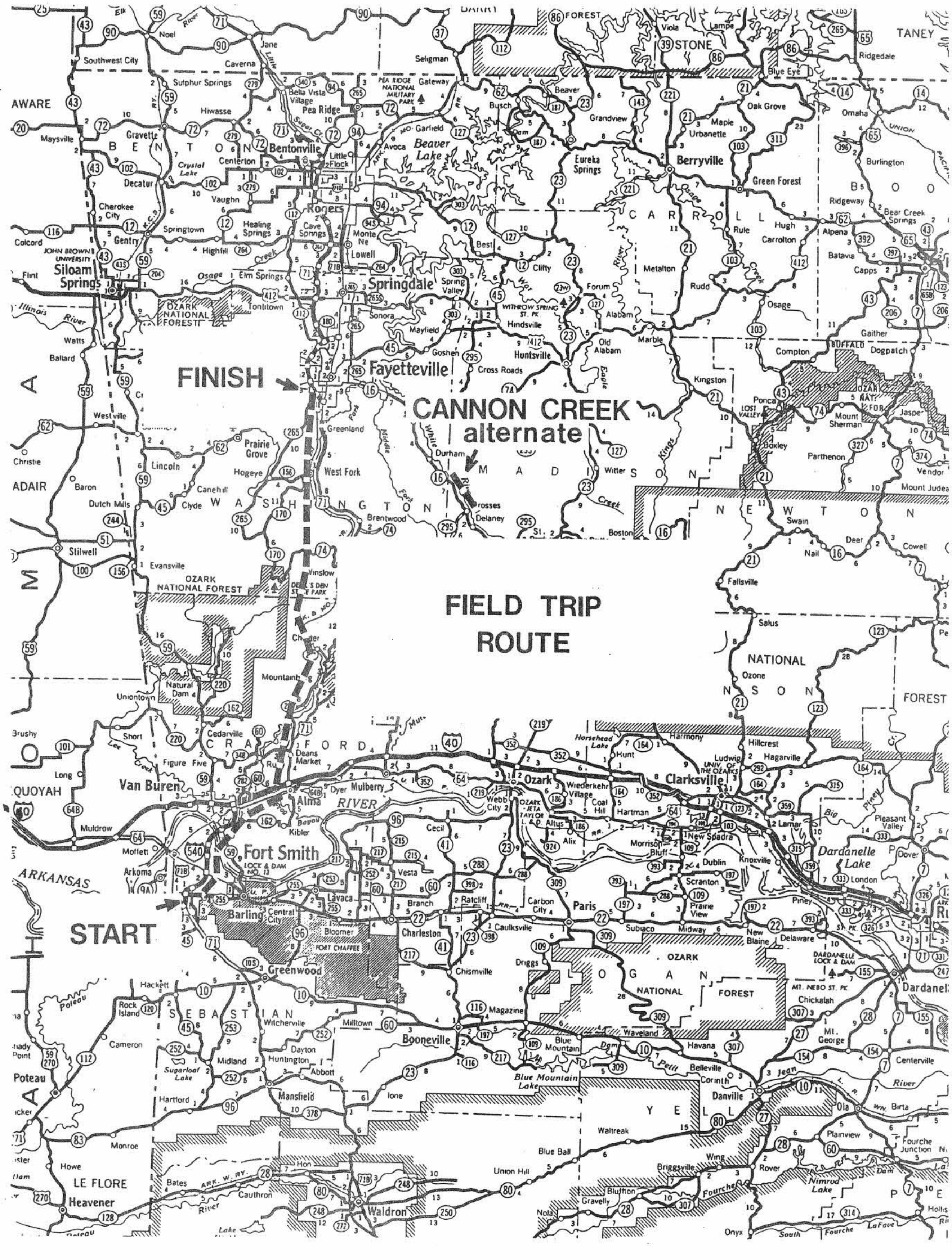

Figure 4. -- *Index map showing field trip route.*

ROAD LOG ITINERARY IN THE BOSTON MOUNTAINS AND ARKANSAS VALLEY NORTHWEST ARKANSAS

By

David W. Lumbert[1] and Charles G. Stone[2]

Depart from the Fayetteville Hilton and proceed south to our first stop in Fort Smith, Arkansas via U.S. Hwys. 71 B, 71, I-40, and I-540 (Figure 4). Enjoy the scenery of the Arkansas Valley and Boston Mountains for about the next 1 1/2 hours. A brief description along the route to STOP 1 follows.

GENERALIZED ROAD LOG FROM FAYETTEVILLE TO FORT SMITH

Cumulative *Mileage*	
0.0	Hilton at Fayetteville, Arkansas. Proceed south on U.S. Hwy. 71B. For approximately the next ten miles you are riding over Fayetteville Shale.
2.8	Junction with U.S. Hwy. 71 and proceed south.
3.6	City limits of Greenland, Arkansas. A former Governor of Arkansas once received a traffic ticket for running a red light here.
8.8	A.H.T.D. maintenance headquarters to right on the north side of West Fork, Arkansas.
9.8	Juntion of State Hwy. 170 at West Fork, Arkansas. Proceed south on U.S. Hwy. 71.
11.0	Abandoned quarry in Pitkin Limestone on left. View of West Fork of White River on right.
11.8	View to west of construction on the new relocation of U.S. Hwy. 71. This will be Stop 4 of our field trip later this afternoon.
12.0	Contact on left of Cane Hill and Prairie Grove Members of the Hale Formation.
12.8	Brentwood Limestone and Woolsey Members of the Bloyd Shale on left.
16.3	Rest area on right; continue south on U.S. Hwy. 71.
21.3	City limits of Winslow, Arkansas. We travel across shales and sandstones of the Atoka Formation to Alma, Arkansas.
24.8	Leave Washington and enter Crawford County.
25.6	Mount Gaylor, Elevation 2,090' above m.s.l.

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Figure 5. -- *Map showing location of Gabion wall complexes in Fort Smith.*

28.3 Artist Point rest area on right; later this will be our LUNCH STOP.

33.6 Junction of State Hwy. 282 to Chester, Arkansas. Proceed south on U.S. Hwy. 71.

36.4 Various schools on right at Mountainburg, Arkansas. Note the dinosaurs in the playground.

40.3 A small remaining section of the "original" U.S. Hwy. 71 on left.

46.1 City limits of Alma, Arkansas.

47.2 Junction of U.S. Hwy. 71 with I-40. Proceed right (west) on I-40.

48.0 Interchange for the newly relocated U.S. Hwy. 71. Continue on I-40 to southern Fort Smith.

52.7 Take exit from I-40 and proceed south on I-540.

55.9 Bridge over Arkansas River. Leave Crawford and enter Sebastian County.

60.8 Rogers Avenue and State Hwy. 22 exit. Continue south on I-540.

62.8 Take exit 10 on I-540. Stop on left side of the exit! This is the first stop of the field trip.

ROAD LOG FROM FORT SMITH TO FAYETTEVILLE, ARKANSAS

Cumulative
Mileage

0.0 **STOP 1. GABION WALL COMPLEXES IN FORT SMITH**

Gabion walls were constructed at two sites along a 0.4 miles stretch on the west side of I-540 and exit 10 (Figure 5). We plan to examine the larger, more westerly gabion wall across from the parking area at Exit 10 (Figure 6 A and B). The soils, thin colluvium, and the weathered to unaltered McAlester Shale failed here primarily because the cut slope was very steep, some weathered shales previously had slipped and rotated downslope into the cut, and the unaltered gray-black shales (while dipping slightly to the northwest) contain joints that are inclined steeply into the cut.

The Gabion walls are constructed of interconnected rectangular 3-foot wire-mesh baskets filled with coarse nondegradable sandstone. The wire for the gabion baskets is 11 gauge with a tensile strength in the range of 60,000 to 80,000 psi. The lacing wire meets the same specifications and is 13 1/2 gauge. Openings of the mesh are approximately 4 1/2 by 3 1/4 inches. These gabions are of single-unit construction with the base, ends, and sides connected to the base section of the gabion in such a manner that strength and flexibility at the point of connection are at least equal to that of the mesh.

0.2 Proceed east on Airport Road beneath I-540 and turn left (north) on I-540. Numerous natural gas wells produce in the area along the north flank of the Massard Prairie anticline.

0.6 View of smaller Gabion wall at overpass to left.

2.0 Exit 8A to Rogers Avenue and State Hwy. 22. Proceed on I-540.

Figure 6 A. -- *Gabion wall at exit 10 on I-540 in Fort Smith.*

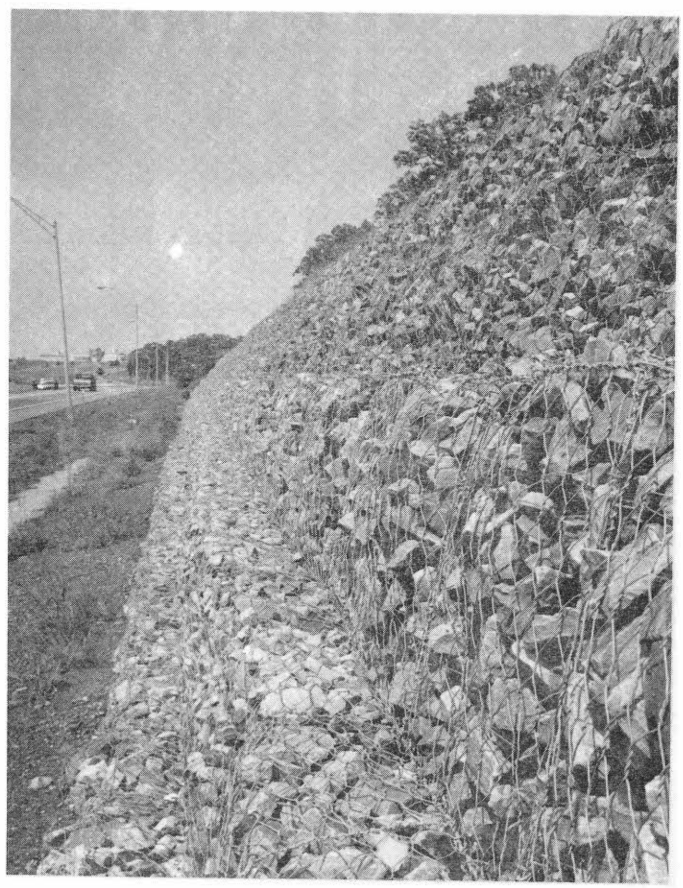


Figure 6 B. -- *Closeup showing details of individual rectangular 3-foot meshed wire baskets filled with stacks of rock forming the Gabion wall.*

Figure 6. -- *STOP 1.*

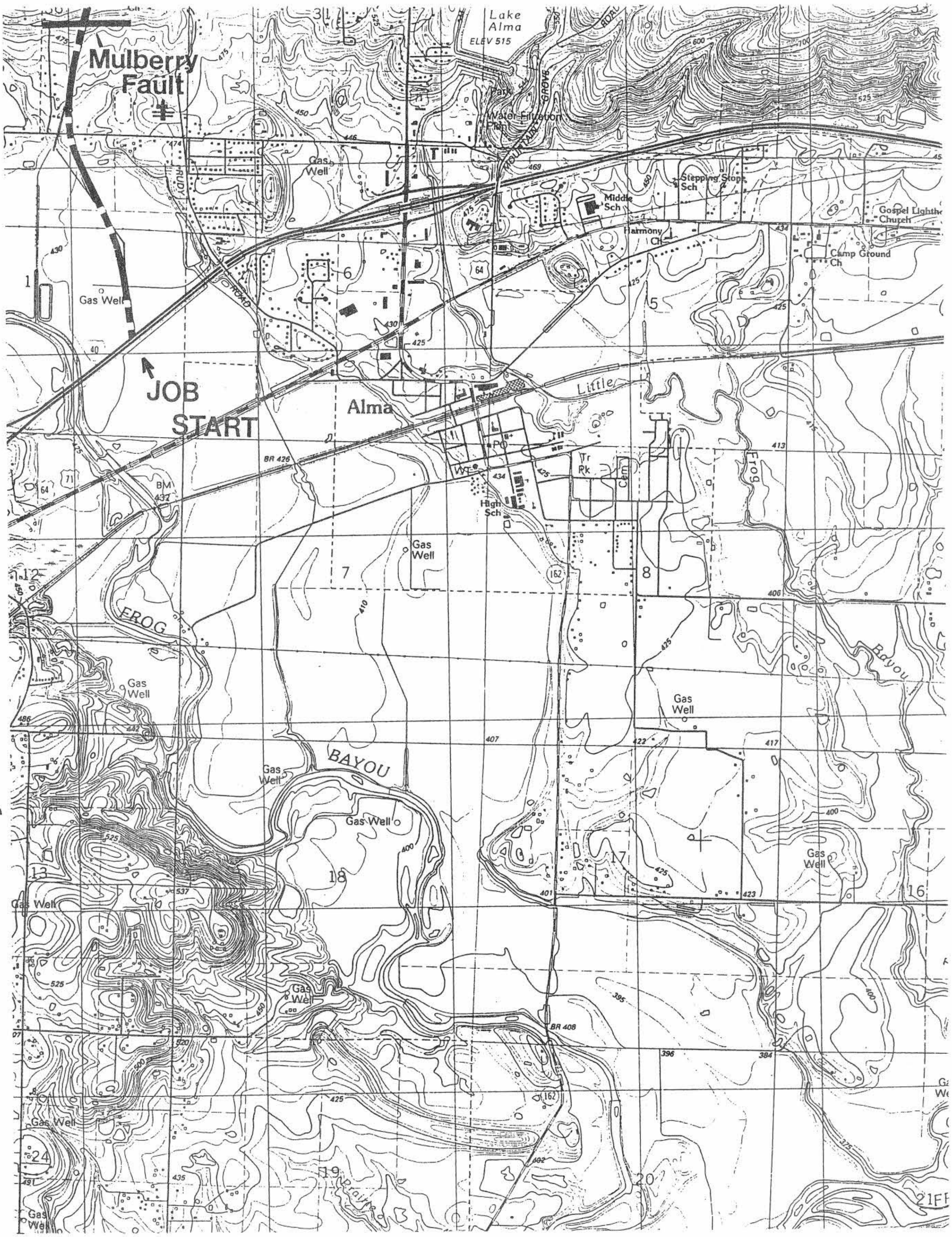


Figure 7. -- *Map showing relocation route for U.S. Highway 71 near Alma, Arkansas.*

6.9 South end of Arkansas River bridge. Leave Sebastian and enter Crawford County. Extensive alluvial flood plains have been developed along the Arkansas River and along the lower courses of many of its tributaries in the area. In times of flood, all these alluvial plains are submerged except where protected by levees. The visible alluvium is mostly silt, but sand and gravel usually occur at depth. Extensive terrace deposits of gravel, sand, silt, and clay are present mostly about 50-60 feet above the Arkansas River. Normal faults have partially determined the present course of the Arkansas River for considerable distances and also the courses of several smaller streams.

7.6 Exit 3 and State Hwy. 59 to Van Buren, Arkansas. Continue on I-540.

9.6 Exit 2B to U.S. Hwy. 64 to Van Buren, Arkansas. Continue on I-540.

10.2 Proceed on exit to right and continue east on I-40.

11.9 A.H.T.D. weight station on I-40.

12.6 Preston quarries in Hartshorne Sandstone to left. Aggregate and riprap used for A.H.T.D. are processed here by Arkhola Quarries, Inc.

14.9 Take exit 13 on the west side of Alma, Arkansas and proceed north on the newly relocated U.S. Hwy. 71 (Figure 7). The Alma gas field is located on the south edge of town.

16.1 Overpass for Collum Lane road.

16.6 Overpass for Maple Shade road. The relocated Hwy. 71 roadbed begins ascent up dipslope of highly jointed sandstones of the middle Atoka Formation. We have passed across the Mulberry fault, just south of this exposure, although it is not exposed. It is a normal fault that is downthrown to the south with some 2,000 to 2,500 feet of displacement. It approximates the break between the Boston Mountains and the Arkansas Valley (Figure 3).

17.1 Road underpass.

17.5 This is a fine exposure of alternating shales, siltstones, and sandstones of the middle Atoka Formation. Several southward-prograding deltaic sequences are present.

18.4 Road overpass.

19.2 On right, small quarry site for aggregate used on this road.

19.8 Overpass for State Hwy. 282.

20.0 Cuesta and dipslope to south formed by massive weathered sandstones of the middle Atoka Formation.

20.6 Slightly older southward-dipping black shales and brown sandstones of the middle Atoka Formation.

21.7 **STOP 2. LOWER ATOKA FORMATION AND LANDSLIDE.** Begin at Gregory Chapel overpass and proceed north 0.2 miles on relocated U.S. Hwy. 71.

This is a good opportunity to examine the highly variable rock types, small faults, and numerous joints that typify many of formations encountered in road excavations throughout this area. These alternating massive to thin beds of brown sandstone, very thin beds to laminae of light gray siltstone,

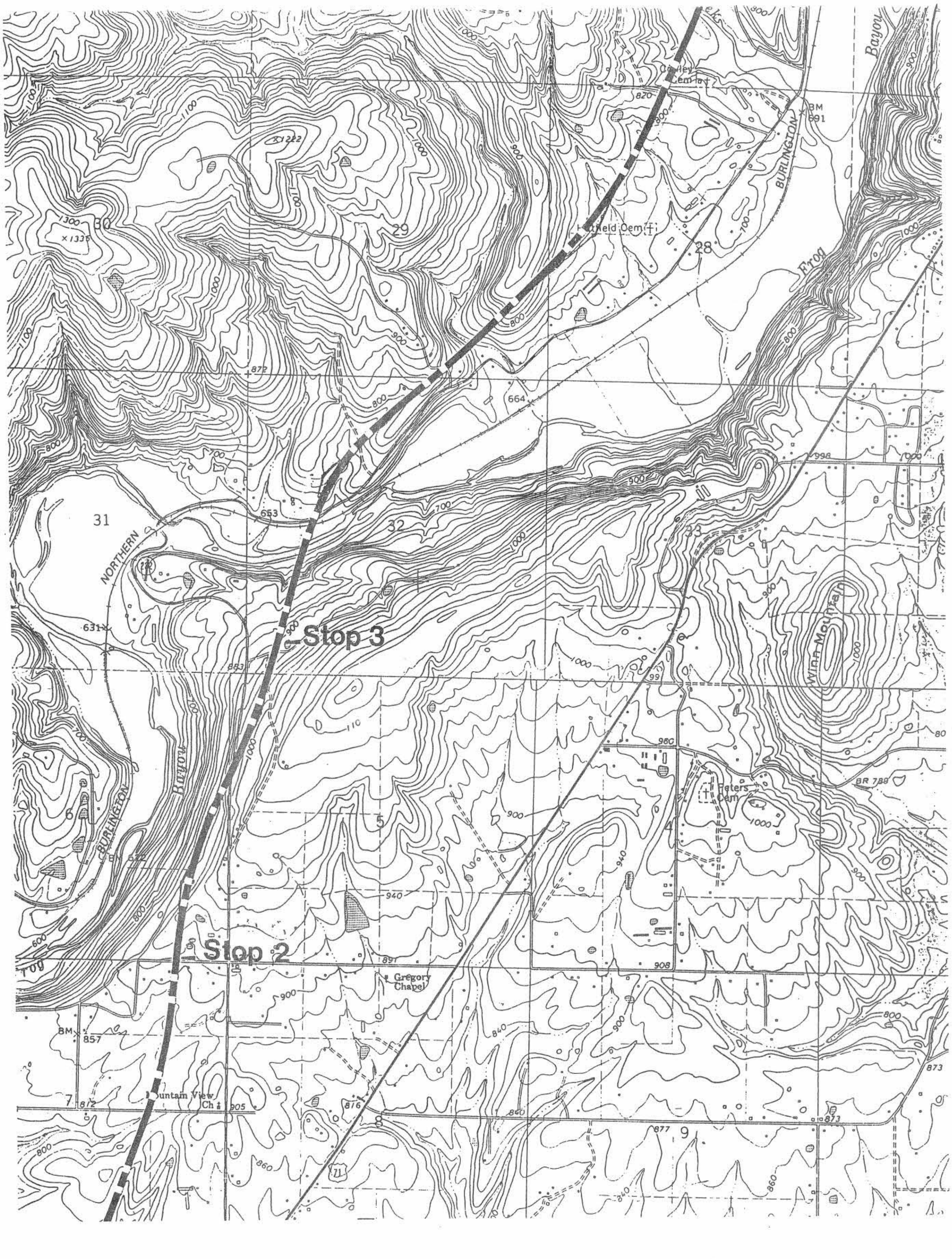


Figure 8. -- *Map showing STOPS 2 and 3 on U.S. Hwy. 71 relocation route at Frog Bayou and vicinity.*

and fissile to clayey gray-black shale represent several cycles of southward prograding deltaic deposits in the lower Atoka Formation (Figure 9A). A thin coaly seam occurs in the shaly clay interval at the top of a channel sequence. Ripple marks, cross-bedding, load features, scour channels, shale and sandstone clasts, and coalified plant fragments are abundant in some sandstones. Bioturbations (worm trails, burrows, etc.) and some invertebrate fossils are present in a few of the siltstones and silty shales. Small amounts of pyrite and its white oxidation product (iron sulfate) and white to yellow sulphur are present in the coaly interval and in some channel sandstones.

Several small normal faults, usually downthrown to the south, offset the gentle southward dipping strata and are marked by an increase in the density of joints. Small slickensides and some brecciated rock often occur in the fault zones. The small faults are likely splays from the larger fault(s) immediately to the north at STOP 3.

At this road cut, 89,000 cubic yards of material were removed. Some relatively small landslides have formed along the northeast side of the excavation, mostly in the soils and partially weathered shales (Figure 9B). They are presently being evaluated for removal and/or remedial procedures. Most of the landslides occur in the same stratigraphic interval that has caused significant landslide accumulations at STOP 3 -- some 0.7 miles to the northeast. The problem is mostly related to the high degree of the slopes and the high surficial water content of the weathered shales. Thin bentonite-rich shales are reported in the lower Atoka and upper Bloyd and they probably occur in these strata. Especially upon weathering, these intervals could further aid and abet the local instability of the bedrock and soils.

22.4 **STOP 3. FROG BAYOU BRIDGE AND LANDSLIDES.** Begin at overpass for State Hwy. 282 and proceed on foot some 0.6 miles to south edge of Frog Bayou bridge (Figure 8).

Here we will discuss problems of landsliding in sandstone-shale complexes in the lower Atoka Formation, and some possible solutions. The engineering properties of these interlayered sedimentary rocks and their residual soils can be complex. The materials are anisotropic, reflecting their original structure and also subsequent changes in the local character, including the man-made changes caused by construction. Most landslides in the Pennsylvanian sandstones and shales are directly related to the original rock structure and their total environment.

A series of rather small northeast-trending normal faults, mostly downthrown to the north, cut across the area between the slide and Frog Bayou Bridge. The lithology on the downthrown side of the fault plane complex is for the most part wet, notably unstable colluvium. In the process of excavation within the area between the slide and the bridge, several large boulders were removed. These boulders are further indication of the presence of the faults. A large downthrown-to-the-south normal fault also occurs near the center of Frog Bayou Bridge thus the area between the two fault zones is a graben (Boyd R. Haley, personal commun., 1992).

Initially, the roadway was excavated with nearly vertical slopes, removing over 91,000 cubic yards of material. During the excavation period, cracks were discovered in the colluvium near the top of the slope. At this time, the contractor began excavating the colluvium on a gentler 3:1 slope to prevent possible failure. However, after a heavy local rainfall, large amounts of surface water runoff and increased subsurface seepage caused two slope failures to occur in the immediate area (Figure 10 A).

In reconstructing the failed slope, all soft unstable material was excavated on a 2:1 slope from near the existing right of way to the durable shale (Figure 11). A rock buttress was constructed on the shale with the toe 120 feet right of centerline. The maximum height is 25 feet as measured from the toe. Constructed on a 4:1 slope, the backfill material consists of a soil and rock mixture and/or Type II material chiefly composed of shale with a Slake Durability Index (SDI) of 50-95, or any other rock-like

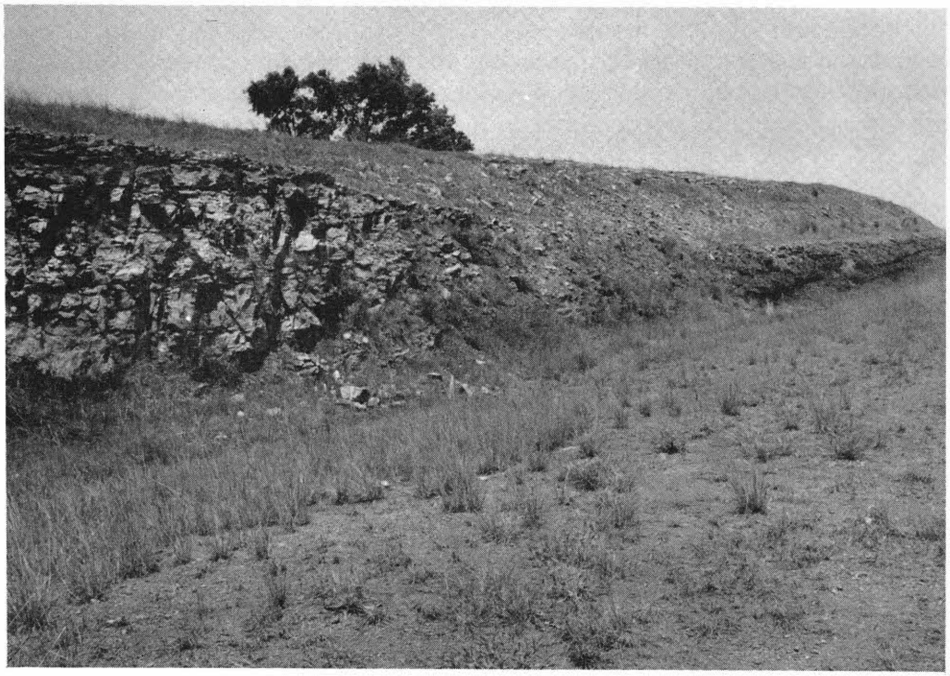


Figure 9 A. -- *Small fault separating massive channel sandstone with abundant joint sets on left from thin siltstones and shales on right in the lower Atoka Formation. The downthrown block is on the left (south).*

Figure 9 B. -- *Minor landslides with a series of crown scarps and small pressure ridges in soils and weathered shales at the northeast part of STOP 2 roadcut.*

Figure 9 -- *STOP 2*

Figure 10 A. -- *A small recent continuation of a formerly larger landslide at the south part of STOP 3.*

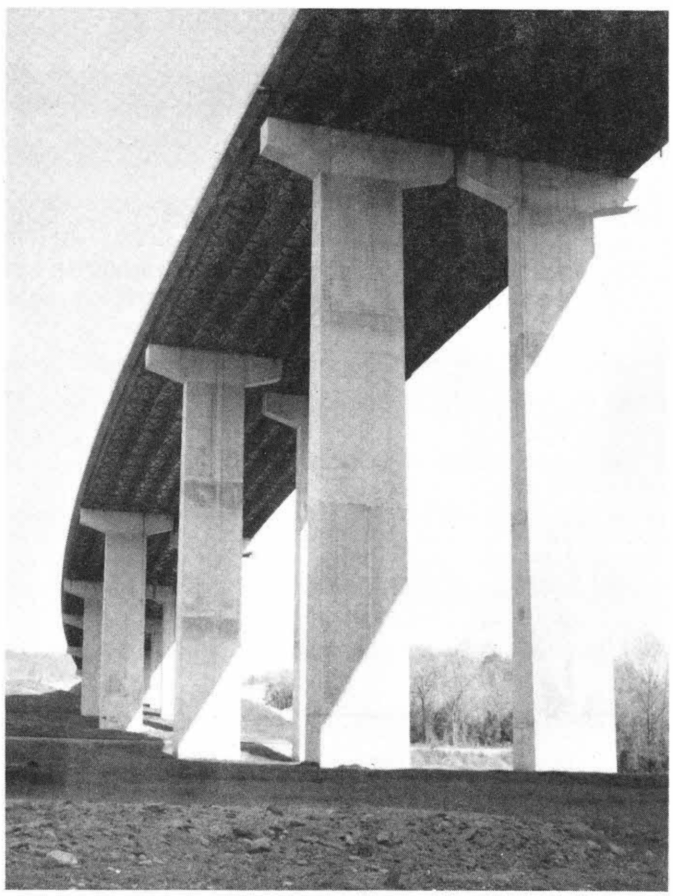


Figure 10 B. -- *View of columns and span on 198-foot high and 2287-foot long Frog Bayou bridge.*

Figure 10 -- *STOP 3*

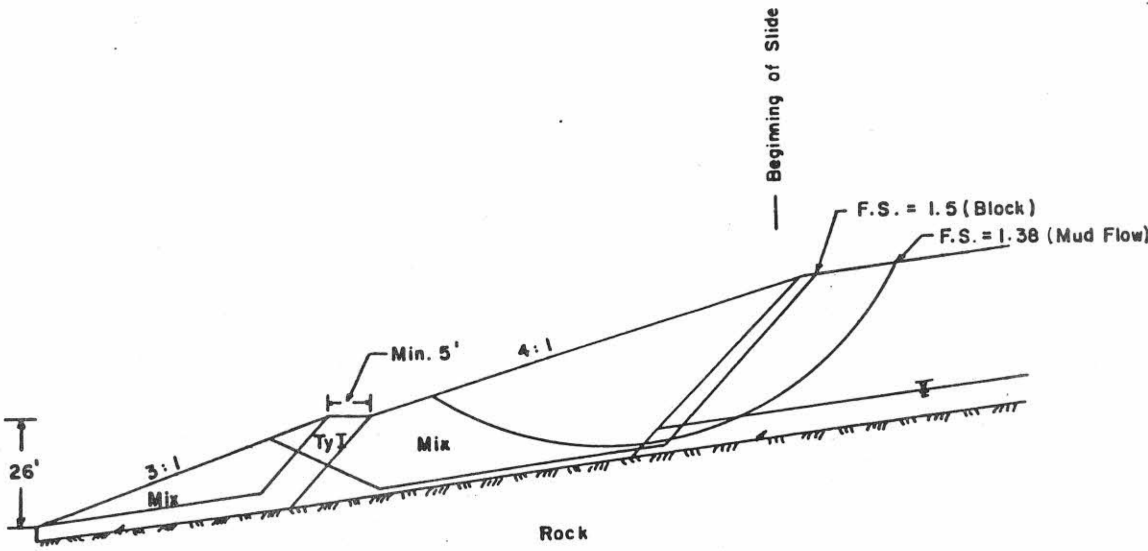


Figure 11. -- *This typical section from the construction plans illustrates the design criteria taken to correct the Slope Failure at STOP 3.*

material. The material used for the rock buttress is composed of Type I granular materials with boulders no greater than 18" or shale with a SDI greater than 95.

This particular slide repair also involved constructing a special 3' x 2' rock drain composed of Class B concrete aggregate and a filter fabric in a ditch on the slope to intercept water and direct it to the roadway ditch.

In addition to discussion of the slides, there will be a summary of the construction at the Frog Bayou Bridge (Figure 10 B). The Frog Bayou Bridge is one of the highest in this part of the country. Its highest point, measured from the bridge deck to the bottom of the pier, is 198 feet. The bridge is 2287 feet in length. Proceed north across the bridge.

23.6 Continue beneath Frog Bayou bridge and turn left (northeast) on State Hwy. 282 to Mountainburg, Arkansas.

24.5 Small concrete bridge on State Hwy. 282.

25.9 Small concrete bridge with minor retaining wall on State Hwy. 282.

26.7 **OPTIONAL SCENIC STOP. SILVER BRIDGE ON STATE HWY. 282 OVER FROG BAYOU.**

There are several normal faults dissecting the lower Atoka and they are indicated by the lithologic "pinchouts" of massive sandstones in the overlying bluff. The stream alluvium is composed mostly of sandstone pebbles and cobbles and locally exceeds 10 feet in thickness.

27.6 Crossing Missouri-Pacific Railroad tracks.

27.9 Town of Mountainburg, Arkansas. Proceed left (north) on U.S. Hwy 71.

28.1 Downtown Mountainburg, Arkansas.

29.7 Lake Fort Smith State Park to right.

30.0 Bridge over Frog Bayou.

31.8 Several small normal faults exposed in lower Atoka Formation on right.

36.8 **LUNCH STOP. ARTIST POINT REST AREA** (on west side of Hwy. 71). This is an opportunity to enjoy views of the rugged scenery of the Boston Mountains, with Lake Shepherd Springs in the valley to the east (Figure 12 A). Ozark handicrafts and other items are available at the nearby shops.

There is a general accordance of the Boston Mountain summits with occasional monadnocks such as White Rock Mountain in the distance to the east. To most early workers these summits represented the oldest "peneplain" surface developed in the Ozark region. Later investigations have added some new concepts about the surface, notably that it was formed by semi-arid pediplain erosion during a late Tertiary or early Pleistocene interglacial cycle. Mr. Jake Clements, a member of A.H.T.D., did graduate work on the origin of these high surfaces and has kindly consented to discuss them during the lunch stop.

39.2 Massive thick channel sandstones in the lower Atoka Formation are exposed in the roadcuts to left.

39.5 Mount Gaylor tower and shops. The elevation is 2,090 feet.

40.5 Leave Crawford County and enter Washington County.

43.1 Entering Winslow, Arkansas.

44.9 Bridge on upper West Fork of White River.

47.5 Junction of State Hwy. 74 (east); continue north on U.S. Hwy. 71.

48.2 Entering Brentwood, Arkansas. This is the type section of the Brentwood Limestone Member of the Bloyd Shale.

49.0 Rest Area on left.

52.5 Turn left on Washington County road 35 at Woolsey, Arkansas. The type section of the Woolsey Member of the Bloyd Shale (Lower Pennsylvanian) occurs in exposures adjoining this site.

52.6 Woolsey bridge over West Fork of White River.

52.8 Crossing Missouri-Pacific Railroad tracks.

53.0 Juntion of Washington County roads 35 and 228, at Pitkin Corner. Proceed right (north). The Pitkin Limestone (Upper Mississippian) was named for the old post office at this site.

53.8 Entering West Fork, Arkansas.

54.7 Turn left on dirt road at Karnes Cemetary sign.

55.2 Junction with several work roads used in construction on relocated U.S. Hwy. 71. Proceed left (south).

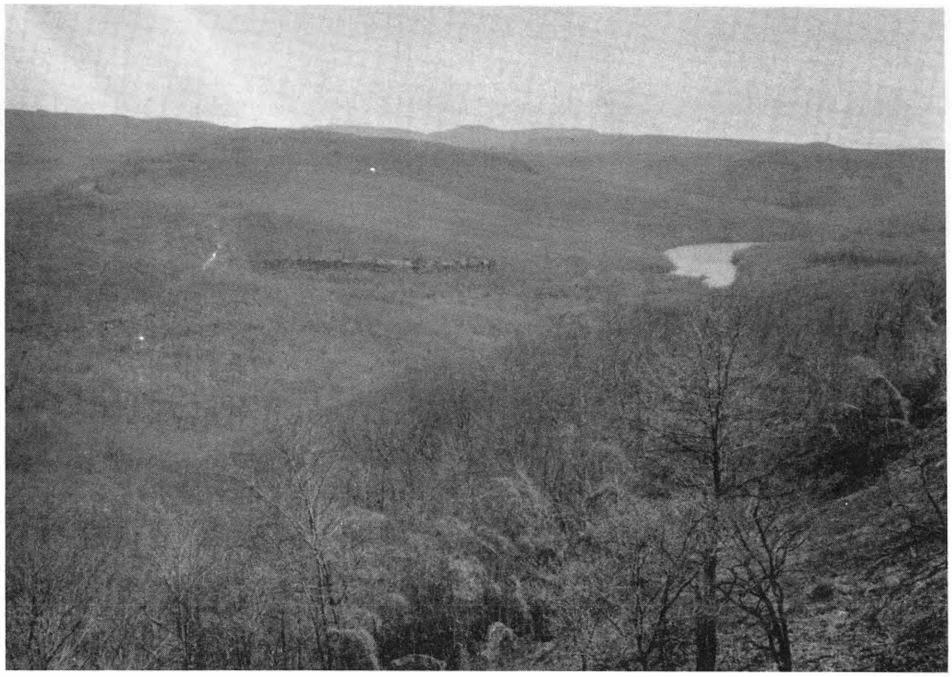


Figure 12 A. -- *Scenic view of the Boston Mountains from Artist Point rest area with Lake Shepherd Springs and large bluff formed by massive sandstones of the lower Atoka Formation in the valley below.*

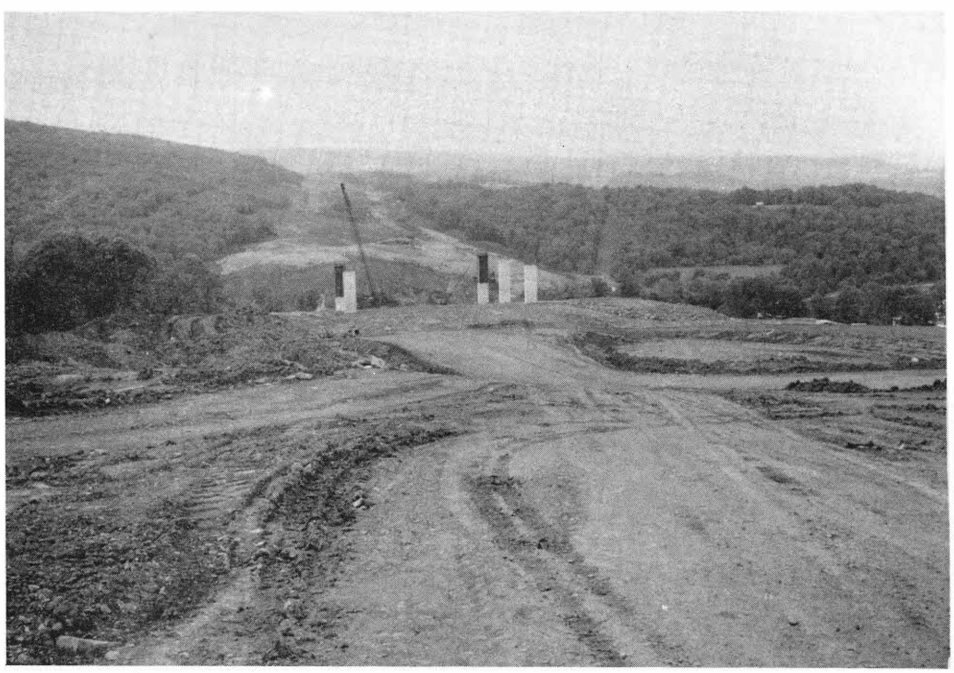


Figure 12 B. -- *Excavation, bridge, and buttress walls south of West Fork, Arkansas in lower Atoka and Bloyd strata at STOP 4.*

Figure 12 - *LUNCH STOP and STOP 4*

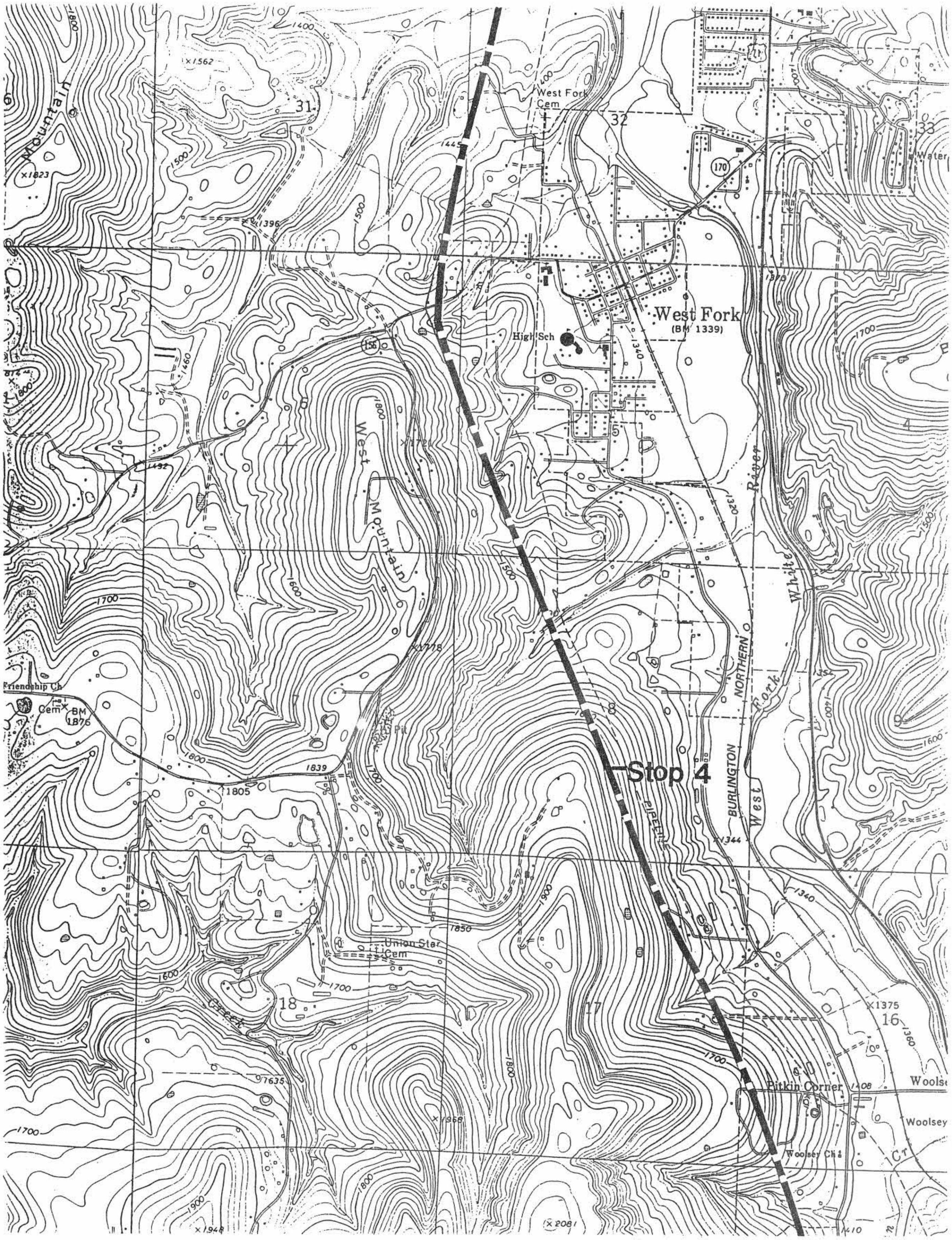
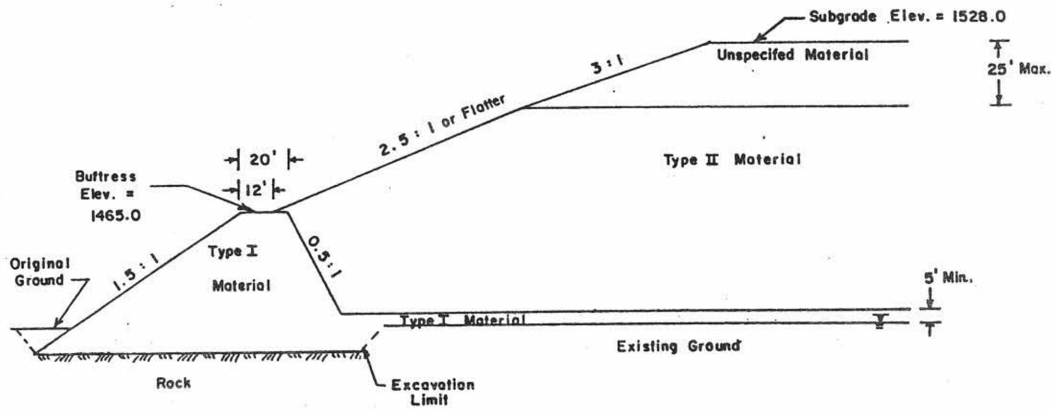


Figure 13. -- *Map showing STOP 4 on relocation route for U.S. Highway 71 in southern West Fork, Arkansas.*

55.5 STOP 4. SOUTHERN WEST FORK EXCAVATIONS, BRIDGE, AND BUTTRESS WALLS

At this stop there will be an opportunity to discuss and evaluate the numerous geotechnical problems of extensive side hill excavations, bridge construction across a narrow valley, and buttress walls over 70 feet high that are undercut as much as 20 feet to achieve foundation stability (Figures 12B,



JOB NO. R40044
TYPICAL BUTTRESS DESIGN

Figure 14. -- *Typical section from the construction plans illustrating the design criteria adapted for the buttress at STOP 4.*

13, and 14). The problems were accentuated by the structural unpredictability of the interbedded Atoka and Bloyd sandstones, shales, and minor limestones and conglomerates. Construction projects in several adjoining states with similar geotechnical conditions have experienced costly failures caused by long-term degradation of shale and interlayered strata in embankments. These include large slope failures and, as here, the potential of detrimental foundation settlement and creep.

Owing to the preponderance of shales along the Highway 71 relocation project, the Slake Durability Index (SDI) test procedure was adapted and used by A.H.T.D. whenever applicable. Based on discussions with highway engineers in other states, and the Federal Highway Administration, and based on our geotechnical investigation, soil and rock parameters were assigned to three types of embankment materials to be used in this project for design purposes: Unspecified, Type II and Type I. The parameters are as follows:

Unspecified Material

c = 500 psf ϕ = 70 degrees δ = 120 pcf	Includes soil and soil-like shale w/SDI 0-50

Type II Material

c = 200 psf ϕ = 26 degrees δ = 130 pcf	Includes intermediate shale with SDI 50-94, and/or non-durable sandstone and weathered sandstone

Type I Material

c = psf ϕ = 35 degrees δ= 135 pfc	Includes rock-like shale with SDI 95+, and /or limestone & durable sandstone

The material specifications were written primarily for thick sequences of shale and did not address sequences composed primarily of sandstone; however, it did address interbedded sandstones with interbedded shale. A solution to the materials problem for the stability of this particular buttress, and to maintain the above design parameters, was to allow Type II materials to contain mostly hard and durable rock and soil-like degradable material.

Due to a shortage of material, one alternative discussed for this job was to redefine the SDI requirements for various specified materials. Obviously, if changes are made in these specifications, design material parameters and embankment designs would require re-evaluation to verify their stability.

Within the immediate area, over 3,336,000 cubic yards of material was removed to meet the specific grade design.

This is also a fine opportunity to examine thick-to thin-bedded alternating rock types along a long hill and valley excavation and the minor effects of a normal fault.

There are many exposures of upper Bloyd and lower Atoka strata at the excavations south of the buttress and bridge. A calcareous conglomerate contains some goniatites and other invertebrate fossils of probable late Morrowan age. These strata contain bioturbations (worm trails, burrows, etc.), ripple marks, cross-bedding and other features indicative of shallow marine and deltaic deposition.

Recently a "small" landslide took place 0.6 miles south of this site during excavation in the same general lithologic sequence. Again it is uncertain whether this landslide is completely due to the slope angle, wet weather conditions, contrasts in rock types or combinations thereof, or, in part, to abnormally high plasticities of some thin bentonite-rich shales.

55.8 Return north to work road junctions and continue east to Washington County roads 35 and 228.

56.3 Turn left on Washington County roads 35 and 228.

57.6 Junction of McKnight and Main Streets in West Fork, Arkansas. Proceed right (east). The shallow West Fork natural gas field is located in this area.

57.7 Turn left on Campbell Street and Washington County road 63.

58.4 Large blocks of slumped Pitkin Limestone on left. The West Fork of White River on right.

58.9 McClinton-Anchor quarry in Pitkin Limestone to (west) and view of relocated U.S. Hwy. 71 which cuts across the former quarry. Crushed rock and riprap is used on local construction projects, as well as on portions of the relocated U.S. Hwy. 71. A monadnock of Pitkin Limestone in the east end of the former quarry now lies east of relocated U.S. Hwy. 71 (Figure 15A). It is underlain by the Fayetteville Shale.

60.5 Junction of Washington County roads 63 and 65. Proceed left on County road 65.

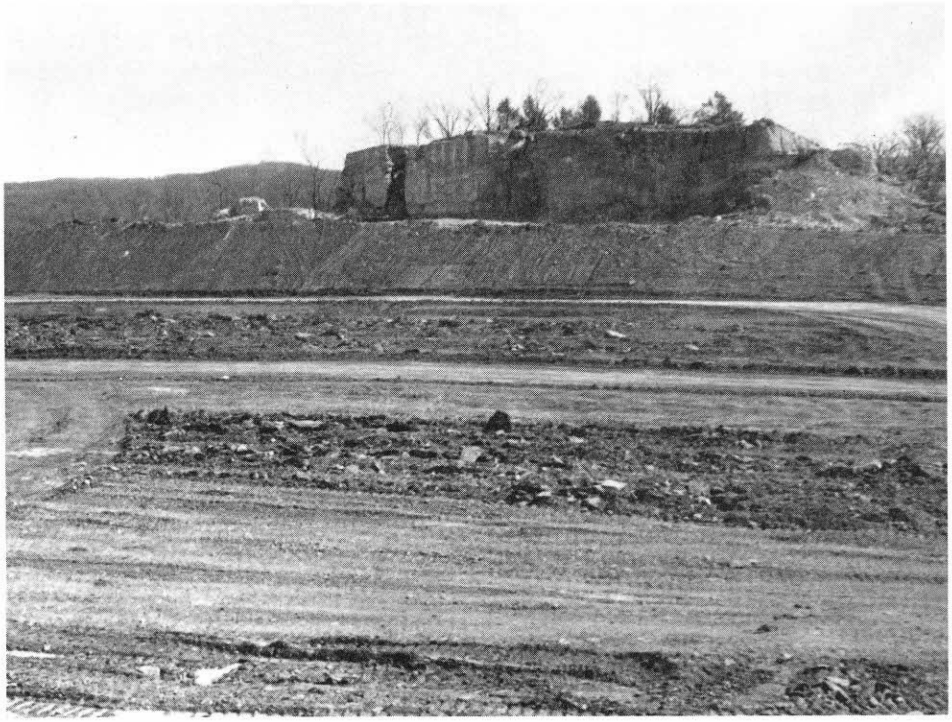


Figure 15 A. -- *A monadnock of Pitkin Limestone underlain by Fayetteville Shale on the east side of relocated U.S. Hwy. 71 and formerly a part of the McClinton-Anchor quarry at mileage 58.9.*

Figure 15 B. -- *Thin-bedded sandstones and shales of the Cane Hill Member overlain by a channel sequence of massive to thin sandstones of the Prairie Grove Member of the Hale Formation at mileage 64.3.*

Figure 15. -- *Mileages 58.9 and 64.3.*

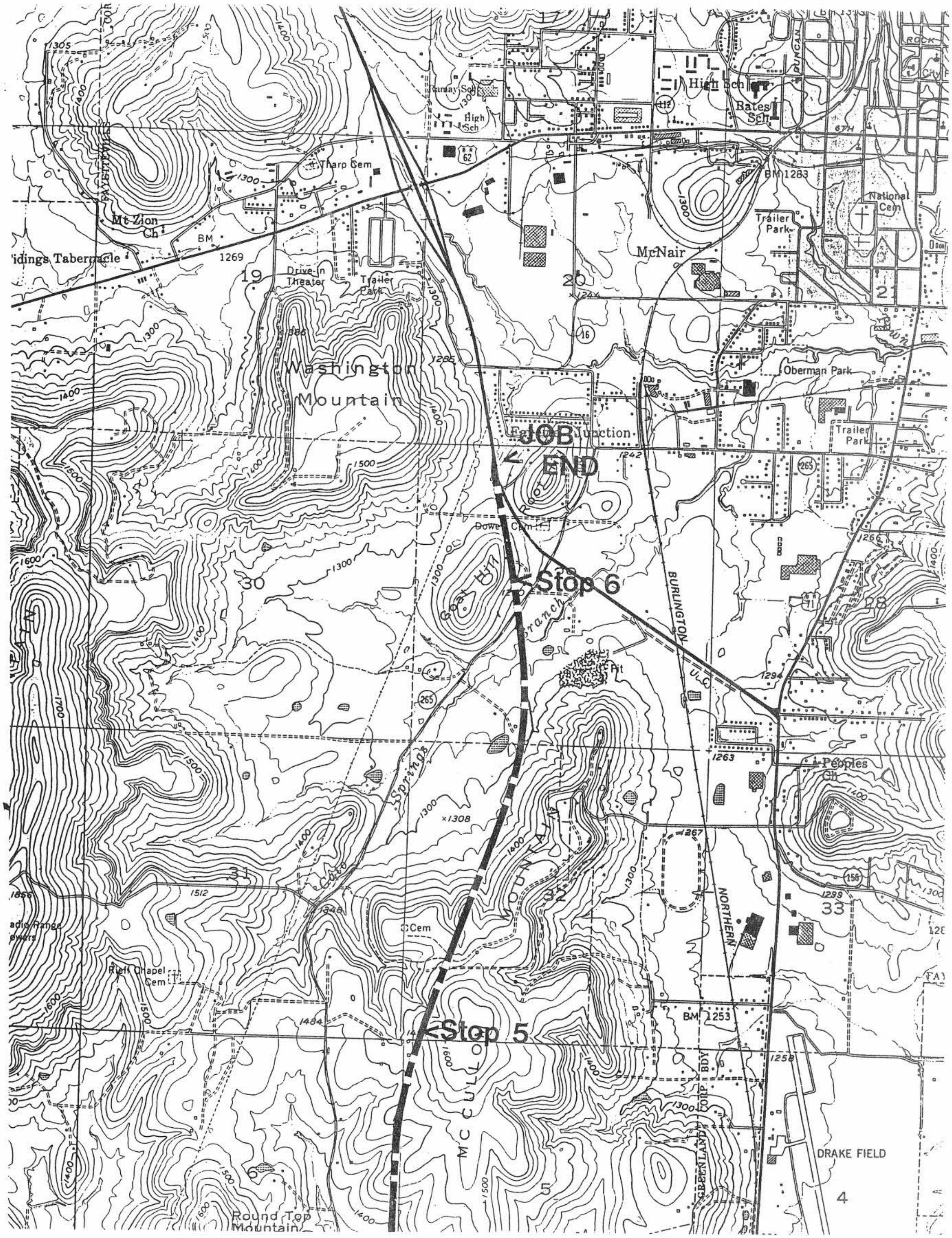


Figure 16. -- *Map showing Stops 5 and 6 on relocation route for U.S. Highway 71 in south Fayetteville, Arkansas.*

60.7 Overpass of Washington County road 65 and relocated U.S. Hwy. 71. Proceed on County road 65. The exposed massive brown sandstones are in the Hale Formation of Early Pennsylvanian age.

61.5 Pavement begins!

62.4 Washington County road 65 with temporary crossover on relocated U.S. Hwy. 71.

63.6 Junction of Washington County road from Greenland, Arkansas. Proceed west partially across relocated U.S. Hwy. 71.

63.7 Turn north on access lane for relocated U.S. Hwy. 71. Minor exposures of the Fayetteville Shale are present here.

64.3 Exposures of gentle south-dipping thin-bedded, brown sandstones and gray shales (Cane Hill Member) overlain by thin to massive brown, channel sandstones (Prairie Grove Member) of the Hale Formation (Figure 15 B).

64.9 **STOP 5. BRENTWOOD LIMESTONE MEMBER -- WESTERN McCOLLUM MOUNTAIN.**

The Brentwood Limestone Member of the Bloyd Shale is exposed in this large excavation (Figures 16 and 17A). The Brentwood consists of several limestone beds seperated by shales. The lowermost limestone with minor shale layers varies from about 3-15 feet in thickness. It is usually rather massive, bluish gray in color, highly cross-bedded, and very fossiliferous. The fossils include brachiopods, corals, bryozoans, crinoids, gastropods, and blastoids. Above this unit is a dark fissile clay shale that ranges from 5 to 12 feet in thickness. Another highly lenticular limestone of the upper part of the Brentwood Member overlies this unit and varies from 2 to over 12 feet in thickness. The total thickness of the Brentwood Member at this site is about 40 feet. About 25 feet of black to brownish gray clay shale with some thin brown silty sandstone beds of the Woolsey Member of the Bloyd Shale overlies the Brentwood Member (Doy L. Zachry, personal commun., 1992). The rocks dip gently to the south and are in the upthrown southeast block of the Price Mountain (Fayetteville) fault system about 0.8 miles to the north at STOP 6.

This locality provides an excellent example of the lateral and vertical variability of the Brentwood Member. Rapid thinning and thickening of the various lithologic types occur in the short distance of less than 1/4 mile. The interval is extensively channeled, and limestone units are often truncated by conglomerate, siltstone or shale.

To meet design requirements, some 1,022,000 cubic yards of material were removed in the excavations at STOP 5.

65.2 Proceed east over Washington County road at temporary "crossover", then north on right lane of relocated U.S. Hwy. 71. There are numerous exposures of brown sandstones and gray shales of the Hale Formation. At the north end of the roadcut, the Hale rests unconformably upon the Fayetteville Shale, the Pitkin Limestone being locally absent by erosion. Round to subangular cobbles and pebbles, mostly of Pitkin Limestone, are present in a reddish brown 4-foot-thick conglomeratic sandstone at the base of the Hale. Plant fossils are notably present in this interval.

65.5 Junction with State Hwy 265 to Cato Springs. Proceed across this road to north on relocated U.S. Hwy. 71 to the juntion with U.S. Hwy. 71 in south Fayetteville, Arkansas.

65.7 **STOP 6. FAYETTEVILLE SHALE AND PRICE MOUNTAIN GRABEN.**

Figure 17 A. -- *Interbedded light gray fossiliferous limestones and dark shales of the Brentwood Member overlain by dark shales and minor brown sandstones of the Woolsey Member at STOP 5.*

Figure 17 B. -- *White veinlets and encrustations of calcite and halloysite(?) on faulted and sheared surfaces of the steeply dipping Fayetteville Shale at STOP 6.*

Figure 17. -- *STOP 5 and STOP 6.*

A most interesting feature at this Stop (Figure 16) is a large graben (E.E. Glick, personal commun., 1992) formed by the downthrown strata between two large northeast-southwest-trending normal faults that form the Price Mountain (Fayetteville) fault system. The centerline cuts through the easternmost fault and the westernmost fault is about 1500 feet to the west. The bedrock is mostly black, fissile, organic rich shales of the lower Fayetteville Shale (Mississippian), and they occasionally contain invertebrate fossils, some being diagnostic goniatites (Doy L. Zachry, personal commun., 1992). Septarian ironstone concretions occur within the shales and have minerals encased in them, including calcite, gypsum, barite, pyrite, and halloysite; a few are oil saturated. Typically the strata dip from 20-35 degrees to the northwest. Thin sheared intervals with rock gouge and shiny slickenside surfaces are also present in the shale. Veins and encrustations of calcite and halloysite(?), up to 6 inches wide locally occur within this shale (Figure 17 B). Interpretation of the many cores from the borings further indicate numerous secondary faults within the graben. There is little lithologic continuity in the sheared and faulted cores. The two large faults forming this graben probably extend to the Precambrian granitic basement about 1500-1800 feet below.

Notice the absence of landslides and the presence of a hearty crop of recently seeded grass on the steep slope to the west where the Fayetteville Shale and the overlying Wedington Sandstone Member were excavated. Incidentally, some 684,000 cubic yards of material were removed from the entire construction site to meet design requirements.

IF TIME AND CONDITIONS PERMIT THE FIELD TRIP WILL CONTINUE TO THE CANNON CREEK ALTERNATE STOP about 22 miles east-southeast of STOP 6. The Cannon Creek locality is located on State Hwy. 16 about 1/2 mile southeast of the Washington-Madison County line.

ALTERNATE STOP. REINFORCED EMBANKMENT AT CANNON CREEK.

This site affords a brief examination of a 76-foot-high reinforced embankment where State Hwy. 16 adjoins Cannon Creek.

Arkansas State Highway 16 is a two-lane secondary road over the Boston Mountains linking Brashears and Fayetteville. In 1985, a realignment project involved replacing a hairpin curve and one-lane bridge over Cannon Creek, with a straightened roadway section, an embankment with a side slope height of 76 feet, and a four-barrel concrete box culvert (Figure 4).

In 1986, slope failures in the upper Bloyd Shale (Doy L. Zachry, personal commun., 1992) during the early stages of construction of the embankment eventually led to the cancellation of the project. In order to attain a greater safety factor against slope failures, several alternatives were considered. In 1987, construction resumed under a new contract which included the use of geogrid material as the primary embankment reinforcement. The new contract also included instrumentation and monitoring plans to evaluate the performance of the reinforced embankment.

While under construction, monitoring instruments were installed at different locations throughout the downstream side of the embankment. Instrumentation consisted of multipoint extensiometers, inclinometers, strain gages, settlement stakes, tensiometers, pneumatic piezometers, soil matrix potential sensors, and moisture-temperature indicators. Instrumentation has provided useful information on the effectiveness of the reinforcement in terms of embankment stability, cost, and long-term maintenance projections.

The material used for the embankment fill was a highly plastic clay (AASHTO[1] type A-7-6). Attenberg limit tests performed on 9 samples recovered from borings in the borrow areas gave a high average plastic index of 35. The clay was believed to have a high shrink-swell ratio. Grain-size analysis indicated that all samples had at least 70% by weight of material finer than the #200 sieve. The

[1] American Association of State Highway and Transportation Officials

unconfined-undrained triaxial tests on compacted samples of the clay indicated an undrained shear strength of about 900 psf.

The design by the geogrid supplier utilized three primary reinforcement grades, designated as types 1, 2, and 3. They are assumed to have allowable 120-year design strengths in one material direction of 1,000, 2,000 and 3,000 lb/ft. respectively. Specifically, total geogrid strain at the allowable design load was limited to 10% over 120 years in order to limit long-term embankment deformations.

The design specified that continous horizontal layers of intermediate reinforcement consisting of lightweight geogrid extending 4.5 feet into the slope, be placed on 1-foot vertical intervals over the entire slope face. Intermediate reinforcement is believed to be a necessity when dealing with expansive clay soils.

The fill was spread in nominal 8-inch lifts. Sheep-foot rollers were used to compact the clay fill to the specified minimum 95% relative compaction according to the AASHTO-T-99 standards. Specified moisture contents ranged from optimum to 4% dry of optimum for the lower 30 feet of embankment and from +2% to -2% of optimum in the upper embankment section.

The design and stability analysis of the embankment was implemented using a factor of safety of 1.3, foil phi angle of 20 degrees, and soil cohesion of 50 psf.

END OF FIELD TRIP -- PROCEED TO THE FAYETTEVILLE HILTON.

ARKANSAS STATE HIGHWAY
AND
TRANSPORTATION DEPARTMENT

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September 16, 1994

AN ADDENDUM TO THE GUIDEBOOK TO THE HIGHWAY GEOLOGY AT SELECTED SITES IN THE BOSTON MOUNTAINS AND ARKANSAS VALLEY, NORTHWEST ARKANSAS published August, 1992.

October 7, 1994 staff from the Arkansas State Highway & Transportation Department will lead a field trip through the U.S. 71 Relocation Project from Alma to Fayetteville. This field trip will differ from the 1992 and last years only in the observation of new construction.

New areas of interest will be grade completion's from the Frog Bayou Bridge near Deans Market to Chester. This area includes another high bridge, nearly 150' in height, and 1200' in length. Also, a couple of deep split rock cuts, one being near the Chester Interchange.

Unfortunately, there is nothing to look at as far as a tunnel. The construction contract for the proposed tunnel is scheduled for letting in February 1995.

The grade is completed now from Woolsey to Fayetteville. We will observe several new features as well as stops we were unable to observe last year due to the weather.

Other handouts will be available at the field trip.

Sincerely

David Lumbert
Geologist