GUIDEBOOK 82--2

STATE OF ARKANSAS

ARKANSAS GEOLOGICAL COMMISSION

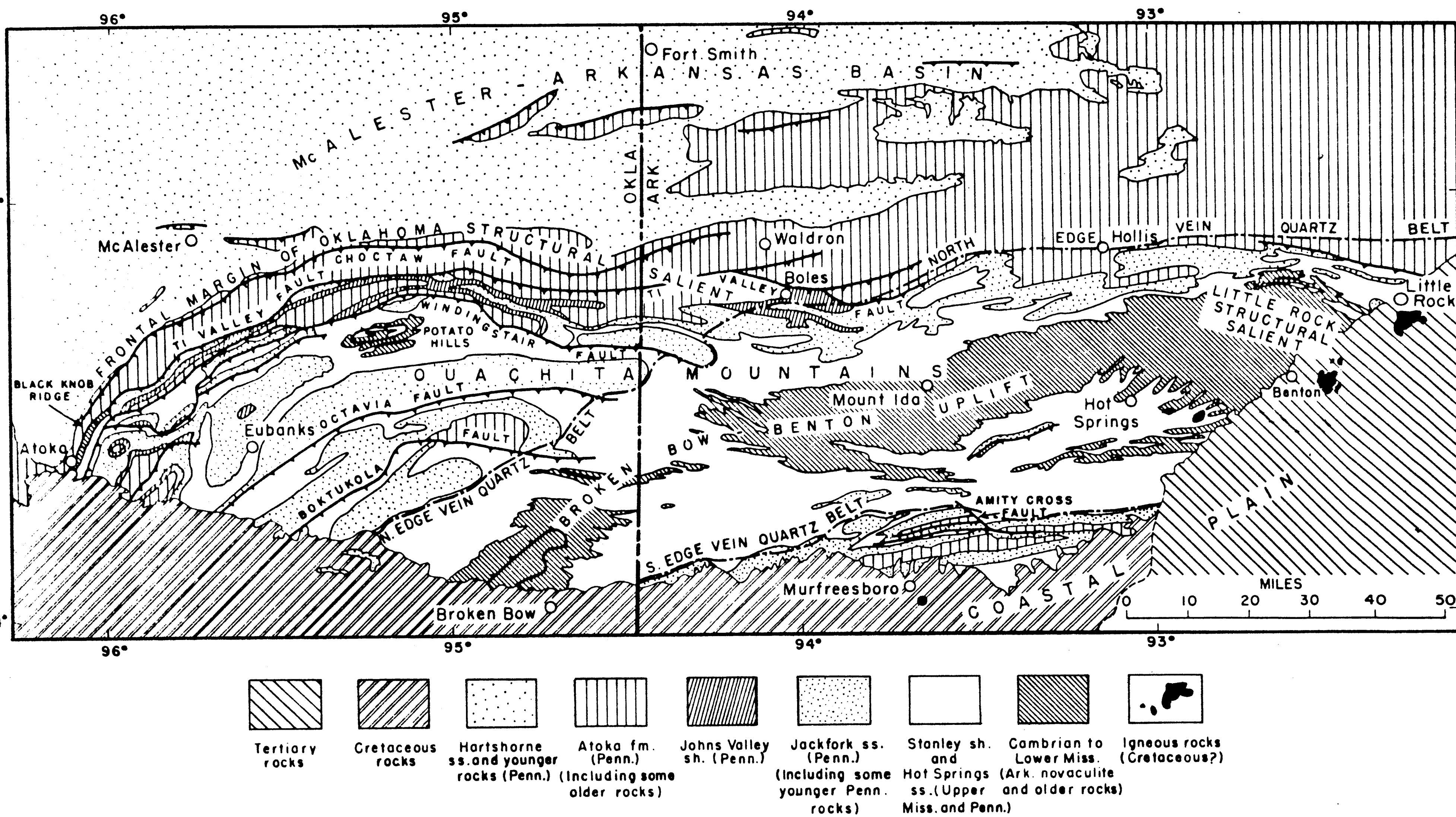
Norman F. Williams, State Geologist

GUIDEBOOK TO THE GEOLOGY OF THE EASTERN OUACHITA MOUNTAINS ARKANSAS

By

Charles G. Stone and William V. Bush

Prepared for the Houston Geological Society
Little Rock, Arkansas
April, 1982



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

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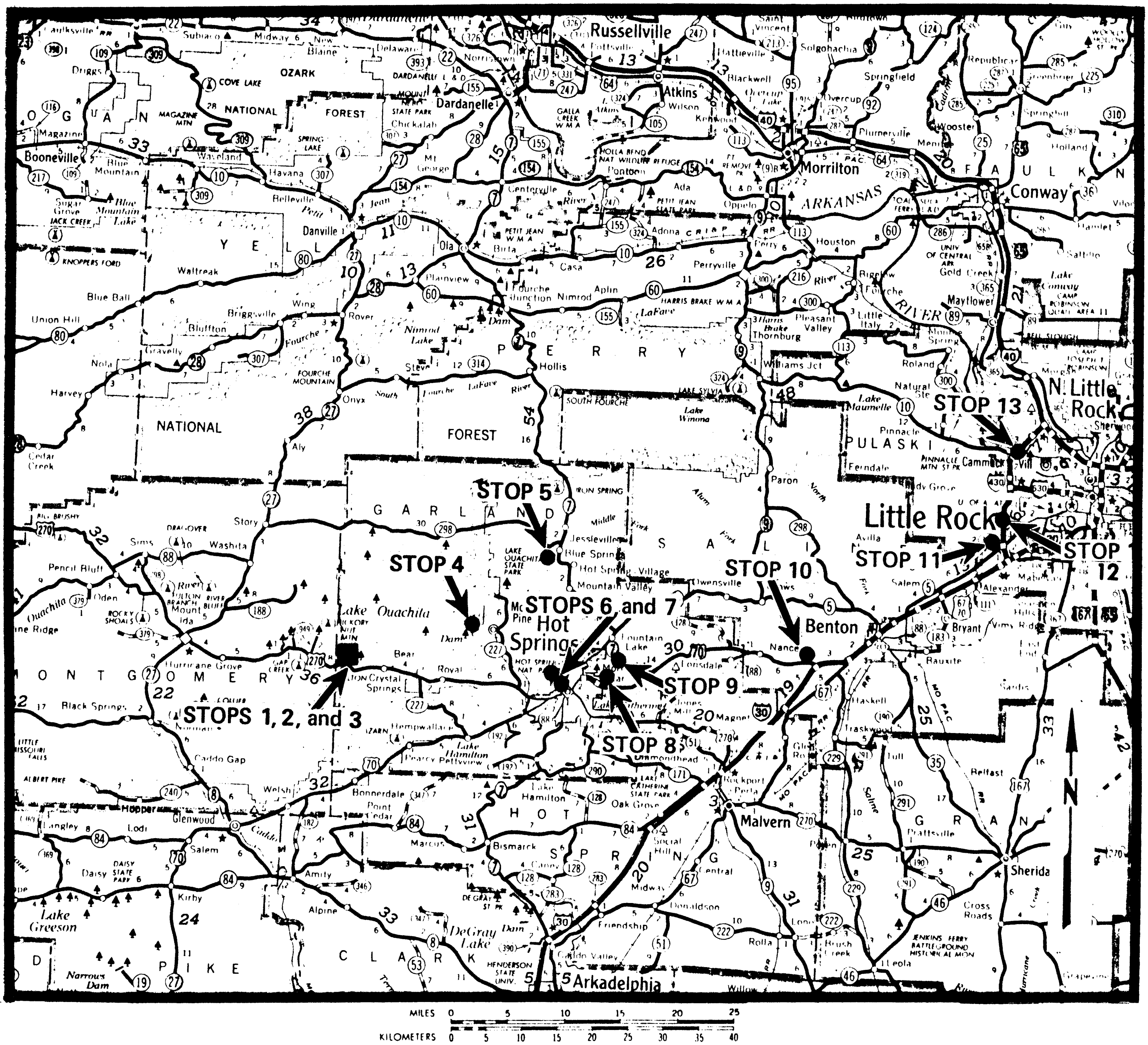
PREFACE

This guidebook provides information on selected outcrops of Paleozoic rocks in the eastern Ouachita Mountains of Arkansas. The purpose of the trip is to show the distinctive lithologies and discuss the depositional environments of the respective rock units, and also to demonstrate the intensity and styles of deformation in various structural belts. Some emphasis is placed on the formation of late Paleozoic hydrothermal quartz veins, early Late Cretaceous igneous intrusions, and pre-Tertiary and Tertiary weathering and overlap.

A debt of gratitude is expressed to Boyd R. Haley (U.S.G.S.), who participated materially in the compilation of this guidebook. Special thanks are also expressed to Jim Coleman for permission to enter the quartz mine, and to Charles Steuart of Malvern Minerals for his contribution to the trip.

LIST OF STOPS



INDEX MAP OF STOPS

GENERAL LITHOLOGIC DESCRIPTION OF UNITS TRAVERSED ON TRIP

	Maximum Thickness
Quaternary System	
Alluvium--clay, silt, sand, and gravel	90′
Terrace Deposits--gravel, sand, and clay	40′
Tertiary System	
Eocene Series	
Wilcox Group--sand, clay, lignite, and bauxite	250′
Paleocene Series	
Midway Group--clay, marl, and limestone	65′
Cretaceous System	
Igneous Intrusives--nepheline syenite, lamprophyre, trachyte and others	—
Pennsylvanian System	
Morrowan Series	
Johns Valley Shale--shale, sandstone, erratic boulders to west	1,500′
Jackfork Sandstone--sandstone and shale. Some as olistolithic intervals.	6,000′
Mississippian System	
Stanley Shale--shale, sandstone, some chert, volcanic tuff, and barite	9,500′
Devonian and Mississippian Systems	
Arkansas Novaculite (Upper, Middle, and Lower Divisions)--novaculite, chert, shale, and conglomerate	950′
Silurian System	
Missouri Mountain Shale--shale with minor sandstone and conglomerate	250′
Blaylock Sandstone--sandstone, siltstone, and shale	1,000′
Ordovician System	
Polk Creek Shale--shale and some chert	150′
Bigfork Chert--chert, limestone, and minor shale	800′
Womble Shale--shale with some thin limestone and sandstone	2,500′
Blakely Sandstone--shale, sandstone, and conglomerate. Some erratic-bearing intervals	450′
Mazarn Shale--banded shale with some sandstone and limestone	2,000′
Crystal Mountain Sandstone--sandstone with some shale and conglomerate	850′
Collier Shale--shale and limestone	1,000′

STOP 1 – CRYSTAL MOUNTAIN SANDSTONE AT MONTE CRISTO

A series of nearly flat-lying interbedded orthoquartzites and buff to gray banded shales of the Crystal Mountain Sandstone are exposed on the south roadcut of U. S. Hwy. 270 northwest of the Monte Cristo Rock Shop. The surrounding hills are formed by massive sandstones of the Crystal Mountain. Near the base of the Crystal Mountain in this area are intervals of thin-bedded, gray micritic limestone and thin-to thick-bedded conglomerate composed of clasts of limestone, sandstone, and chert. Hydrothermal quartz veins in cavities and joints are common in the Crystal Mountain.

Small cross-laminations and graded bedding indicate that the rocks are upright. These rocks appear to be near the center of an anticlinal flexure, but they dip under the Collier in all directions. The contact between the two formations is a low-angle thrust fault that has been folded. The Crystal Mountain is being seen through a structural window.

Sequences of upward bed thinning and grain fining suggest that the sandstone at this stop was deposited in a submarine fan channel. The sediments were derived from submarine ridges, slopes, scarps, and possibly foreland facies to the north and northeast, and deposited as turbidites and fluxoturbidites in middle and upper submarine fan deposits. Davies and Williamson (1977) stated that the Crystal Mountain and Blakely Formations were deposited in a shallow-marine basin.

STOP 2 -- COLLIER LIMESTONE AT MURPHY CREEK

The upper Collier Shale crops out 0.2 miles east of the Monte Cristo Rock Shop on Murphy Creek. The outcrop consists of micritic to pelletoidal, very thin to massive bedded limestone, gray shale, and black chert. Small pellets and oolites are present in the more massive limestone south of the bridge, which forms a good marker in the Collier throughout the region. Some of these massive limestones contain clasts of chert, limestone, and sandstone.

Graded bedding and cross laminations indicate the beds are upright and inclined to the south. The isoclinal folds are overturned or recumbent to the south. Strain has caused well-developed cleavage, flowage of shale in the fold hinge line, and boudinage in some beds. Small hydrothermal quartz-calcite veins fill fractures in the Collier. The folds appear to be relatively straightforward, but detailed studies in the area by Stone and Haley in 1980 and a thesis by Paul Soustek (SIU 1979) have proved otherwise. There are several epochs of folding, the earliest probably caused by soft-sediment deformation. The faulting is equally complex.

Wise (1963) reported biologic features in thin limestones of the Collier south of Mount Ida, Arkansas. These were thought to represent algal structures but now are considered trace fossils. Repetski and Ethington (1977) obtained conodonts from Collier limestone intervals in Arkansas and Oklahoma that confirmed an Early Ordovician (Tremadocian) rather than a Cambrian age. They stated that the presence of *Cordylodus angulatus* Pander established the Early Ordovician age. They further stated that this species joined by other distinctive elements includes both simple cones and multidenticulate forms. These include: *Paldotus bassleri* Furnish, *Loxodus bransoni* Furnish; *Ancanthodus lineatus* Furnish; *"Oistodus" triangularis* Furnish, and *Chosondina herfurthi* Muller. This fauna was designated "Fauna C" in North American studies, thus making the Collier correlative with the McKenzie Hill Formation of the Arbuckle Mountains and the Oneota Dolomite of the Upper Mississippi Valley.

In the Broken Bow area of Oklahoma Pitt (1955) applied the name Lukfata Sandstone to a sequence of shales, thin bedded limestones, and sandstones that he considered older than the Collier Shale. Repetski and Ethington (1977), on the basis of conodonts, showed that the Lukfata is younger than the Collier and can be correlated with the Crystal Mountain Sandstone or possibly the Mazarn Shale.

STOP 3 — MAZARN SHALE, BLAKELY SANDSTONE AND WOMBLE SHALE AT THE CHARLTON RECREATION AREA

The upper Mazarn Shale, Blakely Sandstone, and lower Womble Shale are exposed along Murphy Creek and in the roadcuts on both sides of U. S. Hwy. 270 south of the Charlton Recreation Area.

Mazarn Shale

The upper part of the Mazarn is poorly exposed in the creek and consists of greenish-black banded shale, thin gray siltstone, light gray fine-grained sandstone, and dark gray micritic limestone.

Blakely Sandstone

East along the creek are outcrops of the lower and middle parts of the Blakely. The lower part consists of thin-bedded quartzitic sandstone and shale. The middle part consists of tan-black banded shale and thin-to thick-bedded quartzitic sandstone. The thicker bedded sandstones are well exposed at the east end of the bridge.

East of the bridge in the roadcut is an outcrop of thin bedded quartzitic sandstone and gray-black banded shale in the upper part of the Blakely. In this outcrop the Blakely is cut by two partially weathered lamprophyre igneous dikes (monchiquite), probably early Late Cretaceous in age.

Bottom marks, cross laminations, graded bedding, and the position of the Womble indicate the top of the complexly folded sequences is to the south. Discontinous sandstone masses, sedimentary pull-aparts, structural boudinage and well-developed northward dipping cleavage are present in the Blakely.

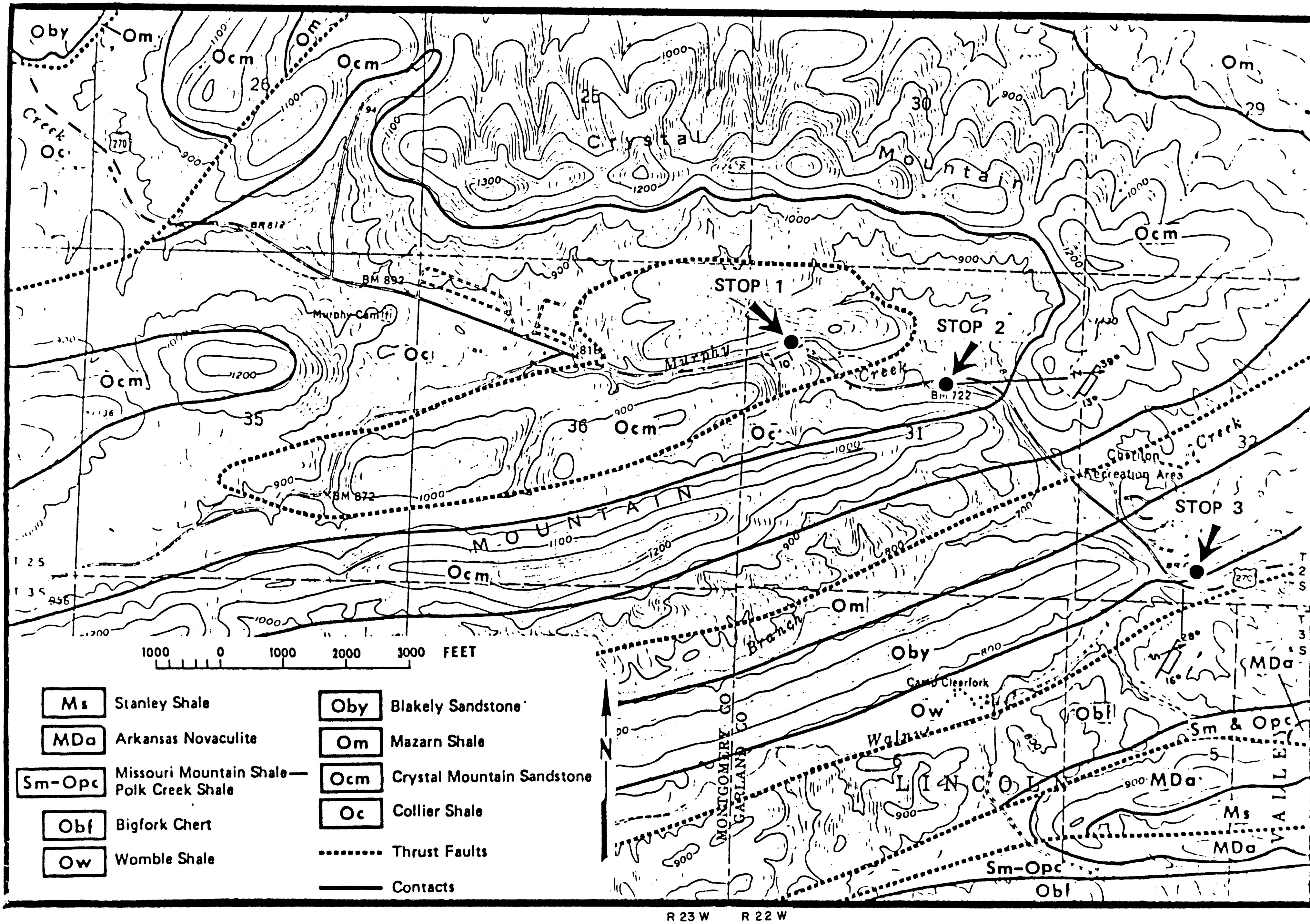
The Blakely often contains two prominent divisions of sandstone, thus has often been referred to as the "double Blakely Sandstone". Several of the sandstone sequences are thinning upward and could have been deposited in a midfan submarine channel with a source area to the northeast.

Womble Shale

The lower part of the Womble is exposed above the upper Blakely in the roadcut. The rocks consist of black shale and thin lenses and beds of medium grained, slightly phosphatic sandy limestone. The shale weathers to a brown color and the limestone contains sponge spicules and other bioclastics. The bioclastic limestone lenses may have been deposited by submarine sediment slurries from local and, in part, extrabasinal sources that existed along the northern flank of the Ouachita trough. J. Keith Rigby of Brigham Young University examined the Womble limestone containing sponge spicules from this site and stated:

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

Recent studies by Repetski in 1980 indicate that the lower Womble is Middle Ordovician in 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 mélange 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) described some similar argillaceous brownish-green sandstones in the Broken Bow area of Oklahoma.



GEOLOGIC MAP OF McGRAW MOUNTAIN AREA — STOPS 1, 2, and 3

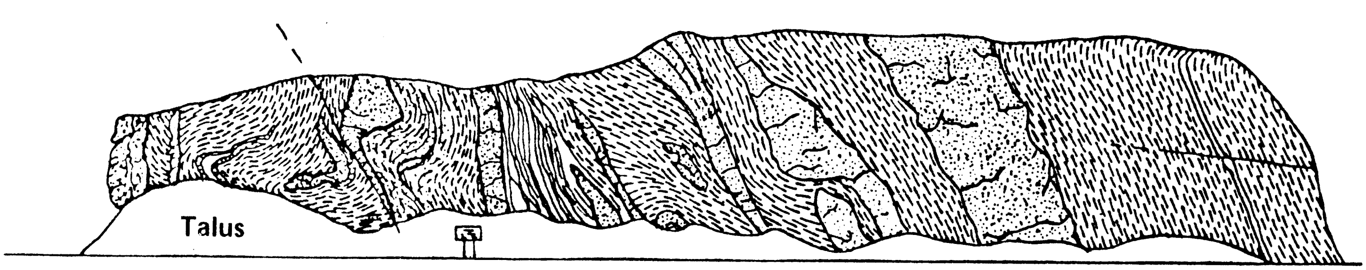
STOP 4 — BLAKELY SANDSTONE AT BLAKELY MOUNTAIN DAM

Rocks of the middle and lower Blakely Sandstone can be examined in two fine exposures at Blakely Mountain Dam. They consist of thin to massive bedded quartzitic sandstone (in part calcareous and conglomeratic), thin-to thick-bedded siltstone, and gray to black banded shale. Bottom marks, cross-laminations, and graded bedding indicate the tops of the beds are to the southeast, thus these beds are southward overturned. Cleavage in the shale dips northward and refracts across thin sandstone beds expecially near the fold hinge lines. This is especially well developed at the western end of both exposures. The sandstone divisions are thinning and fining upward and probably represent upper and middle submarine fan channel deposits derived from submarine scarps and slopes and possibly foreland facies to the north and northwest. Quartz veins of late Paleozoic age fill fractures in many of the sandstones. Graptolites are present in some of the shales.

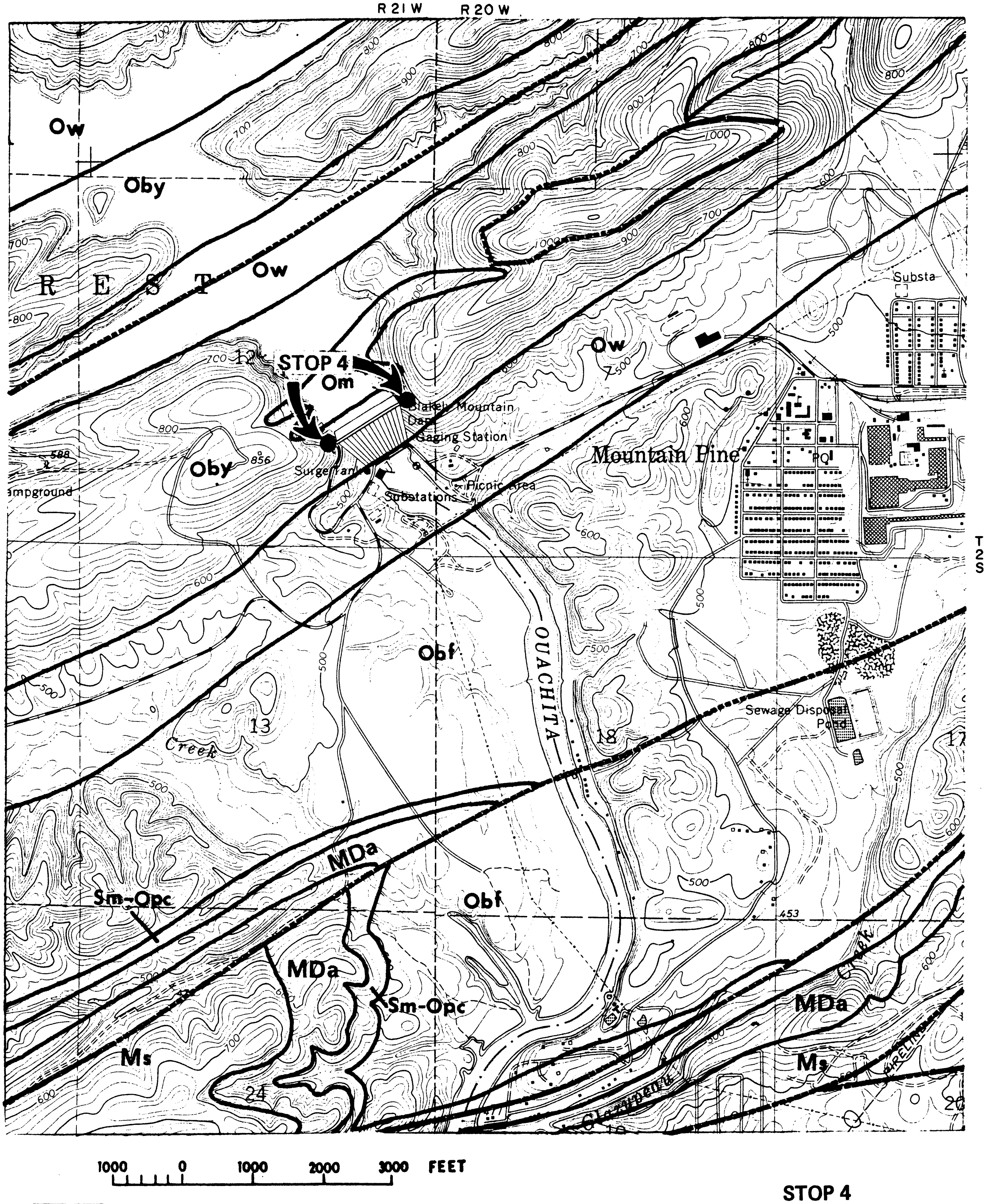
The Hot Springs structural trend (northeast) as mapped by Purdue and Miser (1923) is the dominant structural feature in this area. Some anomalous directions of fold rotations in outcrops downstream indicate an older period of folding. At least two sets of cleavage are present. Most folds are overturned toward the southeast and hinge lines are near horizontal or rake gently northeast or southwest. Clastic dikes, in part parallelling cleavage, suggest deformation of soft water-saturated sediments. Sedimentary pull-aparts, debris flows, and soft-sediment slump features are present.

Riprap on the face of the dam is a gray, micritic and conglomeratic limestone quarried from the lower part of the Womble. The quarry is located in the NW¼ SW¼ NW¼ Sec. 34, T. 15 N., R. 22 W. a few miles northeast of the dam. This sequence of limestones represents a large sedimentary slurry deposit containing probable shallow-water pelletoidal and deep-water micritic materials. Repetski and Ethington (1977) made conodont collections from these limestones and indicate a Middle Ordovician age with affinities both to European and North American strata.

SOUTH END — BLAKELY MOUNTAIN DAM



From S.A.S.G.S Fall Field Trip Guidebook 1978



Ms	Stanley Shale
MDa	Arkansas Novaculite
Sm-Opc	Missouri Mountain Shale Polk Creek Shale
Obf	Bigfork Chert
Ow	Womble Shale
Oby	Blakely Sandstone
Om	Mazarn Shale

.... Thrust Faults

———— Contacts

N

STOP 4

GEOLOGIC MAP

OF

BLAKELY MOUNTAIN DAM

STOP 5 – COLEMAN'S QUARTZ CRYSTAL MINE

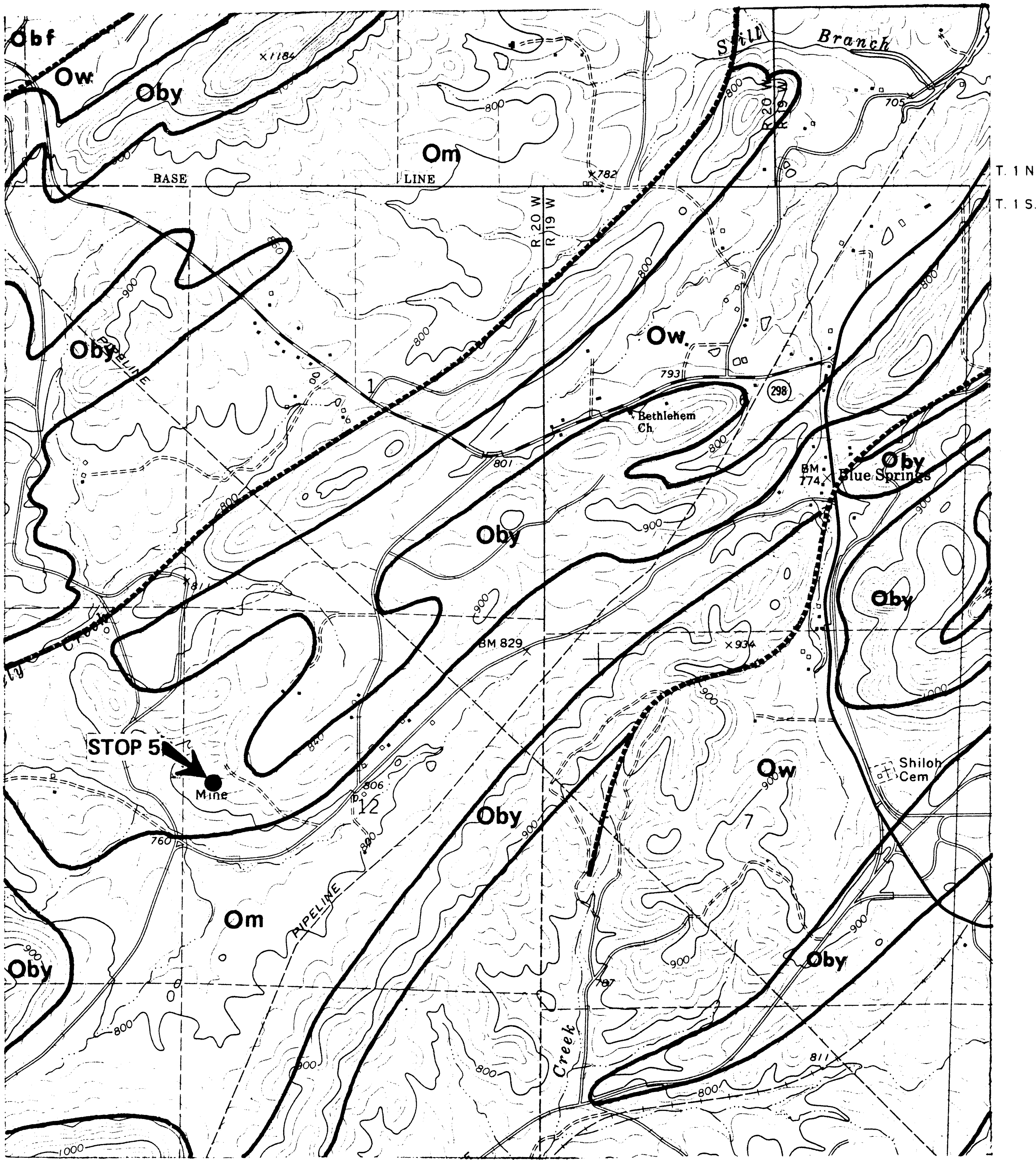
Mining of quartz crystals in the Ouachita Mountains of Arkansas has been going on for many years, the first miners probably being the Indian tribes that shaped them into arrowheads. Because of the clarity and perfect shape of many of the individual crystals and crystal clusters, the principal market for the quartz over the years has been as specimens in both individual and institutional mineral collections. During World War II about five tons of clear quartz crystals from Arkansas was used in the manufacture of radio oscillators to supplement the production from Brazil. Currently, the quartz crystals are being used for: manufacturing fusing quartz, which has many chemical, thermal and electrical applications; for seed crystals (lasca) for growing synthetic quartz crystals; and, of course, for mineral specimens. It should be noted that the "Hot Springs Diamonds" for sale in the local rock shops and jewelry stores are cut from Arkansas quartz crystals.

Quartz veins are numerous and are found in a wide belt extending from Little Rock, Arkansas to Broken Bow, Oklahoma, in the central core area of the Ouachita Mountains. These veins, up to sixty feet in width, commonly contain traces of adularia, chlorite, calcite and dickite. In a few places lead, zinc, copper, antimony and mercury minerals are associated with the quartz veins. At relatively few localities, however, within the quartz vein belt do individual quartz crystals and crystal clusters attain the size and clarity requisite for mining.

In the Ouachita Mountains there is a close association of quartz veins with fault zones. It is believed that the quartz veins represent, in part, dewatering processes that took place along the fault zones. The increase in pore fluids may well have contributed to overpressuring and related conditions and enhanced the overall faulting and folding process. The quartz veins with their associated minerals are presumed to be hydrothermal deposits of tectonic origin formed during the closing stages of the late Pennsylvanian-early Permian orogeny in the Ouachita Mountains.

The quartz crystal deposits at the Coleman Mine are also known as the West Chance Area, Dierks No. 4 Mine, and Blocher Lead. The quartz crystals occur in veins in limy sandstone and conglomeratic sandstone beds of the Blakely Sandstone. Beds of conglomeratic sandstone exposed in the pit contain abundant weathered meta-arkose and granitic boulders, cobbles, and pebbles; and some clasts of limestone, chert and shale. It is likely that these sediments were deposited in submarine fan channels and were derived from a granite-rich terrane to the north-northeast. This area is comprised of many thrust-faulted sequences with at least two major periods of folding resulting in differing attitudes in fold hinge lines and axial planes. The mine itself is situated on the nose of a large, complexly-deformed syncline.

The quartz crystal veins are fracture fillings with the larger and more productive cavities being located at the intersection of two veins. Mining operations are relatively simple, consisting initially of removing overburden and loose rock with a bulldozer to expose the crystal-filled cavities, and then removing the quartz crystals with hand tools. Individual quartz crystals up to five feet in length weighing as much as 400 pounds and clusters 15 feet in length weighing over five tons have been produced from these mines.



GEOLOGIC MAP OF BLUE SPRINGS AND VICINITY STOP 5

1000 0 1000 2000 3000 FEET

N

Obf	Bigfork Chert	Oby	Blakely Sandstone
Ow	Womble Shale	Om	Mazarn Shale

Thrust Faults (dashed line)

Contacts (solid line)

STOP 6 – POLK CREEK SHALE AND BIGFORK CHERT AT HOT SPRINGS

The Polk Creek Shale and Bigfork Chert (both Upper Ordovician) are exposed in an outcrop on Whittington Avenue. The lower part of the Polk Creek is on the south end of the outcrop and consists of carbonaceous black shale and siliceous shale. There is a gradational lithologic change from rocks in the Polk Creek to the siliceous shale, thin chert, and calcareous siltstone of the underlying Bigfork. These beds are overturned to the south.

The Polk Creek ranges in thickness from 150 to 200 feet in this area. The narrow valleys and slopes between the ridges of Arkansas Novaculite and Bigfork Chert are formed by the Polk Creek Shale, Blaylock Sandstone, and Missouri Mountain Shale. About 10 feet of thin flaggy silty sandstone of the Blaylock and 60 feet of maroon and green shale and gray conglomerate of the Missouri Mountain overlie the Polk Creek.

The Polk Creek is considered a very slowly deposited, carbon-rich, deep-water, pelagic deposit. The upper part of the Bigfork is a pelagic to hemipelagic deep-water deposit, with some calcareous siltstones representing clastic influxes from low energy turbidity or bottom currents.

OPTIONAL STOP
"HOT SPRINGS"
(Located on Central Avenue in Hot Springs)

This stop is to acquaint geologists with the unique Grand Promenade Trail, its hot springs and tufa rock, and with the fine museum at Hot Springs National Park, the first Federal Reservation (1832) and the Eighteenth National Park (1921) in the United States.

The U. S. Park Service regulates the use of the water from the world famous hot springs which issue from fractures and joints in the Hot Spring Sandstone along the base and slope of East Mountain a short distance south of this Stop. A museum, display spring, numerous trails and camping areas are provided for the public.

East Mountain is a westward plunging, faulted, southward overturned anticlinal ridge of the Zigzag Mountain subprovince. Early American Indian tribes, Spanish conquistadors, early settlers and modern man have all exploited the therapeutic properties of the springs. "Tah-ne-co", the place of the hot waters, was the Indian name for the site. About 50 of the original 71 springs produce hot water. According to J. K. Haywood and W. H. Weed (1902) the daily flow aggregates 850,000 gallons with the largest spring yielding a little over 200,000 gallons. The temperature range is from 95.4° to over 147° F. The hot spring water is slightly radioactive, apparently caused by radon gas. A soil-and-vegetation-covered gray calcareous tufa formed by the Hot Springs, covers an area of 20 acres and in places is 6 to 8 feet thick. Measurements of the hot springs flow to the central collection reservoir have been made periodically since 1970 by the U. S. Geological Survey. These measurements indicate a range in spring flow of 750,000 to 950,000 gpd with an average flow of about 825,000 gpd.

The tritium and carbon 14 analyses of the spring water indicate a mixture of a very small amount of water less than 20 years old and a preponderance of water about 4,400 years old.

Bedinger et al. (1979) state that the geochemical data, flow measurements and geological structure of the region support the concept that virtually all the hot springs water is of local meteoric origin. Recharge to the hot springs artesian flow system is by infiltration of rainfall in the outcrop areas of the Bigfork Chert and the Arkansas Novaculite. The water moves slowly to depth where it is heated by contact with rocks of high temperature. Highly permeable zones related to jointing or faulting collect the heated water in the aquifer and provide avenues for water to travel rapidly to the surface.

STOP 7 – QUARRY IN BIGFORK CHERT AT HOT SPRINGS

Folded and faulted rocks in the middle part of the Bigfork Chert are exposed in a quarry north of the Weyerhaeuser office on Whittington Avenue. The quarry is near the axis of the southwestward plunging Hot Springs Anticline.

In the quarry the Bigfork consists of very thin interbedded and often graded, calcareous (often decalcified) siltstone, gray chert, and minor beds or laminations of siliceous to carbonaceous shale. The basal silty part of each interbedded sequence likely represents minor influxes of fine clastics transported into the Ouachita trough by turbidity and bottom currents and the underlying cherts and siliceous shales representing slowly deposited deep-water pelagic accumulations.

The Bigfork is complexly folded in the quarry with chevron and buckle folds inclined both to the south and north. Most of the strata dips to the north indicating a dominant southward overturning. North dipping cleavage often refracts across the cherts and calcareous siltstones. Flowage of rock can be seen in some of the tight fold hinges.

Massive novaculite of the Lower Division (Devonian) of the Arkansas Novaculite forms the ridges to the north and south.

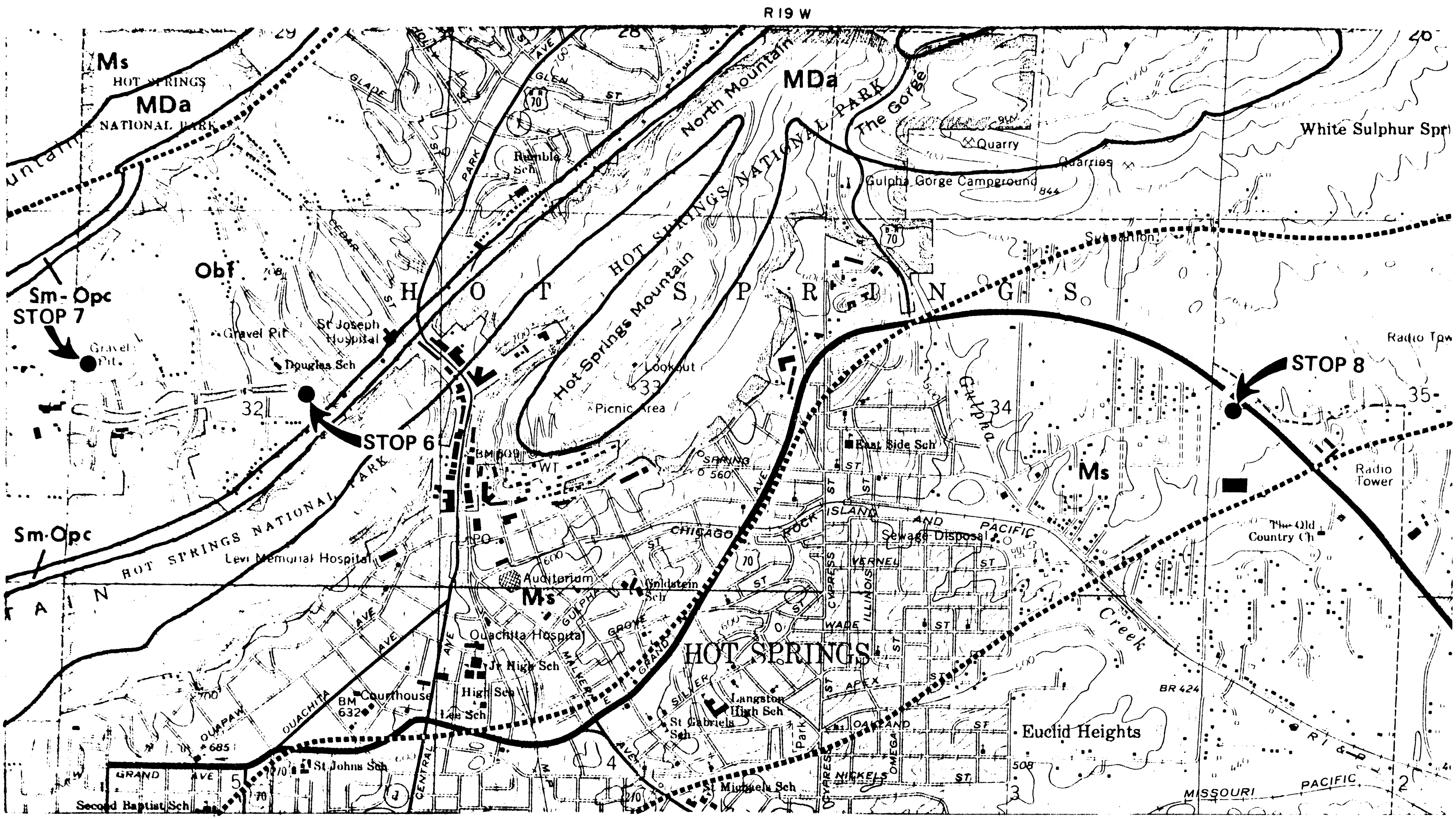
The Bigfork Chert is the most reliable aquifer in the Ouachita Mountains. Clear or small chalybeate (iron rich) springs are often present in the basal outcrops. The water moves along joints, fractures, and bedding planes in the thin-bedded basal sequence.

STOP 8 — LOWER STANLEY SHALE EAST OF HOT SPRINGS

The lower part of the Stanley Shale is well exposed at several localities east of Hot Springs along U. S. Hwy. 70. At this outcrop the rocks consist of black shale or slate, thin bedded siltstone, thin–to thick-bedded subgraywacke and graywacke, chert, and a few cone-in-cone concretions. The maximum thickness of the Stanley is approximately 9500 feet, these rocks are about 1200 feet above the base. Most of the rocks are overturned to the south into the Mazarn Basin and dip steeply to the north. The lower Stanley is complexly folded, with both flexural-flow and slip types, and exhibits at least two generations of cleavage. Thrust faults cutting the sequence are indicated by numerous slickenside zones with quartz veins and dickite coating on the rock surface.

Sedimentary features include bottom marks, ripple marks, graded bedding, cross-laminations, debris flows, loading and slumping, and bioturbations. Many of the beds thicken and coarsen upward and are believed to represent lobe sequences of an outer submarine fan depositional environment. Some sandstone packets thin upward, indicative of a submarine fan channel depositional environment. These sands were likely derived from sources to the south and southeast. The sands were initially carried to the north and northwest down deep-water submarine fans and subsequently carried by turbidity currents to the west down the Ouachita trough. The clastic units show both structural boudinage and sedimentary pull-aparts. The weathered Stanley Shale at the top of the roadcut is characteristically greenish-brown.

The middle and lower parts of the Stanley Shale are in the Tenmile Creek Formation of the lower part of the Stanley Group in the Ouachita Mountains of Oklahoma. In Arkansas and Oklahoma there are chert intervals in the lower, middle and upper parts of the Stanley that represent reliable markers. Sandstones in the Stanley are often tuffaceous in Arkansas, but the acidic volcaniclastic beds of the Hatton and Mud Creek Tuff lentils, which are prominent in the lower 1500 feet in southwestern Arkansas and southeastern Oklahoma, are rarely present in this area. Miser (1934) and Niem (1977) have shown that the tuffs were derived from a source south or southwest of Broken Bow, Oklahoma.



GEOLOGIC MAP OF HOT SPRINGS AND VICINITY. STOPS 6, 7, and 8

1000 0 1000 2000 3000 FEET

- Ms — Stanley Shale
- MDa — Arkansas Novaculite
- Sm-Opc — Missouri Mountain Shale – Polk Creek Shale
- Obf — Bigfork Chert
- Thrust Faults (dotted line)
- Contacts (solid line)

N

STOP 9 – TRIPOLI MINE IN ARKANSAS NOVACULITE

The Malvern Minerals Company of Hot Springs operates this mine and a plant to produce Novacite from tripolitic novaculite of the Arkansas Novaculite. Novacite is a microcrystalline silica (99.6%) used as a filler and extender in paints and plastics and as an abrasive. The Arkansas Novaculite here is overturned to the southeast and the rocks are dipping 32^{o}-45^{o} to the northwest. The tripolitic novaculite is mined from the Upper Division of the Arkansas Novaculite which is about 60 feet thick. It is overlain by the Middle Division (about 20 feet thick) and the Lower Division (about 400 feet thick). The Upper Division is white and friable with an average particle size of 7 microns. The Middle Division consists of a highly siliceous, carbonaceous black shale which the company mines and markets under the trade name Ebony for use as an extender pigment and other purposes. Typical analyses of the Novacite and Ebony are:

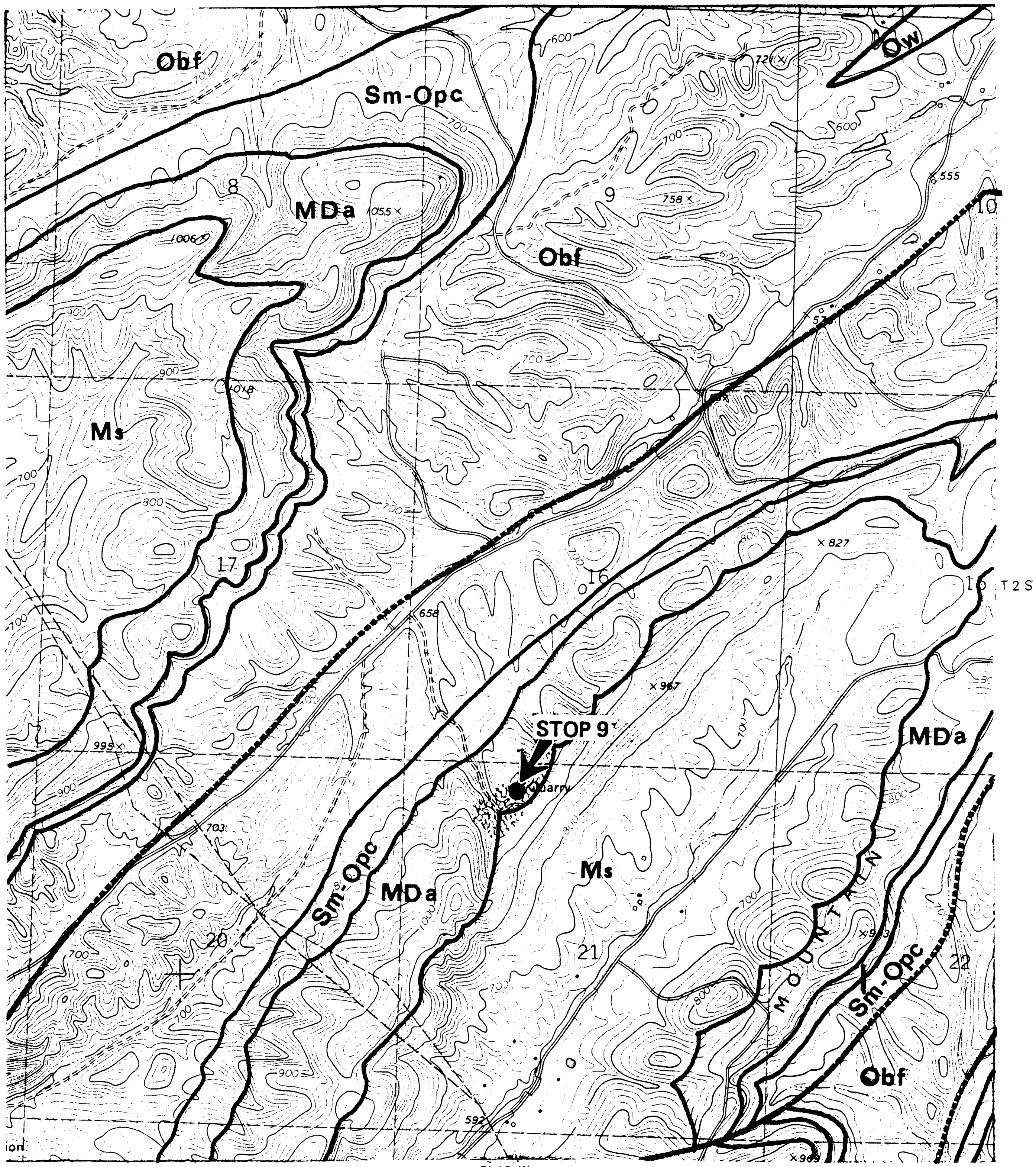
		Novacite	Ebony
Silica	SiO_2	99.49 %	60.40 %
Carbon	C	0.00 %	3.37 %
Sulphur	S	0.00 %	0.07 %
Aluminum oxide	AL_2O_3	0.102 %	22.40 %
Ferric oxide	Fe_2O_3	0.039 %	2.15 %
Titanium oxide	TiO_2	0.015 %	1.70 %
Calcium oxide	CaO	0.014 %	2.00 %
Magnesium oxide	MgO	0.021 %	0.38 %
Loss on Ignition		0.190 %	9.75 %

The tripoli in the Upper Division is probably formed by the leaching of calcium carbonate cement from the novaculite. Scanning electron micrographic studies of the novaculite and tripoli by Keller et al. (1977) confirm that the silica has been slightly recrystallized at this locality and that polygonal triple-point texture is present.

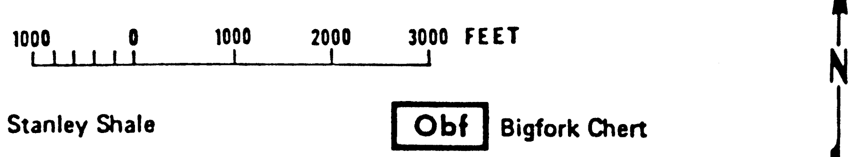
At the top of the Lower Division at this locality there is about a 20 foot interval of sedimentary slurried boulder-like novaculite, minor sandstone, and other materials forming a very coarse conglomerate or breccia. Minor granitic fragments are present in similar rocks about ten miles to the north. Honess (1923) reports igneous and volcanic debris in the Arkansas Novaculite in the Broken Bow area of Oklahoma. These deposits likely represent slurries derived from submarine scarps and ridges to the north that, in part, had active extensional faulting and igneous activity in Devonian times. Richard Lane of Amoco Production Company tentatively identified Middle Devonian conodonts from the shales about 18 feet stratigraphically below the boulder-interval.

Other interesting geologic features in or near the quarry are:

1. Secondary oxides, often forming manganese and iron dendrites, coatings and discolorations on fracture surfaces;
2. Unusual development of grooved-like curtains or sheets of tripoli are present on the wall face;
3. Some of the fractures are filled with weathered to fresh igneous intrusives (alkalic dikes, early Late Cretaceous);
4. Novaculite in the Lower Division that is of very high quality for whetstones, including both hard (Arkansas) and soft (Washita) types;
5. Minor thrust and tear faults with slickensides;
6. The ridge south of the quarry is formed by the overlying Hot Springs Sandstone of the lower Stanley Shale. It is about 75 feet thick and is composed of quartzitic sandstone and shale with sandy chert-novaculite conglomerate typically near the base;
7. Thin films of gorceixite (barium phosphate) coating novaculite fractures.



GEOLOGIC MAP EAST OF HOT SPRINGS. STOP 9



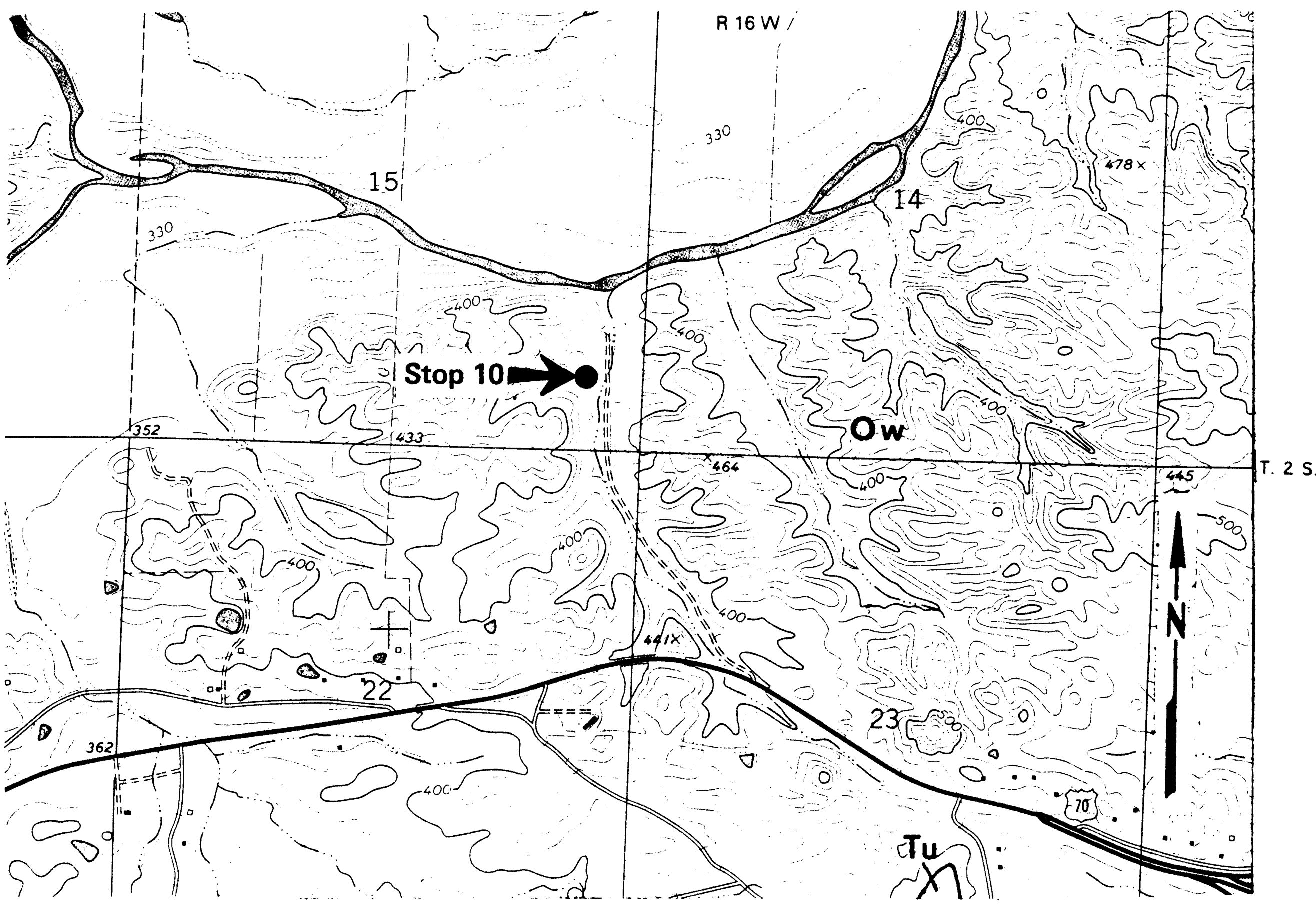
Ms	Stanley Shale	Obf	Bigfork Chert
MDa	Arkansas Novaculite	Ow	Womble Shale
Sm-Opc	Missouri Mountain Shale - Polk Creek Shale	--------	Thrust Faults
		———	Contacts

STOP 10 – LOWER WOMBLE LIMESTONE AND SHALE

Recumbently folded rocks in the lower part of the Womble Shale are well exposed in the creek west of the access road to Saline River. These rocks consist of very thin bedded, silty, gray, dense limestone and very thin layers of black shale. The beds are nearly horizontal with minor structural changes. Load and groove casts, cross-laminations, and graded bedding indicate the beds are inverted. Tight isoclinal recumbent folds with horizontal hinge lines are present and the flatter limb (longer) of these folds is inverted. It is difficult to determine the exact rotation of the strata since there has been more than one phase of folding and faulting, but it is likely that the paleocurrents were from the northeast to southwest. There are minor bioturbations in some of the strata. Alkalic-lamprophyric dikes (early Late Cretaceous) are present and locally cut quartz or quartz-calcite veins or veinlets of late Paleozoic age.

South of this stop near U. S. Hwy. 70 weathered basaltic dikes were mined in the early 1900's for high grade Fuller's Earth for refining edible oils. Farther east are large novaculite boulders in gravels (Late Cretaceous) that possibly represent exotics in mud and debris flows derived from the southwest. A few occur in the soils in this area.

Studies are still in progress in the eastern region of intense tectonic deformation (recumbent folds, klippens, windows, and décollements) and some changes can be expected in the stratigraphic and structural interpretations.



GEOLOGIC MAP OF STOP 10 AND VICINITY

MILES 0 5 10 15 20 25
KILOMETERS 0 5 10 15 20 25 30 35 40

Ow Womble Shale   Tu Tertiary Undifferentiated

STOP 11 – BIGFORK CHERT TO ARKANSAS NOVACULITE WEST OF LITTLE ROCK

Intensely sheared and tightly folded Bigfork Chert, Polk Creek Shale, Missouri Mountain Shale, and the Lower and Middle Divisions of the Arkansas Novaculite are exposed on both sides of I-430 about 0.4 miles north of Arkansas Hwy. 5. Beginning at the north end of the outcrop the rocks consist of: chert and siliceous shale of the Bigfork; black shale and dark gray chert of the Polk Creek; gray and tan shale with thin chert and novaculite of the Missouri Mountain; massive bedded, very light gray novaculite (tripolitic at the base) and chert of the Lower Division; and black siliceous shale and chert of the Middle Division. The rocks dip to the north and are overturned to the south. The style of folding varies with lithology. Pervasive north dipping cleavage is evident in the Bigfork. Some northward dipping thrust faults with quartz veins and minor gouge are also present. Their direction of displacement is as yet unclear. The intense shearing has obliterated many of the lithic characteristics and microfossils. Some conodonts, sponge spicules, and radiolaria are present in a few beds in the Middle Division. These early trough sediments represent exceptionally slow rates of deposition with only minor clastic accumulations.

An alkalic igneous dike (altered to clay) of early Late Cretaceous age dissects the Middle Division of the Arkansas Novaculite on the west side of the road. Both of these are overlain unconformably by a remnant of clay, sand, and some gravel 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 at this stop is likely related to low-rank regional (thermal) metamorphism, as well as very local enhancement or development due to Cretaceous pluton emplacement. The triple-point grains in the chert and novaculite from this stop average about 40 microns in diameter and are among the coarsest determined in chert or novaculite from the Ouachita Mountains. Most of the triple-point texture was formed during late Paleozoic deformation.

According to Viele (1973), two major fold trends have been developed in the Lower Paleozoic rocks in this general area. The Alexander trend consists of southward overturned folds that have nearly horizontal hinge lines. The Ellis Mountain trend is overturned to the southwest but the fold hinge lines are reclined. Most of the folds at this site belong to the Alexander trend but the cleavage is believed to be associated largely with the Ellis Mountain trend.

STOP 12 — BIGFORK CHERT AND THRUST FAULTS WEST OF LITTLE ROCK

Ordovician age rocks of the Polk Creek Shale, Bigfork Chert, and Womble Shale are exposed on both sides of I-430 north of Colonel Glenn Road. These rocks are dipping gently to the north and contain isoclinal folds with southward vergence (especially the Bigfork). There is very little variance in the dip of the beds in the tightly folded sequence and the well-developed cleavage is typically parallel to bedding. The sequences are cut by northward dipping thrust faults that are essentially parallel to the bedding 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 early Late Cretaceous age 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 11, 12, and 13). Viele, University of Missouri, has proposed gravitational sliding and cascading of rock units northward from a series of nappes. Stone and Haley in 1981 suggested 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 fault planes south of Stop 13 can be attributed to backfolding of the toe of each thrust plate and also to subsequent thrust faulting. Subsequent or younger faulting is suggested by the outlier of Arkansas Novaculite overlying Womble at this stop and by the six mile wide belt of Ordovician rocks overlying Mississippian rocks in the area southwest of Paron (25 miles west of this stop).

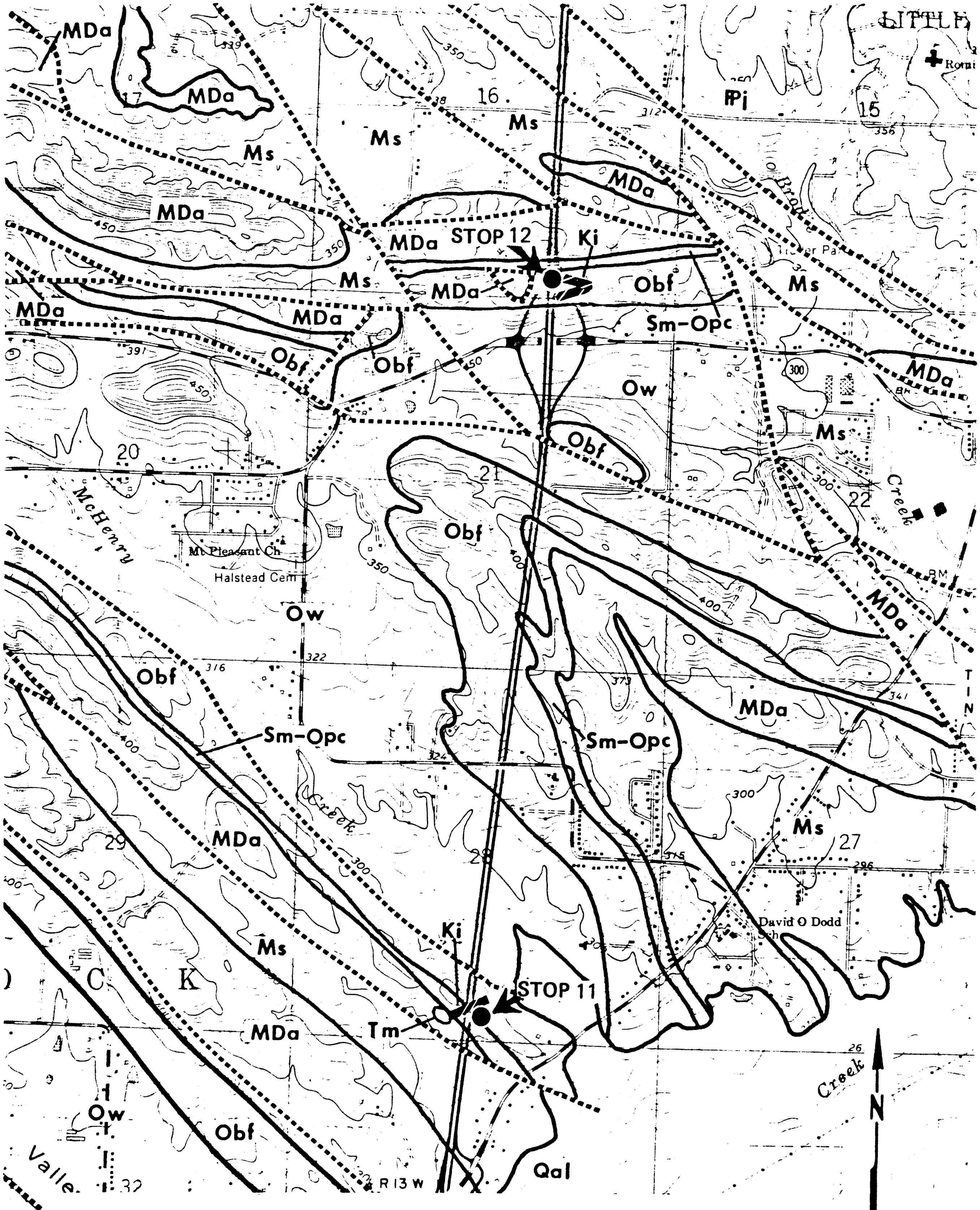


PLATE 8 — GEOLOGIC MAP OF SOUTHWESTERN LITTLE ROCK ALONG INTERSTATE HIGHWAY 430 — STOPS 11 AND 12

1000 0 1000 2000 3000 FEET

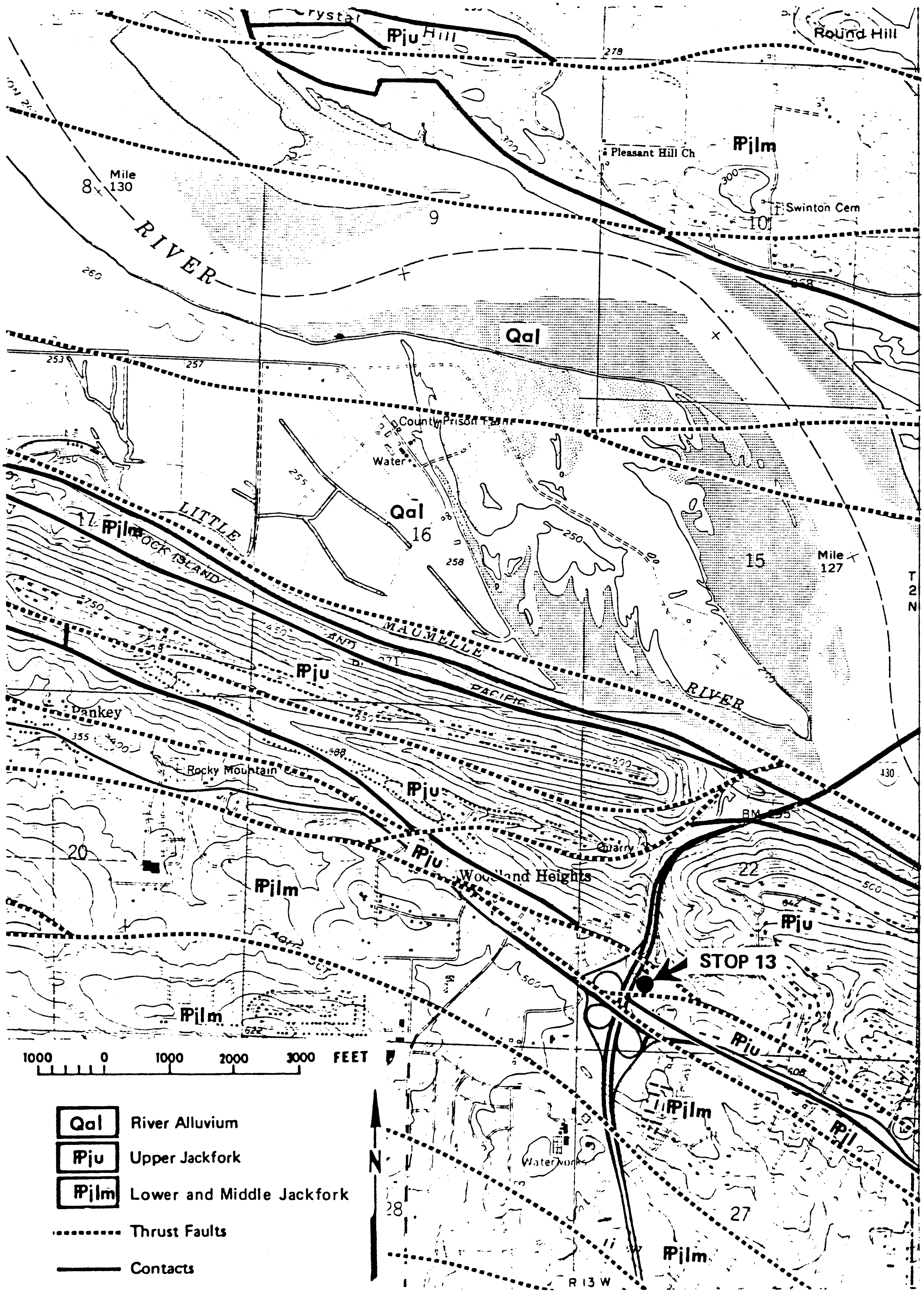
Qal	Stream Alluvium	Ms	Stanley Shale	Obf	Bigfork Chert
Ki	Igneous Dikes	MDa	Arkansas Novaculite	Ow	Womble Shale
Pj	Jackfork Sandstone	Sm-Opc	Missouri Mountain Shale – Polk Creek Shale	········	Thrust Faults
				———	Contacts

STOP 13 — JACKFORK SANDSTONE NORTHWEST OF LITTLE ROCK

Large exposures of the lower and upper parts of the Jackfork Sandstone are located on both sides of I—430, north of Arkansas Hwy. 10. The lower part of the Jackfork consists mostly of black shale and the upper part of the Jackfork consists of interbedded massive to thin bedded gray quartzitic sandstone, dark gray shale that weathers to brown or maroon, and minor intraformational sandstone-shale conglomerate. Grain size fining upward and beds thinning upward are present in the sandstone sequences and represent deposition in a submarine fan channel. These rocks were probably deposited farther down the slope of the submarine fan than the equivalent strata at Big Rock Quarry a few miles to the east. A major source area for the sediments in this part of the Jackfork existed to the northeast where major streams were draining the Illinois Basin. Many structural features generated by soft-sediment deformation and further deformed by tectonic deformation are present in this exposure.

The minor folds are upright and overturned to the southwest and have nearly horizontal hinge lines. 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 could be a product of a combination of geologic events: (1) southward slumping of soft sediments in a submarine continental slope depositional environment; (2) northward stacking of several thrust fault slides; (3) several periods of folding; or (4) backfolding and faulting caused in part by "piling up" and crowding at the toe of the larger northward moving thrust plates.

A tectonic mélange, termed the *Maumelle Chaotic Zone,* within the southward diving subduction zone has been suggested for this area by Viele (1966 and 1973). Stone et al. (1981) stated two problems with this concept: (1) there are mappable, rather straightforward sequences and structures in the upper Jackfork in this belt; and (2) the olistolithic masses, boulders and fan channel lenses in the lower parts of the Jackfork in this belt are all thought to be derived from slope and foreland facies to the north; after deposition they were tectonically deformed.



GEOLOGIC MAP ALONG INTERSTATE HIGHWAY 430
IN WESTERN LITTLE ROCK STOP 13

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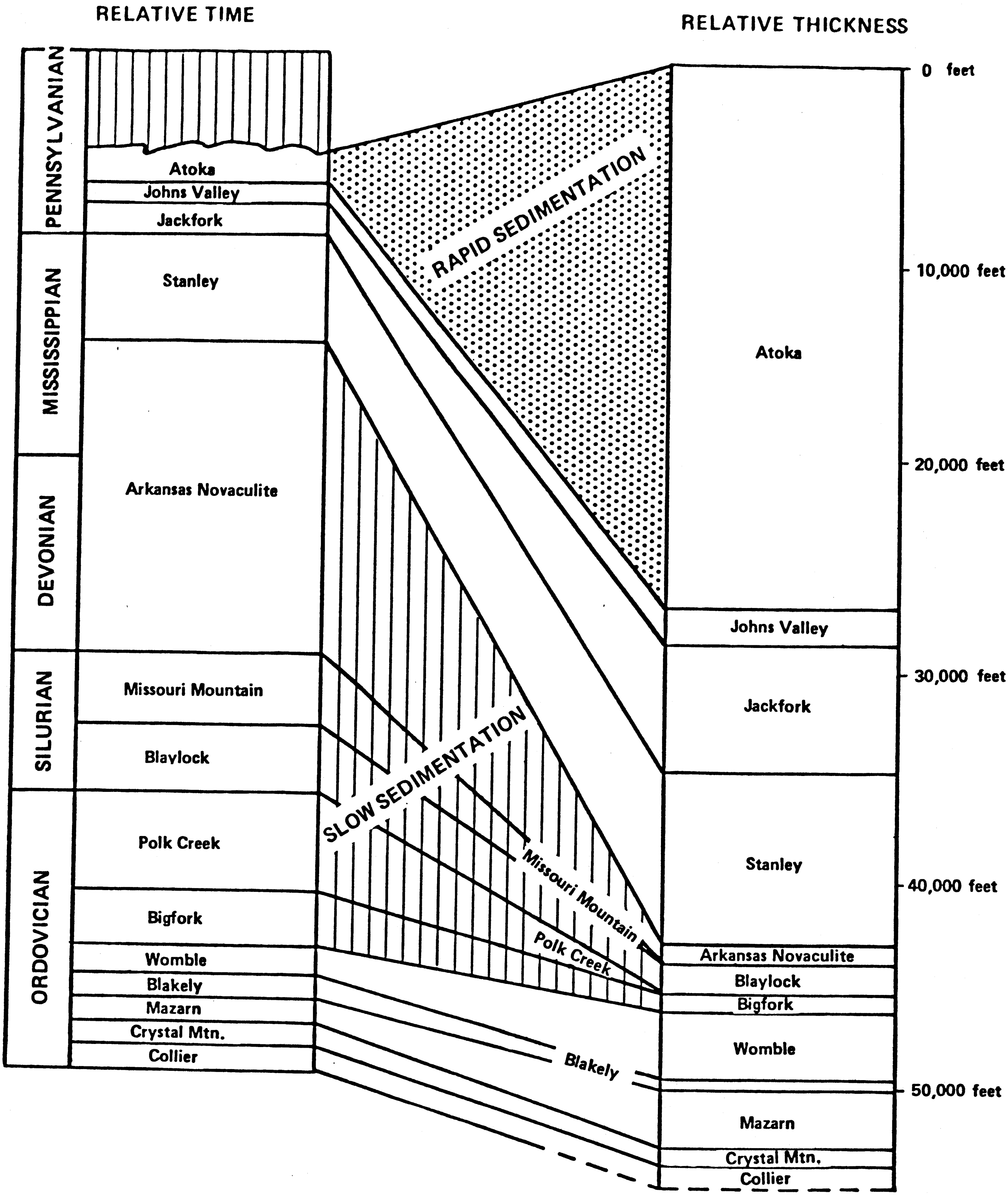

CHART SHOWING SEDIMENTATION RATES OF THE PALEOZOIC ROCKS IN THE OUACHITA MOUNTAINS, ARKANSAS.