GUIDEBOOK 82–1

STATE OF ARKANSAS
ARKANSAS GEOLOGICAL COMMISSION
Norman F. Williams, State Geologist

FIELD GUIDE TO THE MAGNET COVE AREA AND SELECTED MINING OPERATIONS AND MINERAL COLLECTING LOCALITIES IN CENTRAL ARKANSAS

By
Charles G. Stone, J. Michael Howard
and Drew F. Holbrook

Prepared for the Fort Smith Geological Society
Little Rock, Arkansas
April, 1982

Reprinted 1993

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TABLE OF CONTENTS

DESCRIPTION OF FIRST DAY STOPS	PAGE
1. Smith Whetstone Company's Plant	3
2. Union Carbide Corporation Vanadium Mine at Wilson Springs	4
3. Christy Vanadium–Titanium Mine	13
4. National Lead Industries Chamberlain Creek Barite Deposit	15
5. "Hot Springs" at Hot Springs	17
DESCRIPTION OF SECOND DAY STOPS	
1. Tripoli Mine in Arkansas Novaculite	19
2. Smith's Hard White (Arkansas) Whetstone Quarry	21
3. Magnet Cove Titanium Corporation Rutile Mine	25
4. Kimzey Calcite Quarry	25
5. Kimzey Magnetite Pit	26
6. Mo–Ti Prospect and Jacupirangite	26
7. Diamond Jo Quarry	27
DESCRIPTION OF THIRD DAY STOPS	
1. and 2. Coleman's Rock Shop and Quartz Crystal Mine	29
3. Dug Hill Wavellite Prospect	31

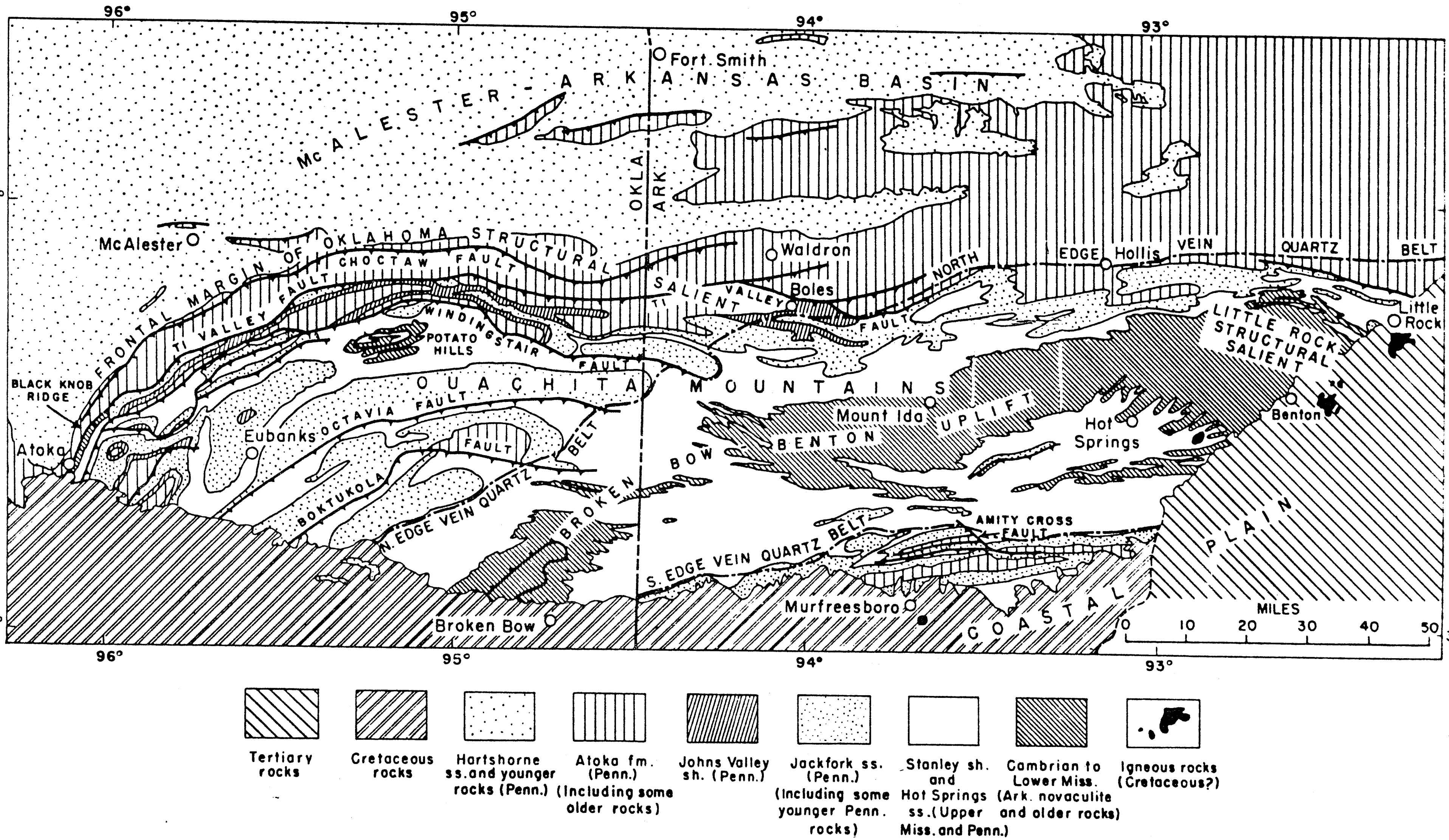
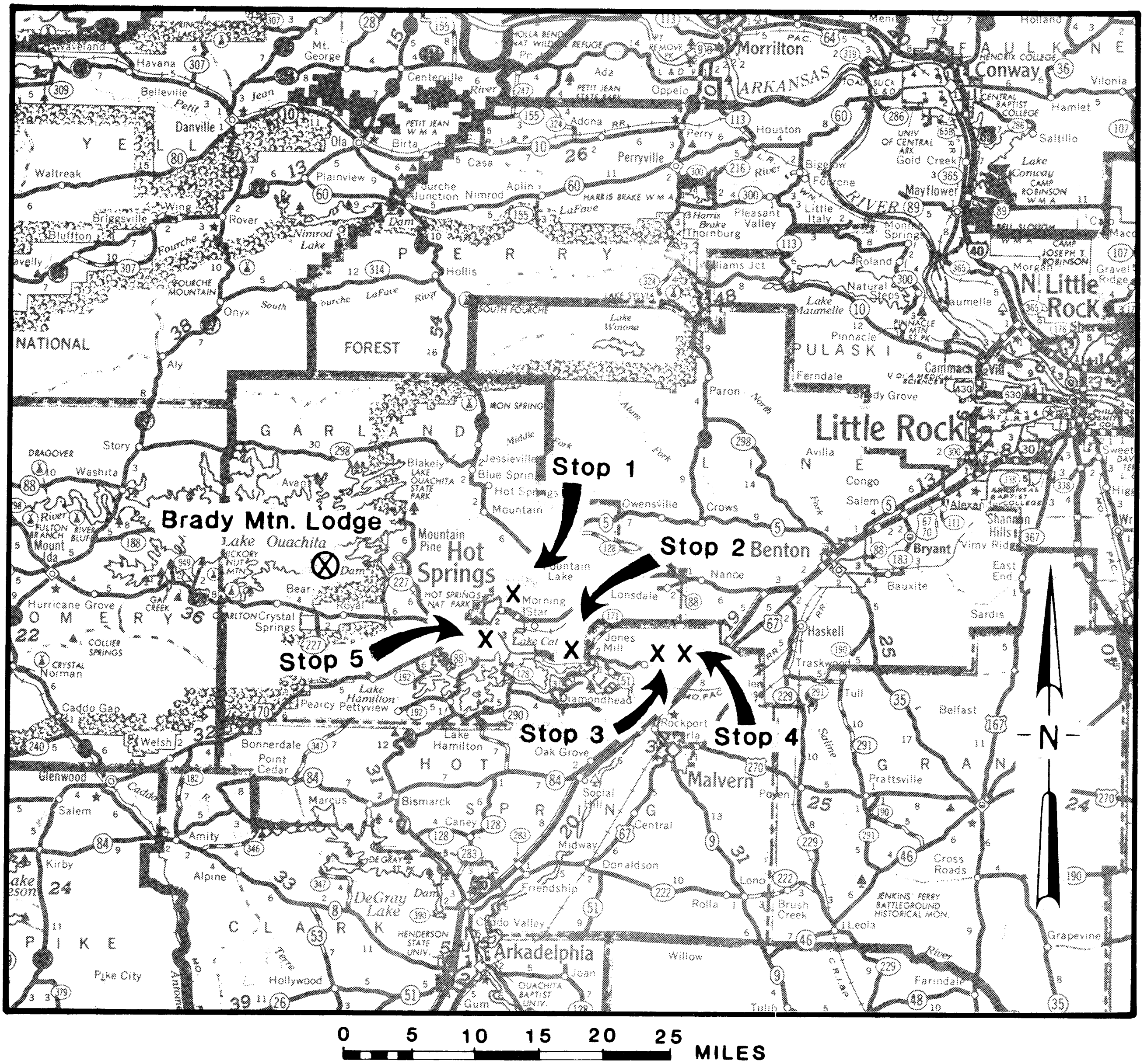


Figure 1. -- Generalized geologic map of Ouachita Mountains. (Modified from Miser, 1959, Fig. 3)

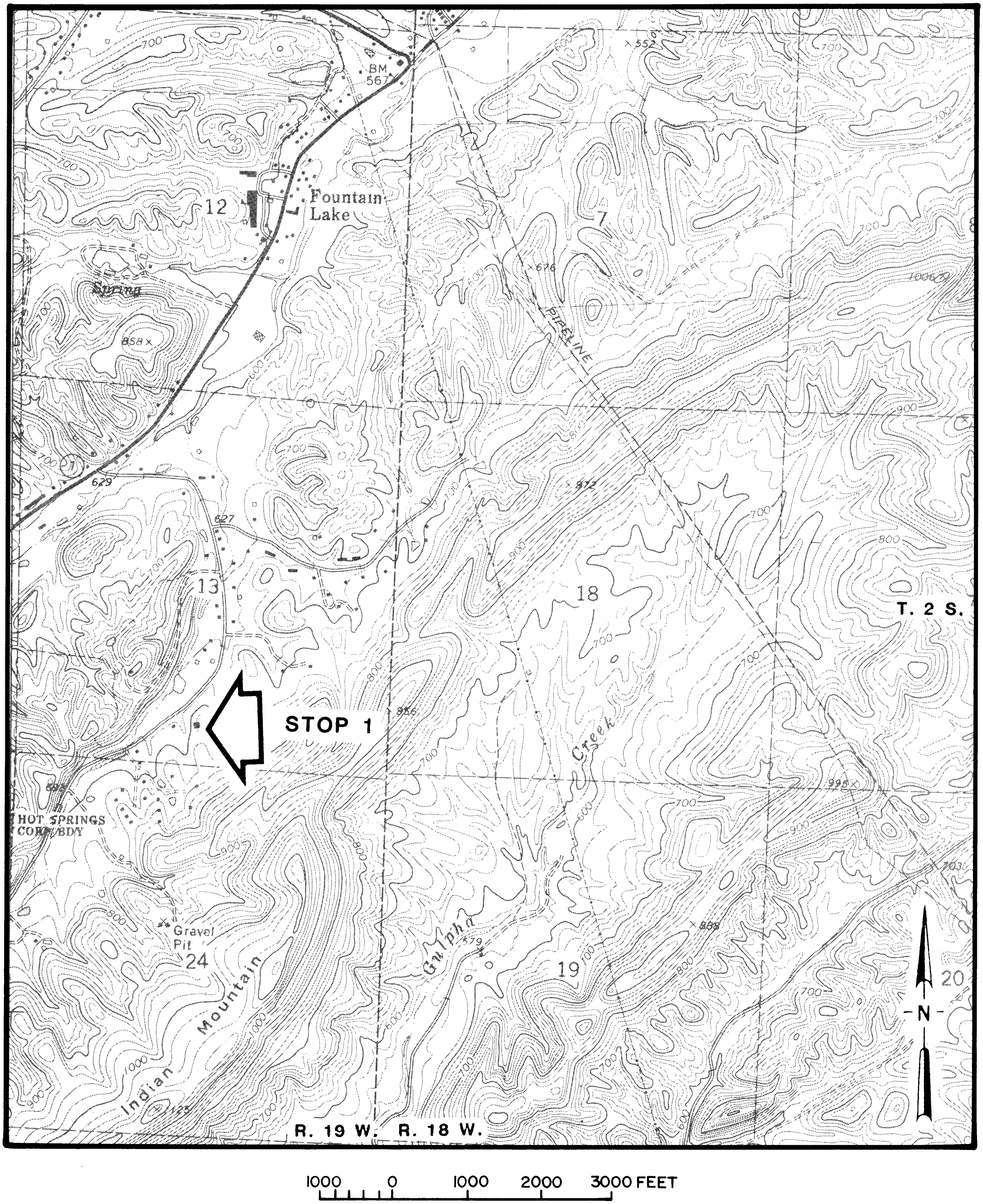


INDEX MAP OF FIRST DAY STOPS

PREFACE

This guidebook provides information on the history, geology and current operations of some of the active mines in central Arkansas. It further describes other mineral resources and mineral collecting localities in the area.

Thanks are due Don Owens of Union Carbide Corporation, Charles Steuart of Malvern Minerals Company, Brian Willis of Smith's Whetstone Co., Jim Coleman and family of Coleman Quartz, Earl Adams of the Hot Springs National Park, Henry deLinde, and Mrs. E. B. Arthur for their cooperation and participation.



STOP 1–HIRAM A. SMITH WHETSTONE COMPANY PLANT

DESCRIPTION OF FIRST DAY STOPS

STOP 1 — SMITH WHETSTONE COMPANY'S PLANT

There are only a few companies in Arkansas that produce whetstones from the Arkansas Novaculite and most of these are in the Hot Springs area. One of these is the Hiram J. Smith Company of Hot Springs which has been in operation for a number of years. The following is a summary (1971) of the Smith's operation by Aileen McWilliams:

> "The first known use of the Arkansas novaculite was by the Indians, the tribes coming from far off to get the rock, taking it in the form of rough blocks to their camps where they shaped it into arrowheads, spear points, knives, plows, scrapers, and other implements. Thus novaculite chips may be found over large areas of the country. The name 'novaculite' is from a Latin word meaning 'sharp knife' and the conchoidal fracture of the rock makes it possible to shape it to a thin, keen edge.
>
> But its more modern use is as a whetstone, the finest honing stone available, sold the world over as Arkansas oilstone. It has been quarried in the Hot Springs area since 1832 by only a few families or groups. One of these is the Hiram Smith family, now into its fourth generation of whetstone men. The company was founded in 1885 by James A. Smith, who turned it over in 1905 to his son, Archer. Archer's son, Hiram Smith, entered the business in 1938, at the age of 18. Up to 1962 the Smiths quarried the stone and shipped it in rough blocks to manufacturers in eastern United States, Europe and Japan for finishing. In 1962 Hiram learned the meticulous technique of finishing the stones himself and found a ready demand. Hiram Smith has now been succeeded by two sons, James and Richard."

The Smith's brochure describes the processing of the novaculite blocks as follows:

> "The rough Novaculite is cut by diamond saws, using large amounts of degradable lubricant as a coolant. Each stone is cut individually by hand, so the quality of each stone is graded many times during the cutting process. To properly cut whetstones, it often takes many, many months to learn the technique of diamond saw operation.
>
> Each stone is lapped (smoothed) on horizontal grinding wheels using industrial grit as an abrasive. This process removes any ridges or saw marks on the stones. The edges of each stone are beveled on vertical grinding wheels to smooth any rough edges the stones may have. During this finishing process each stone is again graded for quality. Due to the hand cutting and finishing of each individual stone, tolerances will be plus or minus 1/16 of an inch."

There are four grades of the whetstones. The Washita Stone is the coarsest grade, used by commercial knife sharpeners, butchers, sportsmen, wood carvers, and others who desire a quick keen edge. Much of this stone is of the rainbow type. Soft Arkansas is a general purpose stone for kitchen cutlery, hunting knives and pocket knives, producing a polished as well as keen edge. Most of this stone is gray or gray marbled. Hard Arkansas Stone, white or almost so, produces a fine polished edge. It is used by gunsmiths, dentists, surgeons, watchmakers, precision toolmakers, and finicky sportsmen. Hard Arkansas stones are the only stones for the precision sharpening and polishing of surgical instruments. Finest of all is the Black Hard Arkansas Stone, used for polishing the final finish on edges already extremely sharp.

STOP 2 – UNION CARBIDE CORPORATION VANADIUM MINE AT WILSON SPRINGS

The following article titled Geology of the Wilson Springs Vanadium Deposit, Garland County, Arkansas was written by Stewart Hollingsworth, Geologist, Union Carbide Corporation in 1967.

INTRODUCTION

The vanadium deposits currently mined by Union Carbide Corporation at Wilson Springs, Garland County, Arkansas, are the only deposits mined specifically for vanadium in the United States. The geologic setting of these deposits is described in this report.

The Wilson Springs operation takes its name from Wilson Mineral Springs (formerly known as Potash Sulfur Springs), which is located near the edge of the small circular alkalic intrusive also named after these springs. J. F. Williams described the igneous rocks of the area in 1890 and noted that a large hotel existed near the springs. The building was first abandoned and later destroyed by a fire in the early 1930's.

Interest in the economic potential of the Wilson Springs area was primarily initiated in 1950 by the discovery of anomalous radioactivity and one boulder containing small amounts of uranian pyrochlore (Erickson and Blade, p. 83). Several investigations were conducted by the U.S. Geological Survey, the Atomic Energy Commission, the Arkansas Geological Commission, and private mineral interests. Only trace amounts of uranium were indicated by drilling and trenching adjacent to the "discovery boulder." Geochemical determinations by the U. S. Geological Survey and others indicated significant concentrations of niobium and vanadium in the vicinity of the uranium prospect (Beroni, 1955).

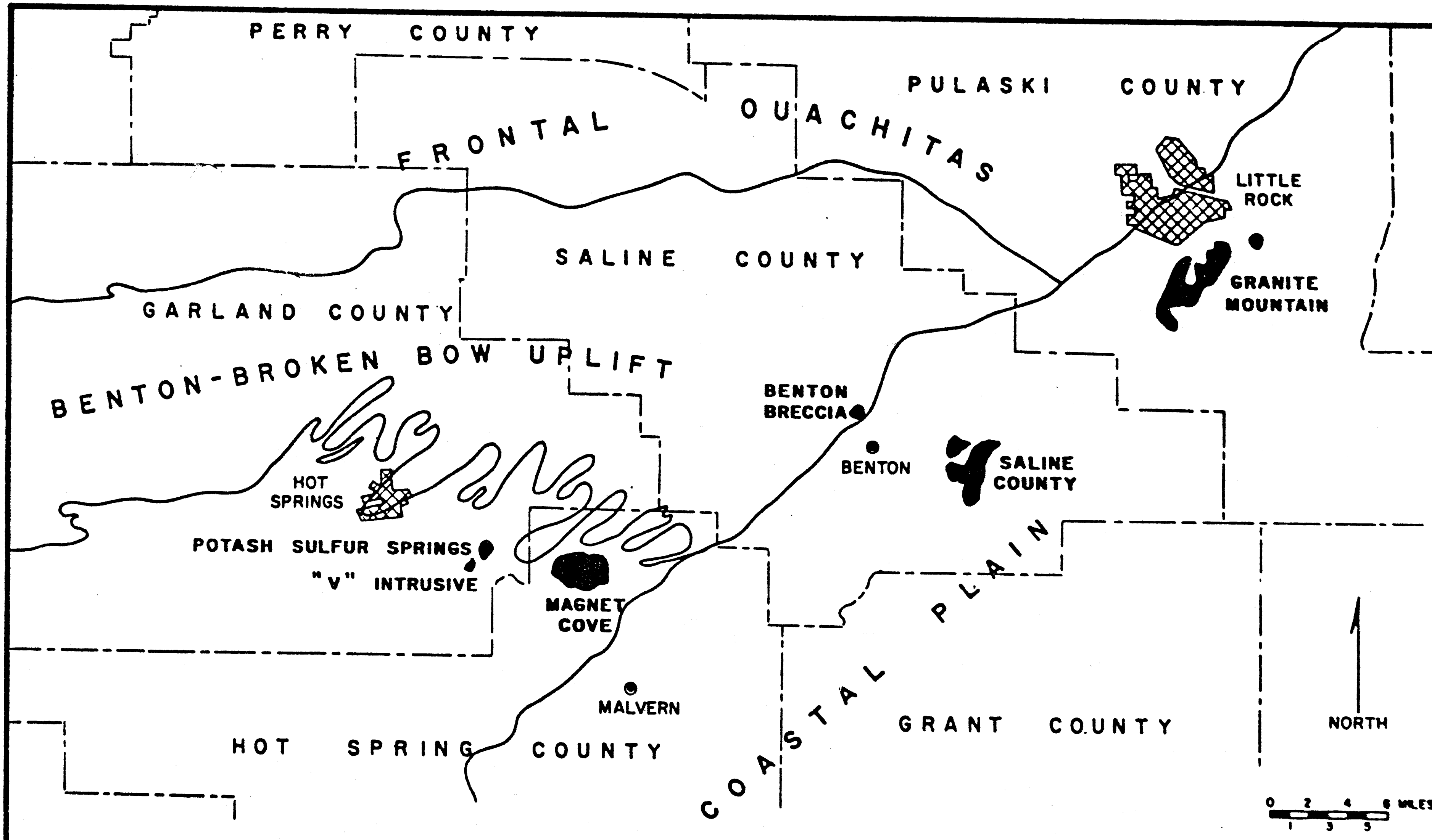
Union Carbide geologists first investigated the Wilson Springs area for vanadium in 1960. After obtaining mineral leases, a preliminary core drilling program during 1961-1962 disclosed vanadium ores. Development drilling was resumed in 1964; and by September, 1965, sufficient reserves were indicated to justify the construction of the Wilson Springs Vanadium Plant.

GEOLOGY

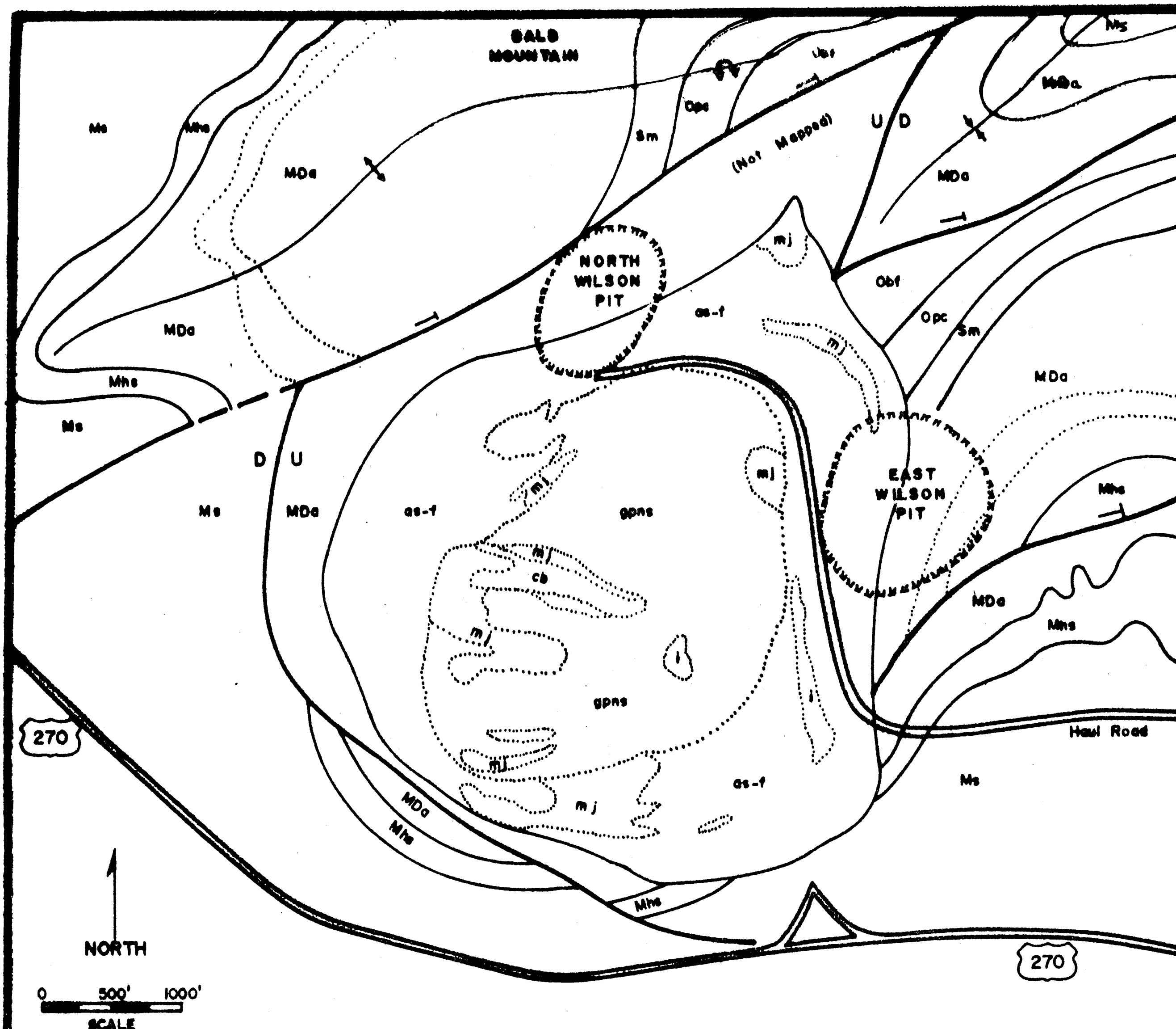
The location and general geologic setting of the Wilson Springs vanadium deposits are shown in Figures 6 and 7. The dominant feature of the area is the Potash Sulfur Springs[1] igneous complex, which intruded folded and faulted Paleozoic rocks. The distribution and description of the various rock types are generalized, with modifications, from D. W. Pollock (1966) who performed field petrographic investigations of the intrusive. The highly variable contact rocks have been studied in detail by V. J. Hoffmann and D. M. Hausen of Union Carbide Corporation.

Igneous Rocks

The Potash Sulfur Springs intrusive is a circular alkalic igneous complex exposed for somewhat less than a mile in diameter, that probably was emplaced in early Late Cretaceous time (Zartman and Marvin determined the Magnet Cove



LOCATION MAP SHOWING POTASH SULFUR SPRINGS INTRUSIVE
AND OTHER EXPOSED ALKALIC INTRUSIVES
OF CENTRAL ARKANSAS



GENERALIZED GEOLOGIC MAP OF THE POTASH SULFUR SPRINGS INTRUSIVE AND VICINITY, GARLAND COUNTY, ARKANSAS

MODIFIED FROM PURDUE AND MISER (1923) AND POLLOCK (1966)

SEDIMENTARY ROCKS		
MISSISSIPPIAN	Ms	STANLEY SHALE
MISSISSIPPIAN	Mhs	HOT SPRINGS SANDSTONE
DEVONIAN AND MISSISSIPPIAN	MDa	ARKANSAS NOVACULITE (upper, middle, lower)
SILURIAN	Sm	MISSOURI MT. SHALE
ORDOVICIAN	Opc	POLK CREEK SHALE
ORDOVICIAN	Obf	BIGFORK CHERT

IGNEOUS ROCKS	
as-f	ALKALI SYENITE AND FENITE
gpns	GARNET PYROXENE NEPHELINE SYENITE
i	IJOLITE
mj	MELTEIGITE, PYROXENITE & JACUPIRANGITE
cb	CALCITE CEMENTED BRECCIA

THRUST FAULT — ANTICLINE

U/D FAULT — SYNCLINE

intrusive to be 95 ± 5 million years). The complex has a crude ring structure similar to the Magnet Cove intrusive exposed about 6 miles to the east. The outer ring of the complex is alkalic syenite and fenite. Much of the central part of the complex is nepheline syenite. Disconnected exposures of jacupirangite, melteigite, and ijolite are present throughout the area. Near the center of the complex a calcite-cemented breccia crops out and carbonatite has been encountered in a few drill holes. Carbonatite is also present as dikes and as irregular masses in the subsurface near the margins of the intrusive. Several igneous and sedimentary rock breccias, commonly with feldspathic matrix, are present within and near the margins of the intrusive.

Saprolite, highly weathered rock averaging about 40 feet in thickness, is developed over much of the igneous area, but the outer portion of the nepheline syenite ring supports a low ridge.

The basic rocks of the Potash Sulfur Springs complex include jacupirangite, pyroxenite, and members of the melteigite-ijolite series. Nepheline content varies from traces in jacupirangite to a maximum of 60 percent in ijolite. Biotite jacupirangite contains small amounts of magnetite and titanite with biotite as the only major constituent. The pyroxenite contains aegirine-diopside, ferroaugite, and biotite. Locally these rocks have been intensely chloritized. The melteigites have aegirine-diopside with 14 to 40 percent nepheline. In one variety of melteigite, titanium-rich andradite (garnet) makes up 30 to 60 percent of the rock. Garnet and pyroxene are present in the ijolites. Secondary minerals such as calcite, orthoclase, zeolites, and pyrite may be up to 55 percent of these rocks.

The nepheline syenite contains 7 percent aegirine-diopside and 7 percent garnet with about 32 percent nepheline. Calcite, secondary orthoclase, and zeolites are present in variable amounts.

The alkali syenite and fenite ring represents 51 percent of the exposed complex. The alkali syenites are medium to coarse grained with 80 to 98 percent orthoclase. Much of the rock in this zone is a product of alkali-metasomatism and, therefore, should be termed fenite rather than syenite. The contact between the fenite and the surrounding sedimentary rock is irregular, and residual blocks and zones of metamorphosed sedimentary rocks are frequently found. Relict bedding can be seen in some fenite exposures. Aegirine is a common accessory mineral in the fenite, and occasionally makes up 80 to 90 percent of the rock. Locally, biotite, apatite, or siderite may be major constituents in the border fenite.

Calcite carbonatite has been encountered beneath the saprolite cover by several drill holes in the central part of the complex. Biotite, aegirine, pyrite, pyrrhotite, and magnetite are the most common accessory minerals. A few feldspar-carbonate veins, similar to the veins at Magnet Cove, have been encountered.

Dikes and sills of various sizes and attitudes are frequent within the igneous mass but appear to be more abundant in the surrounding sedimentary rocks. A large variety of rock types is present ranging from phonolites and trachytes to the very basic varieties including ouachitite, monchiquite, and fourchite. Outside the igneous complex, most of the dikes are partially or completely argillitized, often to depths of several hundred feet——only the texture remains to identify the origin of such clays. Many dikes are xenolithic; a large irregular dike mass in the North Wilson pit contains rounded as well as angular fragments of the adjacent rocks.

Stratigraphy

The sedimentary rocks in the immediate vicinity of the Potash Sulfur Springs intrusive range from Ordovician (Bigfork Chert) to Mississippian (Stanley Shale) in age. The approximate observed thicknesses of these units and a brief description are shown in the accompanying table.

Within 1000 feet of the igneous rocks, the Arkansas Novaculite has been recrystallized by thermal metamorphism to a very fine to medium grained quartzite. Closer to the intrusive, the siliceous units contain cristobalite, wollastonite, tremolite, aegirine, miserite, and calcite in a highly variable metamorphic rock suite. The shale units have been metamorphosed to hornfels. Large areas of shale have been argillitized, at least in part by hydrothermal solutions, thus many of the stratigraphic units cannot be distinguished in the immediate vicinity of the ore deposits.

Structure

The Potash Sulfur Springs intrusive is located on a southwest plunging anticlinal nose of the Zigzag Mountains. The sedimentary rocks were intensely folded and faulted during the Late Pennsylvanian Ouachita orogeny. These structures trend about N 65° E. Several anticlines and at least three thrust faults are present in the area (Figure 2). The northernmost anticline at Bald Mountain is overturned to the north for much of its length.

The Potash Sulfur Springs intrusive considerably distorted the older Ouachita structural fabric. Minor faulting is quite common within 1,000 feet of the intrusive contacts. One large concentric fault is shown on the geologic map (Figure 7) and many others have been noted (Figure 8). Some of the older Ouachita faults were re-opened, altered, and mineralized by the intrusive, especially the thrust fault at the north edge of the North Wilson pit.

The high west wall of the North Wilson pit shown in Figure 9 displays the structural complexity of the near-contact areas. On the far right is a shattered zone probably representing an anticline. A broad fault zone left of the xenolithic dike cuts the bottom of a syncline. The contact between the Lower and Middle Divisions of the Arkansas Novaculite in the center marks the north limb of an anticline. Southward the Middle Division shales and cherts reappear in a syncline with two or three small faults and numerous dikes. Farther south fenite replaces the novaculite along an irregular contact.

ORE DEPOSITS

The vanadium ore deposits of the Wilson Springs area occur near the contact between the alkalic igneous rocks and the surrounding sedimentary rocks. Two ore bodies are being developed by separate open pits. Other deposits are present in the area that will be developed at a later date.

The vanadiferous ores occur as local concentrations within large, irregular areas of argillic alteration. Fenite, feldspathic breccias, and metamorphosed sedimentary rocks have all been altered and mineralized in such areas (Figure 8). Iron oxides are common near the present surface, and pyrite is present at depth.

TABLE I

STRATIGRAPHIC UNITS IN THE VICINITY OF THE POTASH SULPHUR SPRINGS INTRUSIVE

AGE	FORMATION	DESCRIPTION	APPROXIMATE LOCAL THICKNESS IN FEET
Mississippian	Stanley Shale	Dark gray platy shale with thick beds of fine-grained clayey sandstone.	over 1,000
Mississippian	Hot Springs Sandstone	Light gray, very-fine grained sandstone interbedded with dark gray shale.	90
Devonian and Mississippian	Arkansas Novaculite	Upper Division: medium to thick bedded white novaculite and ferruginous sandstones. Some gray shale interbeds are present and the base is marked by 1–2′ of conglomerate.	75
		Middle Division: thin bedded novaculite interbedded with dark gray fissile shale—strongly argillitized in the immediate area.	120
		Lower Division: white and black massive novaculite.	380
Silurian	Missouri Mountain Shale	Pale red to greenish gray shale, 1–2′ of ferruginous fine-grained sandstone at base may represent the Blaylock Sandstone.	100
Ordovician	Polk Creek Shale	Black, fissile, graphitic shale with thin beds of limy chert.	130 to 200
Ordovician	Bigfork Chert	Gray and black chert regularly interbedded with gray siliceous shale.	over 300

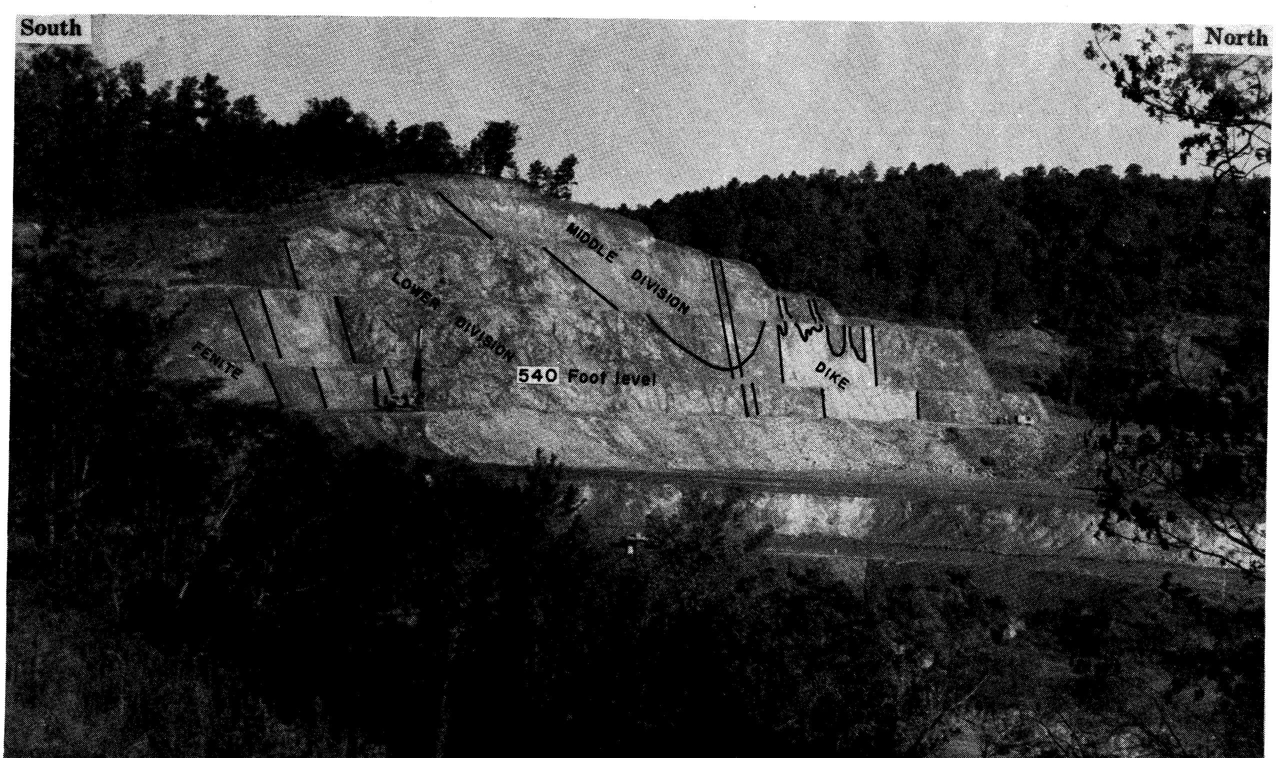
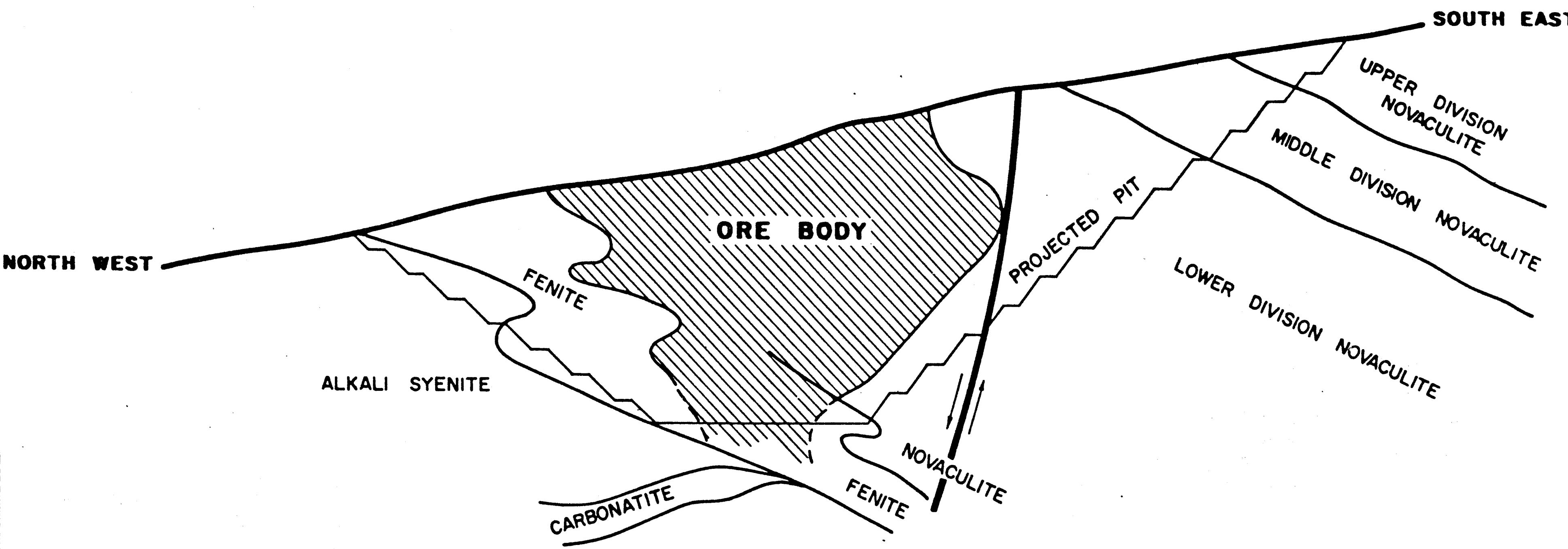


Figure 9. View of the North Wilson Pit looking northwest at the north-south high wall. Description in text.



DIAGRAMMATIC CROSS SECTION
OF THE EAST WILSON PIT

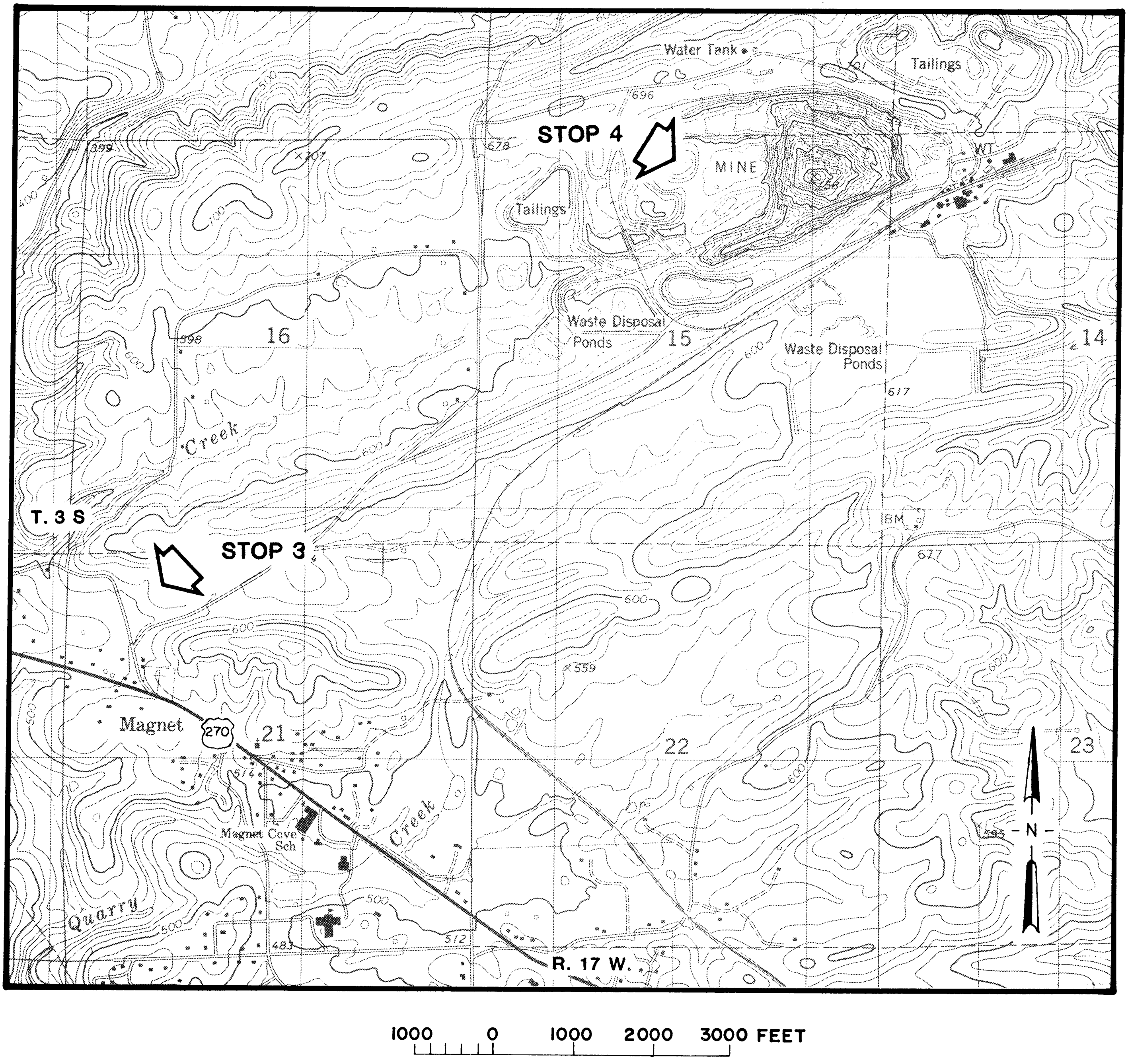
NOT TO SCALE

The ores contain about one percent V_2O_5 which very rarely occurs as discrete vanadium minerals. Montroseite ($VO \cdot OH$) and such secondary minerals as fervanite ($2Fe_2O_3 \cdot 2V_2O_5 \cdot 5H_2O$) and hewettite ($CaO \cdot 3V_2O_5 \cdot 9H_2O$) have been noted. The vanadium occurs as a vicarious element in several rock-forming minerals and their alteration products.

Even though the Wilson Springs area has been investigated as a potential niobium deposit (Fryklund, Harner, and Kaiser, p. 55), the niobium content of the ores being mined is low, generally under 0.10% Nb_2O_5. Titanium occurs in minor quantities, mainly as anatase, which contrasts sharply with the higher values in the titanium prospects at the Magnet Cove intrusive.

Close control of the vanadium content must be maintained to derive optimum metallurgical results in the processing of the ore. The varying nature of the ore requires close spaced test drilling, generally 20 foot centers, directly ahead of mining. Visual inspection is of limited value in ore control due to the variability of values and the non-descript nature of the ore.

Recent work by Howard (1975) characterized the intrusive rocks of Potash Sulfur Springs as a carbonated nephelinitic stock which was intruded by late mafic differentiates and high volatile residual carbonates. Heathcote (1979) reported on the alteration of masses of Arkansas Novaculite adjacent to the intrusion to felspathic fenite. Early carbonatite phases were implicated as the source of feintizing fluids. Heathcote and Owens (1980) envisioned formation of the orebody to have proceeded according to the following scheme. Fenitizing fluids carrying Na, Al, Fe, V, and P permeated the country rock above ascending alkaline magma. These fluids altered the Upper and Lower Divisions of the Arkansas Novaculite to Or85Ab15 + apatite, while the argillaceous Middle Divison fixed Na, Fe and V as it altered to Fe-sanidine bearing aegirine pyroxenite. Some aegirine also formed in the Lower Division as a replacement of feldspar. A later hydrothermal phase attacked the aegirine, and deposited pyrite. Intense fracturing and brecciation of the country rock preceeded injection of carbonatite and alkaline dikes. Vanadium ore was formed during weathering of the altered pyroxenite, probably in early to middle Tertiary time.



STOP 3–CHRISTY VANADIUM–TITANIUM MINE

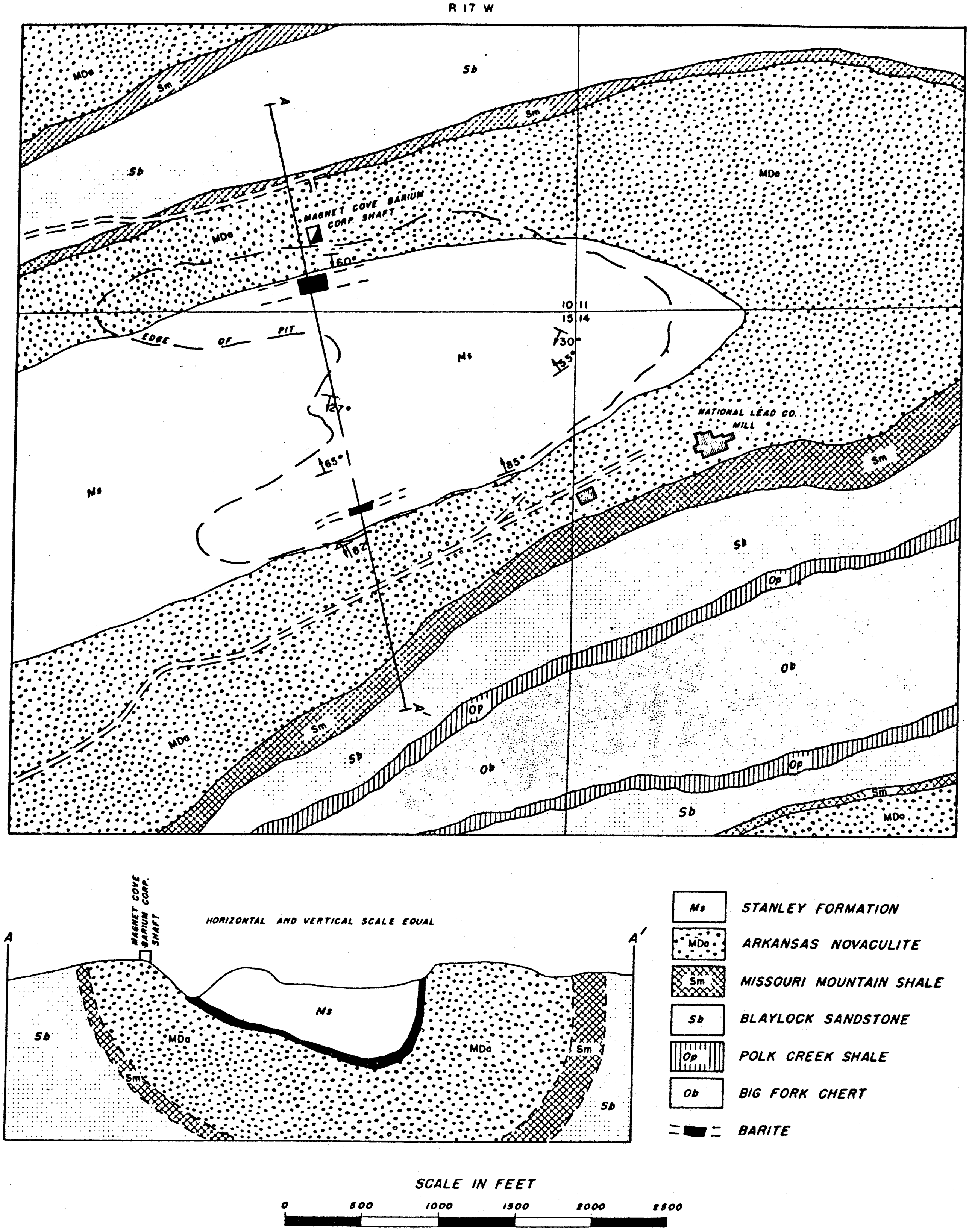
STOP 4–NATIONAL LEAD INDUSTRIES CHAMBERLAIN CREEK BARITE DEPOSIT

STOP 3 – CHRISTY VANADIUM–TITANIUM MINE

The Christy deposit is located on the east rim of Magnet Cove about half a mile northwest of the community of Magnet. Drilling by the U. S. Bureau of Mines in 1949 was undertaken to establish the extent of the titanium mineralization (brookite) in the deposit. The deposit lies on the top and partly on the south slope of an east-west ridge of metamorphosed Arkansas Novaculite. This ridge is the south limit of the Chamberlain Creek syncline, which is overturned so that the sediments dip about 45^o south. A few hundred feet to the west of the deposit the syncline is truncated by a coarse-grained nepheline syenite intrusive. Analyses of core samples from the USBM project varied from less than 1% to a maximum of 26% TiO_2, averaging about 5% TiO_2 for the orebody. Appreciable percentages of V_2O_5 (1 to 2%) were encountered in several core samples. Union Carbide Corporation obtained leases on this property during their vanadium-titanium exploration program in Arkansas in the mid-1960's. The deposit was drilled out by Union Carbide shortly thereafter. The test pit, dug in 1975, was developmental work to allow testing of the ore for both amenability to their present mill at Wilson Springs and blendability of Christy ore with those of Wilson Springs. The Christy vanadium ore consists of goethite-rich clay and brookite and averages slightly less than 1% V_2O_5. In December, 1981 developmental work began for ore stockpile sites and water control ponds.

Minerals found with the vanadium ores besides brookite, include smoky quartz, taeniolite, rutile, anatase, siderite, and pyrite.

Fryklund and Holbrook (1950) suggested that the Christy deposit was formed by the introduction of mineralizing fluids from the Magnet Cove intrusion into the folded and metamorphosed Arkansas Novaculite, with subsequent erosion and weathering of mineralized rock. In a recent investigation of TiO_2 - polymorph-bearing vein deposits adjacent to the Magnet Cove intrusion, Viscio (1981) discovered adularia at the Hardy-Walsh brookite deposit (approximately 2 miles to the N NW) on the northern limb of the Chamberlain Creek syncline, suggesting that the brookite deposits adjacent to Magnet Cove may be an aborted initial phase of alkali metasomatism (fenitization) by late fluids from the Magnet Cove intrusion.



GEOLOGIC MAP OF THE CHAMBERLAIN CREEK BARITE DEPOSIT HOT SPRING COUNTY ARKANSAS

AFTER B. J. SCULL 1956

ARKANSAS GEOLOGICAL COMMISSION

STOP 4 — NATIONAL LEAD INDUSTRIES CHAMBERLAIN CREEK BARITE DEPOSIT

This extensive barite deposit is currently inactive, but there is still ore remaining in deeper portions of the syncline to the west.

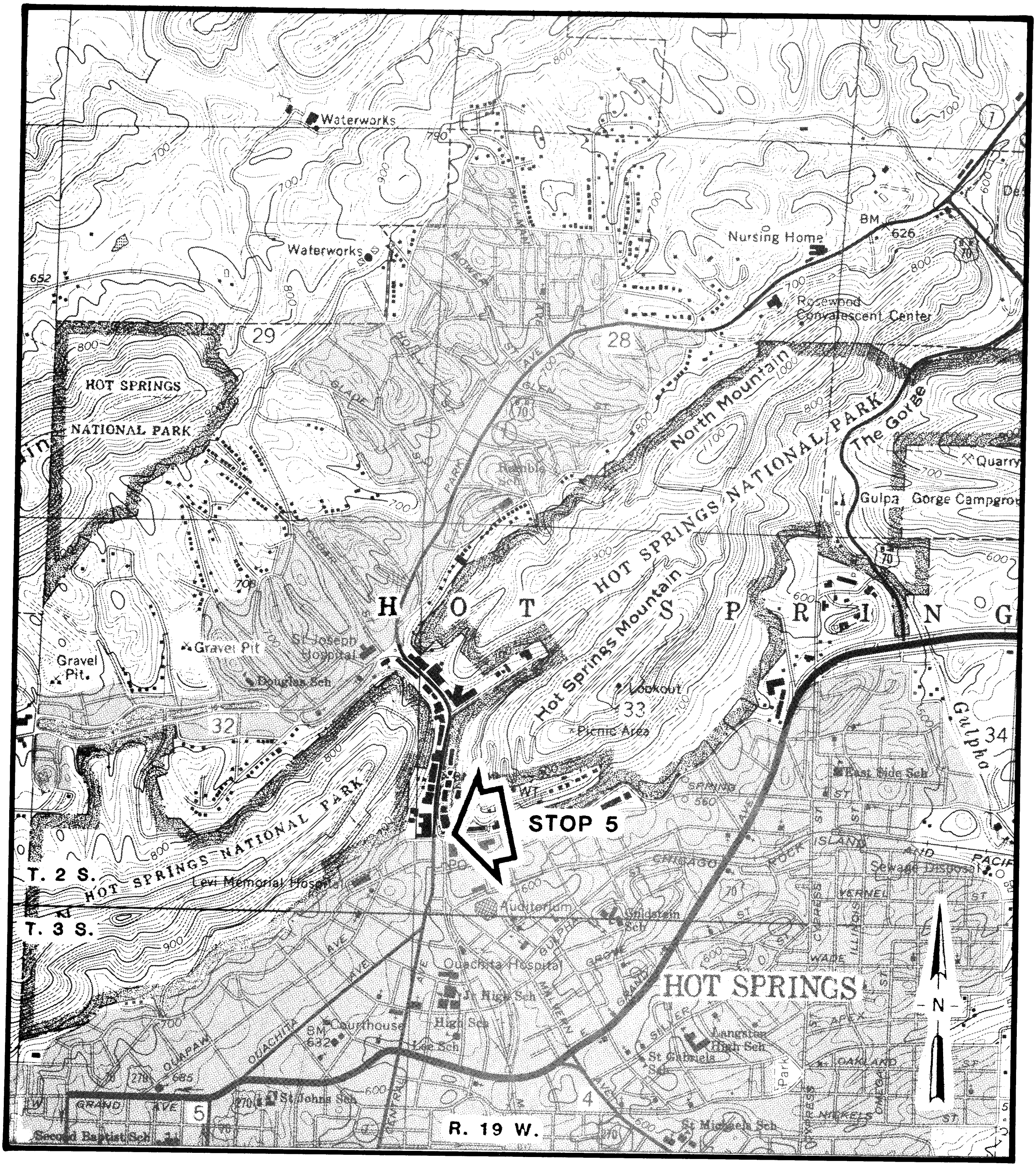
The two companies formerly operating this deposit produced several hundred thousand tons of barite from this deposit. Exploitation of the deposit began in 1939 when the Magnet Cove Barium Corporation started mining and milling operations utilizing flotation to concentrate the ore. The Baroid Sales Division of National Lead Industries started mining and milling barite in 1942.

The office and mill of Baroid Division of National Lead Industries is on the southern limb of the syncline. They originally removed the shallow ore along the syncline by stripping, but the depth of their ore then forced them to go exclusively to underground mining. Mining at the deposit was terminated in recent years, but the mill is still processing ore from deposits in Montgomery County to the west.

In the milling operations the ore is ground to 325 mesh and processed by froth flotation. The concentrates produced run about 98 percent $BaSO_4$ with a loss of only about 10 percent of the original values. All of the barite produced from this deposit was used as a weighting agent in oil well drilling muds.

The Chamberlain Creek barite deposit is a stratiform deposit at the base of the Stanley Shale (Mississippian). This zone is essentially conformable with the bedding of the enclosing sediments and averages 60 feet in thickness. Structurally, the deposit lies in an asymmetrical syncline. The syncline plunges southwest toward the Magnet Cove intrusive one mile to the west and is truncated at its eastern end by erosion giving the orebody a spoon-like shape. The maximum length of the orebody is 3200 feet and its maximum width is 1800 feet. Some of the ore is nodular, but most of it has a dark gray, dense appearance resembling limestone. The barite is intimately mixed with minor amounts of fine-grained quartz, pyrite, and shale. A typical analysis of high-grade ore would be 85 percent $BaSO_4$, 11 percent SiO_2, and 3 percent iron oxide and alumina. The average mill feed was about 60 percent $BaSO_4$.

The origin of the barite in Arkansas has been the subject of two Ph.D dissertations: B. J. Scull, University of Oklahoma, 1956 (published 1958, Arkansas Geological and Conservation Commission, Information Circular 18) and R. A. Zimmermann, University of Missouri, 1964. Scull postulated that all of the Arkansas barite deposits were lower Upper Cretaceous in age, derived from the sub-silicic Upper Gulf Coastal Plain igneous suite and, with the sulfide deposits in the Ouachita Mountains, represented a minerogenetic province. Zimmermann concentrated on the deposits in the Stanley Formation (several thousand times greater in volume than the combined other types of deposits) and postulated that they are of sedimentary origin, and thus Mississippian in age.



1000 0 1000 2000 3000 FEET

STOP 5—HOT SPRINGS NATIONAL PARK VISITORS CENTER

STOP 5 — "HOT SPRINGS" AT HOT SPRINGS

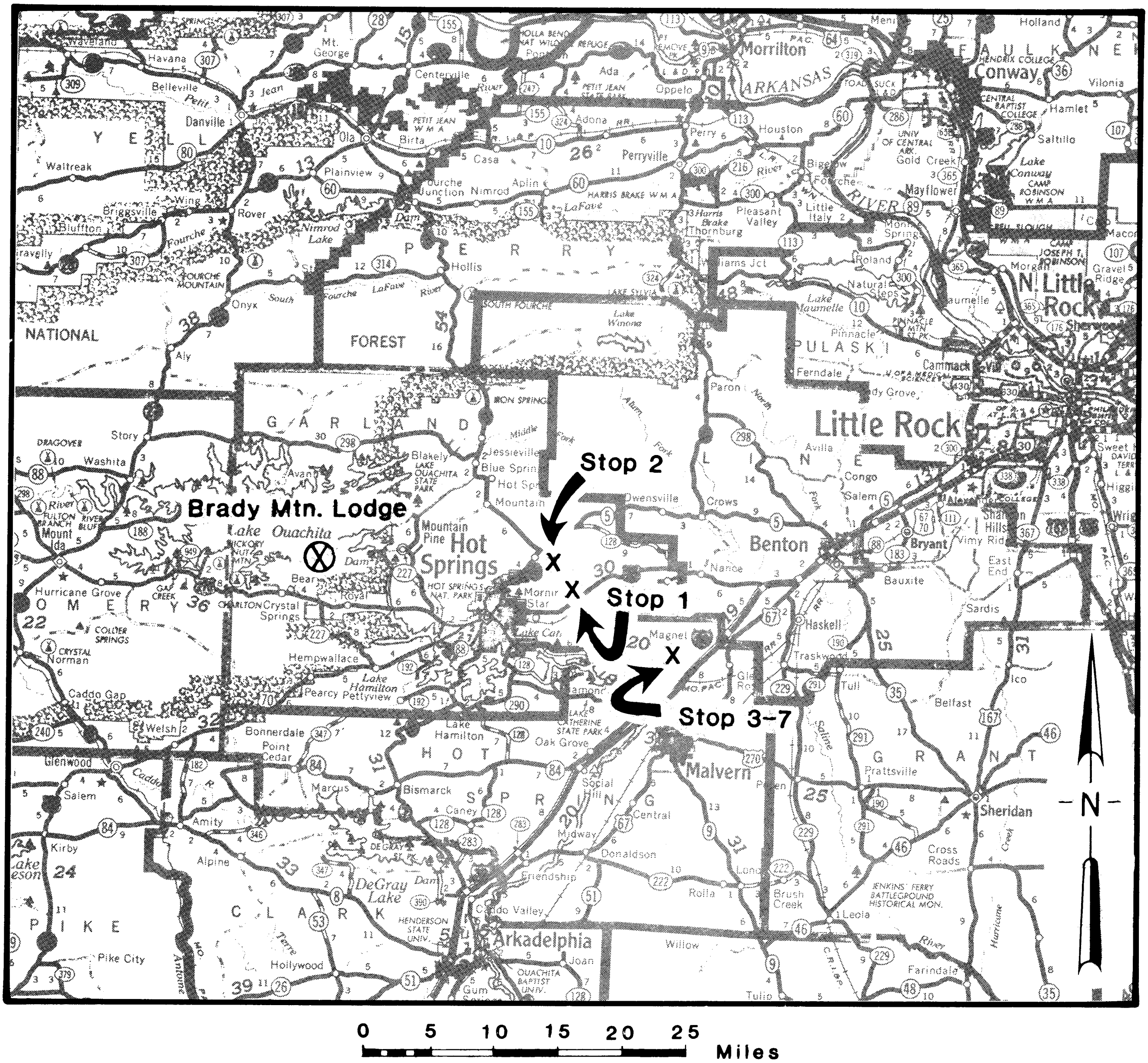
This stop is to acquaint geologists with the unique Grand Promenade Trail, its hot springs and tufa rock, and with the fine museum at Hot Springs National Park, the first Federal Reservation (1832) and the Eighteenth National Park (1921) in the United States.

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^{o} to over 147^{o} 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. Spring flow fluctuates seasonally.

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.

Beddinger 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.



INDEX MAP OF SECOND DAY STOPS

DESCRIPTION OF SECOND DAY STOPS

STOP 1 – 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 or other purposes. Typical analyses of the Novacite and Ebony are:

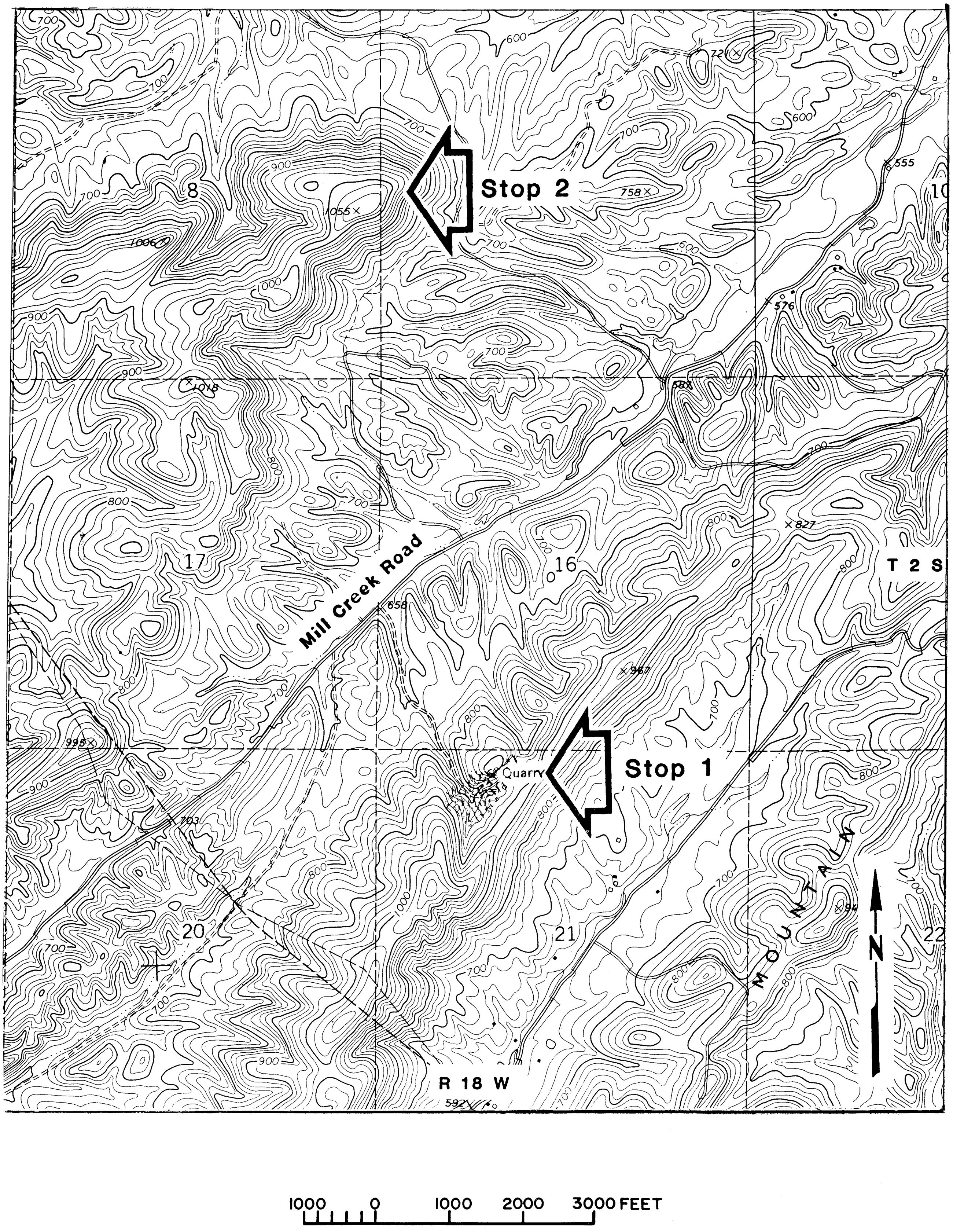
		Novacite	Ebony
Silica	SiO_2	99.49 %	60.40 %
Carbon	C	0.00 %	3.37 %
Sulphur	S	0.00 %	0.07 %
Aluminum oxide	AL_2O_3	0.102 %	22.40 %
Ferric oxide	Fe_2O_3	0.039 %	2.15 %
Titanium oxide	TiO_2	0.015 %	1.70 %
Calcium oxide	CaO	0.014 %	2.00 %
Magnesium oxide	MgO	0.021 %	0.38 %
Loss on Ignition		0.190 %	9.75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

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 that have flowed vertically down 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;



STOP 1 – MALVERN MINERALS COMPANY'S TRIPOLI MINE

STOP 2 – SMITH'S HARD WHITE (ARKANSAS) WHETSTONE QUARRY

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.

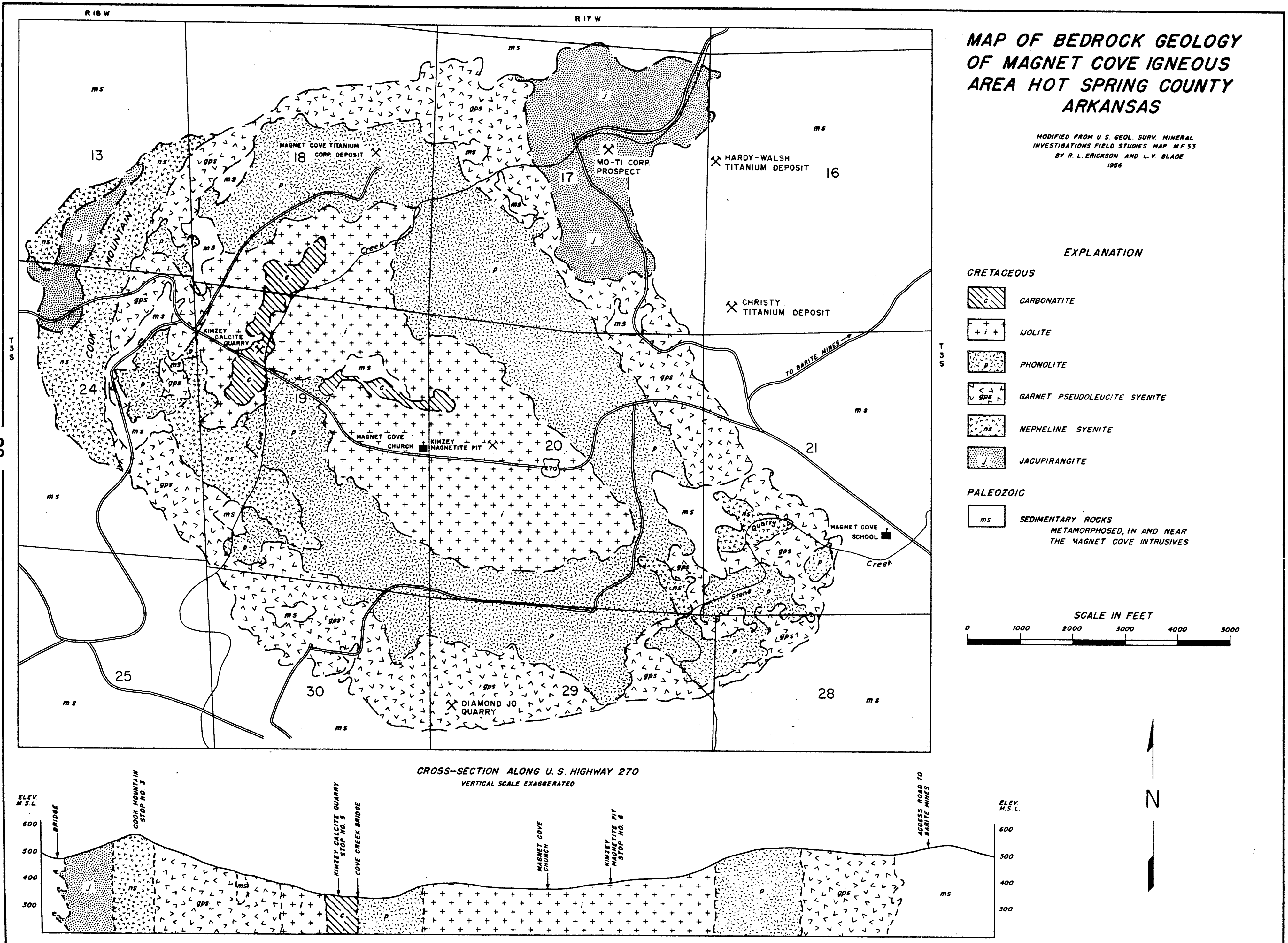
STOP 2 — SMITH'S HARD WHITE (ARKANSAS) WHETSTONE QUARRY

The Arkansas novaculite consists mainly of an unusual type of rock, to which Schoolcraft, as early as 1819, gave the name "novaculite", a term now in general use. Although this kind of rock is uncommon in most areas, it is widely distributed in the Ouachita Mountains. The novaculite crops out in an almost unbroken trend from around Little Rock, in Pulaski County, Arkansas, westward to McCurtain County, Oklahoma, a distance of about 200 miles. Its greatest extent from north to south is in the eastern Ouachitas, where the distance between the northernmost and southernmost outcrop is more than 30 miles. Because of the great hardness of the novaculite, these belts stand out as steep, narrow ridges, both the younger and the older beds forming the adjacent valleys. The novaculite is thickest in its southern outcrops, where its average thickness is about 700 feet, but it thins toward the north rather rapidly. The novaculite itself is dense, homogeneous, highly siliceous, translucent on thin edges, and is commonly bluish white. At some places it is red, green, brown, yellow, and even black, the various shades being produced by carbonaceous matter or by iron and manganese oxides. When weathered the rock loses its calcium and manganese carbonate and becomes white and porous. The Arkansas Novaculite is Mississippian-Devonian age and the shales often contain conodonts and other fossils.

The Smith's quarry is one of several quarries in the Lower Division of the Arkansas Novaculite in Garland and Hot Spring Counties, Arkansas that produces whetstone-grade novaculite. The novaculite that is quarried occurs as rather thin, even beds of slightly weathered, white to light gray novaculite near the base of the Lower Division of the formation.

According to Brian Willis of Smith's Whetstone Company, a typical novaculite quarrying operation consists of:

(1) Clearing the proposed site, and removing rough weathered rock;
(2) Drilling shallow shot holes with five foot spacing on a 20′ x 20′ grid;
(3) Loading and shooting the hole with "lump coal" (black powder);
(4) Loading suitable size blocks with a front end loader;
(5) Splitting oversize blocks with hand tools;
(6) Removing excess material from the quarry floor with a front end loader or back hoe;
(7) Repeating the cycle.


MAP OF BEDROCK GEOLOGY OF MAGNET COVE IGNEOUS AREA HOT SPRING COUNTY ARKANSAS
MODIFIED FROM U. S. GEOL. SURV. MINERAL INVESTIGATIONS FIELD STUDIES MAP MF 53 BY R. L. ERICKSON AND L. V. BLADE 1956
EXPLANATION
CRETACEOUS
CARBONATITE
IJOLITE
PHONOLITE
GARNET PSEUDOLEUCITE SYENITE
NEPHELINE SYENITE
JACUPIRANGITE
PALEOZOIC
SEDIMENTARY ROCKS METAMORPHOSED, IN AND NEAR THE MAGNET COVE INTRUSIVES
SCALE IN FEET
0 1000 2000 3000 4000 5000
N
R 18 W
R 17 W
T 3 S
MAGNET COVE TITANIUM CORP. DEPOSIT
MO-TI CORP. PROSPECT
HARDY-WALSH TITANIUM DEPOSIT
CHRISTY TITANIUM DEPOSIT
TO BARITE MINES
KIMZEY CALCITE QUARRY
MAGNET COVE CHURCH
KIMZEY MAGNETITE PIT
MAGNET COVE SCHOOL
DIAMOND JO QUARRY
COOK MOUNTAIN
Creek
Cove
Stone
Quarry
270
13
18
17
16
24
19
20
21
25
30
29
28
CROSS-SECTION ALONG U. S. HIGHWAY 270
VERTICAL SCALE EXAGGERATED
ELEV. M.S.L.
600
500
400
300
BRIDGE
COOK MOUNTAIN STOP NO. 3
KIMZEY CALCITE QUARRY STOP NO. 5
COVE CREEK BRIDGE
MAGNET COVE CHURCH
KIMZEY MAGNETITE PIT STOP NO. 6
ACCESS ROAD TO BARITE MINES

GEOLOGY OF MAGNET COVE

Magnet Cove is an area of unusual petrologic and mineralogic interest that derives its name from the presence of magnetite in the surface soil and from its basin-like shape. The Cove is located in northern Hot Spring County, Arkansas about 12 miles east of the city of Hot Springs. U.S. Highway 270 between Malvern and Hot Springs passes approximately through the center of the Cove.

The Cove lies at the eastern end of the Mazarn synclinorium about 1½ miles from where the Tertiary sediments of the Gulf Coastal Plain overlap the folded Paleozoic rocks. The parallel or almost parallel ridges and valleys adjacent to the Cove area are the topographic expression of plunging anticlines and synclines. The ridges are even-crested and are arranged in an unusual pattern that has given the name ZigZag Mountains to this subdivision of the synclinorium.

The sedimentary rocks cropping out in the immediate vicinity of Magnet Cove are Upper Devonian and Mississippian in age. The oldest rocks belong to the Arkansas Novaculite Formation and consist of novaculite with some interbedded shale. Overlying the novaculite is the Stanley Shale of Mississippian age.

The Cove itself is an elliptical basin with a maximum northwest-southeast diameter of about three miles and it includes an area of about five square miles. The rim of the basin is broken through only at two points where Cove Creek enters and leaves the Cove. The rim of the Cove consists of an outerbelt of light-colored nepheline syenites and an inner belt of phonolites. A large part of the Cove interior is covered by deep residual and alluvial soils that are presumed to be underlain by ijolite, a basic variety of nepheline syenite. Within the ijolite core are at least two large masses of carbonatite one of which is exposed in the Kimzey calcite quarry.

There are three generalizations that may be made about the Magnet Cove igneous rocks:

(1) They are all varieties of nepheline syenite.
(2) They contain a variety and abundance of titanium minerals.
(3) They become increasingly basic from the rim to the center of the Cove.

Several theories have been suggested for the emplacement of the Magnet Cove intrusives. H. S. Williams (1890) believed that the igneous rocks were formed during three different periods of igneous activity. The first period produced the basic nephelitic rocks which constitute a large part of the interior basin. During the second period monchiquitic rocks filled the cracks in the first period rocks. The light-colored syenites of the Cove rim were formed along with numerous dikes during a third period. H. S. Washington in 1900 suggested the differentiation of a magma in place.

R. L. Erickson and L. V. Blade of the U. S. Geological Survey have made a detailed field and laboratory study of the Magnet Cove rocks. This project included the complete remapping of the Cove as well as intensive petrographic and geochemical studies of the igneous rocks. This work has been published as U. S. G. S. Professional Paper 425, "Alkalic Igneous Complex at Magnet Cove, Arkansas". In revising the Cove map the authors have used current terminology in naming the rock units and they have also made a number of significant corrections in the original map of the Cove by Williams. Most important of these changes were recognizing as igneous rock (phonolite), the band of rock lying on the inner rim of the Cove that was originally considered metamorphosed sediments and identifying the so-called "tufa" of the Cove interior as the weathered residual of carbonatite masses. In adapting this U. S. Geological

Survey map for field trip use many of the smaller rock units were necessarily omitted and similar rock types were combined into single units. For a more detailed examination of the rock types of Magnet Cove, the reader is referred to the U. S. Geological Survey Professional Paper.

A description of the rock names used on the geological map of Magnet Cove is included here as the terms are unfamiliar to many geologists:

Carbonatite –

Dikes and irregular bodies of coarsely crystalline calcite. Locally contains concentrations of apatite, monticellite, magnetite, perovskite, and black garnet.

Ijolite –

Fine-to-coarse-grained rocks composed chiefly of nepheline, diopside and black garnet. Contains biotite in some places but does not have any feldspars.

Phonolite --

Fine-grained, gray to greenish to black rocks locally brecciated and banded.

Garnet Pseudoleucite Syenite –

Light gray, medium-grained rock composed of white pseudoleucite, tabular feldspar, pyroxene and black garnet. The coarse-grained phase of this rock is composed of black garnet, nepheline, feldspar, and pyroxene.

The Magnet Cove intrusive complex and the surrounding host rock alteration zone, primarily the Arkansas Novaculite, have long been known for its unusual minerals. Over one hundred minerals are known to occur in the area. Some of the more outstanding minerals to the collector are: cyclic rutile eightling and sixling twins, paramorphs of rutile after brookite, brilliant lustered black Brookite crystals perched on rusty smoky quartz crystals, one foot long plus black smoky quartz crystals, eighteen inch long aegirine crystals in pegmatite matrix (originally mistaken for tourmaline), pink eudialyte crystals, a variety of crystal forms of perovskite, clusters of octahedral magnetite, massive lodestone, black to dark brown melanite crystals intergrown with apatite needles, lime green vesuvianite crystals, pyrite crystals coated with molybdenite, mica books to six inches across, and trapezohedral pseudoleucite crystals. The micromount collector visiting Magnet Cove should look for any rock containing cavities. Depending on the rock type one may discover a variety of well crystallized minerals including kimzeyite (the only known location for this zirconium-bearing garnet), barite, pectolite, natrolite, labunsovite, brookite, reticulated rutile, aragonite, diopside, orthoclase, brookite perched on rutile needles, aegerine, taenolite (a litium mica), and several new not yet described species.

STOP 3 – MAGNET COVE TITANIUM CORPORATION RUTILE MINE

Rutile was produced from this open pit mine from 1934 through 1944 and was utilized in the manufacture of titanium alloys and ceramic raw materials. The U. S. Bureau of Mines core-drilled the deposit in 1945 and found rutile mineralization present to as deep as was drilled (≃200′).

The deposit is comprised of a variety of feldspar-carbonate-rutile veins and vein masses which cut phonolite porphyry (Fryklund and Holbrook, 1950). Hydrothermal alteration and extensive weathering of both veins and country rock to clay and reworking of these clays by rainwash have obscured the vein-country rock relationships in the pit. Knobs of black, fine-grained phonolite project from the pit floor. The most easily recognizable vein type is a hard, buff-colored porous feldspar-carbonate rock containing coarse pyrite and variable amounts of rutile. The vein rutile is characterized by a blue-black metallic luster and striated crystal faces. The black color is due to the presence of niobium (> 1.0 %). Tantalum is also present in the rutile having been captured along with niobium due to their similar chemistry. The average grade or ore in this deposit is estimated to be about 3 % rutile.

Other minerals which have been noted from this locality are rutile paramorphs after brookite, ankerite, sphalerite, sphene, galena, hematite, brookite, fluorapatite, and ilmenite.

STOP 4 – KIMZEY CALCITE QUARRY

Originally opened to produce agricultural lime, the quarry is situated in one of several large carbonatite bodies that occur in and near the center of the Magnet Cove intrusive complex. Carbonatite is a rare intrusive igneous rock which is generally associated with nepheline syenite and more mafic alkaline rock types. The carbonatite is dominantly composed of coarsely crystalline calcite with subordinate amounts of carbonate-apatite, magnetite, and monticellite. Unusual minerals found here include kimzeyite, perovskite (Nb bearing variety dysanalyte) pyrite, biotite, aegerine and vesuvianite. Recent work by M. L. Johnson (1975) on the carbon isotope ratios of the carbonate phases of the Magnet Cove intrusion supports the theory that most of the carbonate is mantle derived and represents a late stage of igneous activity. Visible at various points in the quarry is ijolite, a mafic igneous rock which is the principal rock type in the center of the Cove. On the south side of the highway directly opposite the quarry masses of eudialyte aegerine pegmatite are exposed. During construction of the bridge at Cove Creek, masses of this pegmatite weighing up to several hundred pounds were exposed which yielded excellent specimens of eudialyte and aegerine.

STOP 5 — KIMZEY MAGNETITE PIT

A small tonnage of magnetite used for drill pipe coating was produced from this open pit during 1950-51. The pit is located in a zone mapped as lime silicate rock by Erickson and Blade (1963). They believe the deposit to be a local alteration of ijolite by late introduction of high volatile carbonate fluids. Residual magnetite litters the surface of the pit. Deep weathering of both the host rock and the lime silicate rock obscure most field relationships. A few residual masses of light-colored rock in the pit are principally vesuvianite which contain scattered pods and lenses of magnetite. Cavities in this rock may contain diopside, aegerine, vesuvianite, and andradite crystals. Veins of apatite intergrown with andradite and vermiculite crosscut the lime-silicate rock and ijolite country rock. This area is of particular interest because Magnet Cove derived its name from the lodestone and magnetite that are abundant in the soil here. Minerals that have been collected at this site are; andradite crystals, masses of nepheline, rutile eightlings, rutile paramorphs after brookite, vesuvianite crystals in cavities, and "bowties" of feldspar, similar in form to stilbite, on this site.

STOP 6 — MO–TI PROSPECT AND JACUPIRANGITE

At the Mo-Ti Prospect, feldspar-pyrite-molybdenite veins cut the jacupirangite in a series of trenches just south of Cove Creek and in an exposure on the south bank of Cove Creek. The larger exposed veins that contain significant molybdenite are concentrated in an area about 225 feet long by 35 feet wide. These veins also contain variable amounts of apatite, brookite, rutile, anatase, quartz and sphene. Molybdenite is scattered irregularly throughout the veins and disseminated in soft, altered jacupirangite adjacent to the veins. Holbrook (1948) investigated and mapped the Mo-Ti prospect. Of twenty-six samples of vein material he collected, eleven contained more than 1% MoS_2. Extent of resources of molybdenite and brookite have not been defined. Exposed in the south bank of Cove Creek is a radioactive vein composed of smoky quartz, pyrite, and feldspar. This vein follows the trend of the feldspar-pyrite-molybdenite veins, but appears to be younger. Adjacent to this quartz vein, are large clusters and masses of pyrite. Pyrite crystals are often coated with a thin film of molybdenite giving the crystals the appearance of striated galena. Intergrown with the pyrite are small clusters of black quartz crystals some of which have a sprinkling of fine pyrite dusted across them.

Jacupirangite is exposed in Cove Creek adjacent to the Mo-Ti Prospect and at a site approximately 1200 feet east (upstream) from the Mo-Ti. Jacupirangite is a black fine-to-medium-grained phanerite which weathers to a dark brown to olive-green saprolite (Erickson and Blade, 1963). Pyroxene (salite) comprises over 50% of the rock with ilmenite varying from 2 to 25%. Apatite, biotite, sphene, garnet and perovskite are always present, at times greater then 10%. Accessory minerals include pyrite and pyrrhotite.

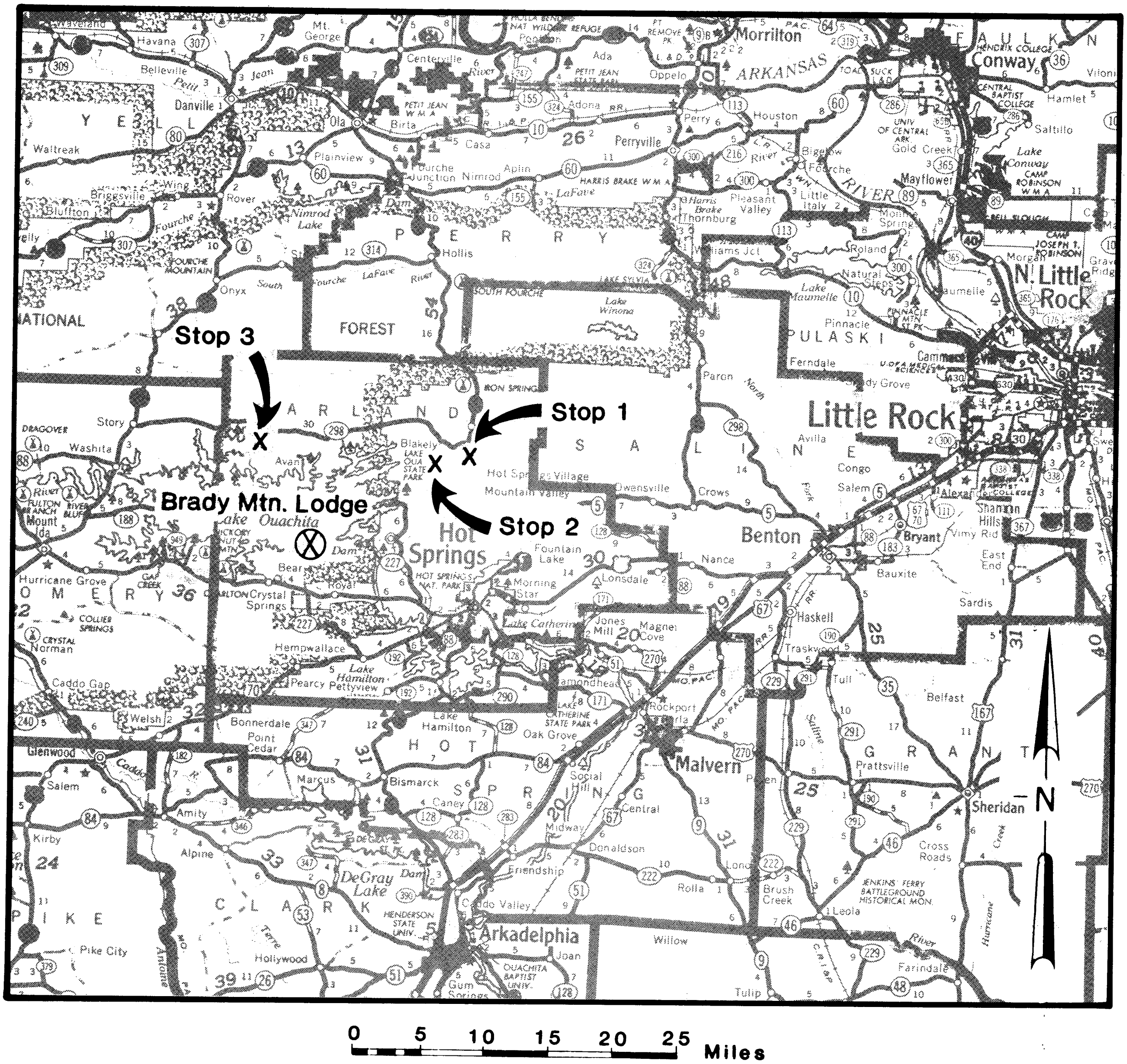
STOP 7 — DIAMOND JO QUARRY

The Diamond Jo Quarry was opened in the 1870's to supply building materials and crushed stone for the "Diamond Jo Line", a narrow guage track which connected Malvern with Hot Springs. The quarry was operated sporadically after 1890 and has been inactive for many years.

The Diamond Jo Quarry is developed in garnet-pseudoleucite syenite and nepheline syenite pegmatite. Chemical composition and field relationships indicate that the garnet-pseudoleucite syenite was emplaced before injection of nepheline syenite pegmatite (Erickson and Blade, 1963).

Garnet-pseudoleucite syenite is a light gray medium-grained rock consisting of orthoclase, black titanium garnet, pseudoleucite, pyroxene, titanite, and nepheline. This rock contains many xenoliths of other igneous and sedimentary rocks. Miarolitic cavities, ranging from pinhead size to three inches across, occur in patches in this rock. Minerals commonly occurring in the larger cavities are; orthoclase, acmite, pectolite, and apophyllite. The smaller cavities contain a host of other minerals, which includes arfvedsonite, barite, barytocalcite, brookite, catapleite, hematite, hornblende, labunsovite, molybdenite, narsarsukite, pyrite, quartz, rutile, siderophyllite, sphalerite, and taenolite.

The nepheline syenite pegmatite is lighter in color and coarser grained than the garnet pseudoleucite syenite. It is composed of barian sodic orthoclase, nepheline, cancrinite, black titanium garnet and pyroxene. Joints developed in this rock type may be covered by fluorite or sodalite (visible in the east face). This rock also is in contact with the Stanley Shale at the southeast edge of the quarry. Little evidence of a chill zone is present at the contact which suggests that the country rock had not cooled from the emplacement of garnet-pseudoleucite syenite before the injection of the nepheline syenite pegmatite. The Stanley shale has been metamorphosed to a hornfels at the contact.



INDEX MAP OF THIRD DAY STOPS

DESCRIPTION OF THIRD DAY STOPS

STOPS 1 and 2 -- COLEMAN'S ROCK SHOP AND QUARTZ CRYSTAL MINE

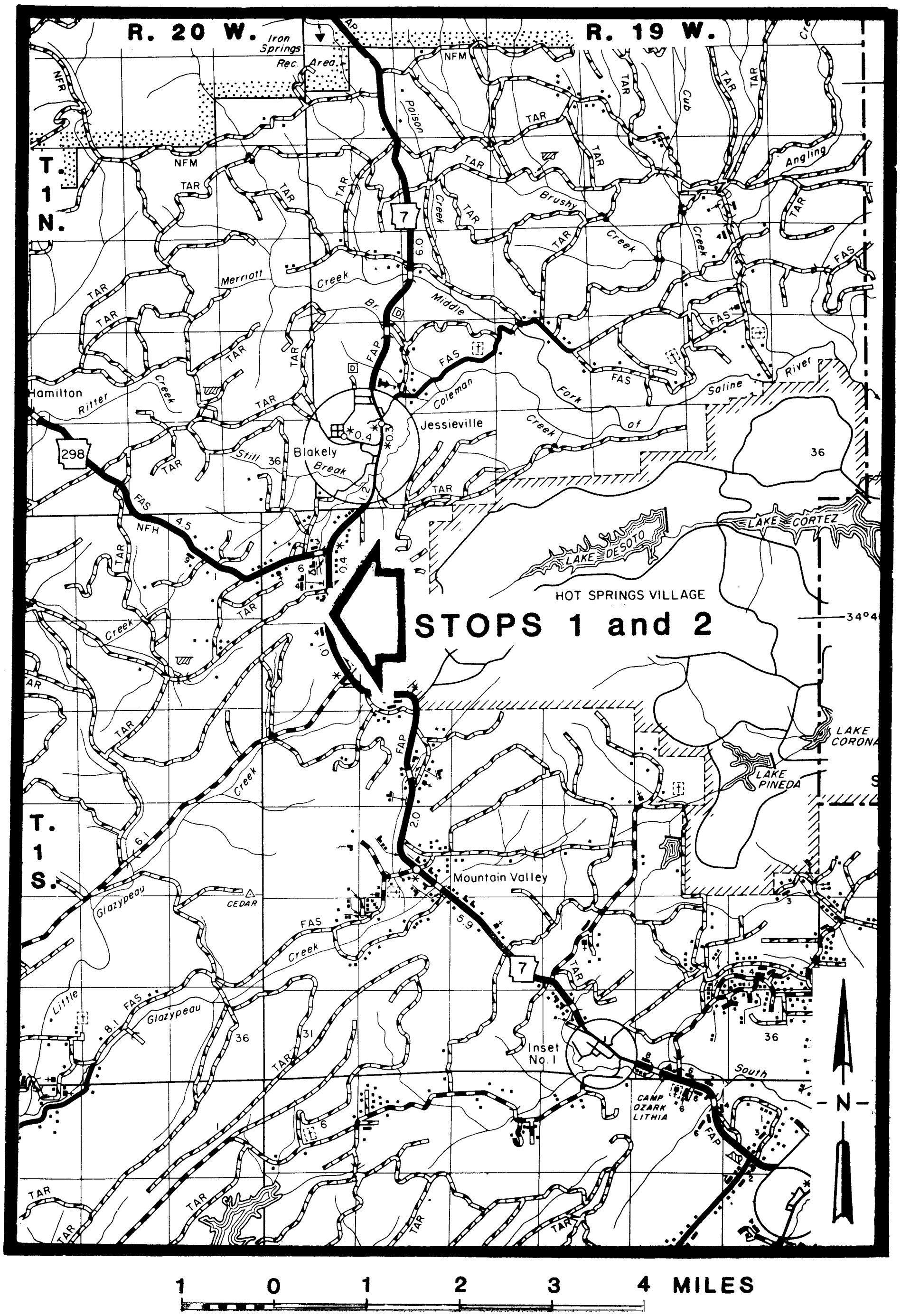
Mining of quartz crystals in the Ouachita Mountains of Arkansas has been going on for many years, the first miners probably being the Indian tribes that shaped them into arrowheads. Because of the clarity and perfect shape of many of the individual crystals and crystal clusters, the principal market 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 fused 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.



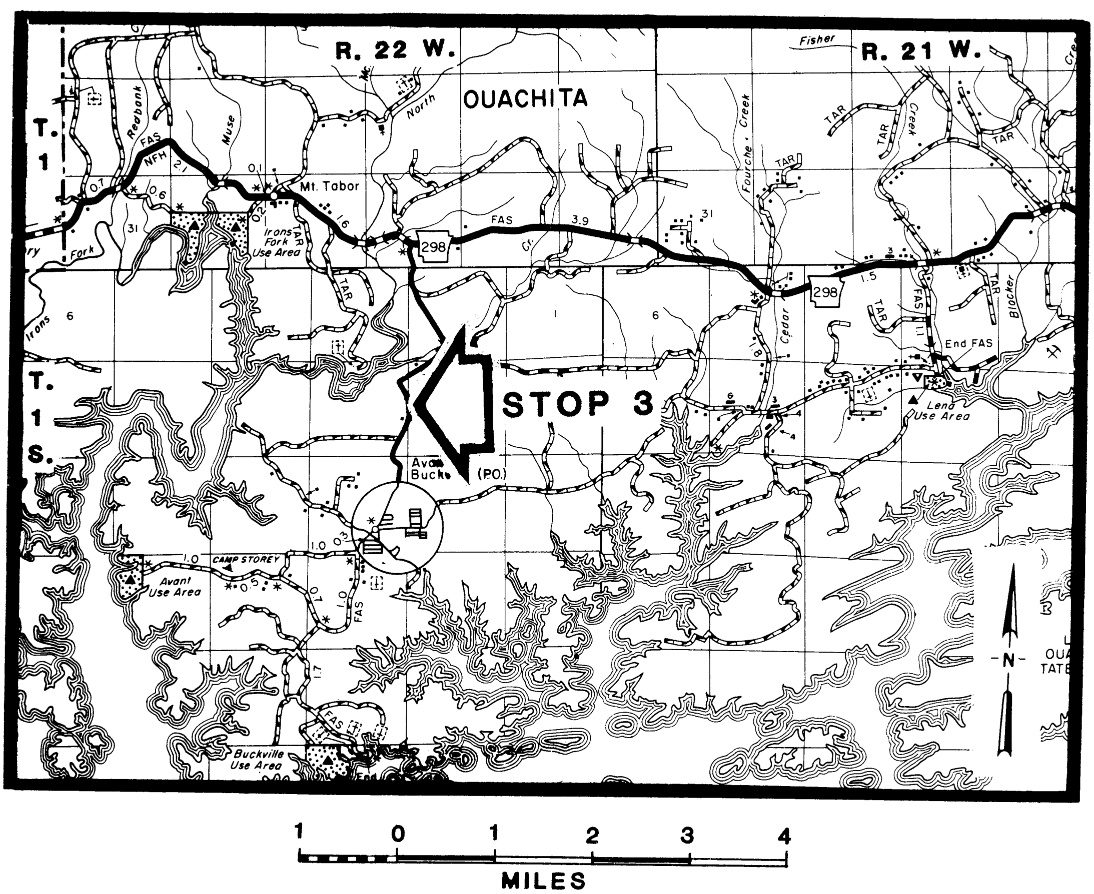
STOPS 1 and 2 – Coleman's Quartz Crystal Mines are located near Coleman's Rock and Mineral Shop in Blue Springs on State Highway 7 in Garland County. This is a commercial attraction and a fee is charged to enter the mines with prospecting done on a finders-keepers basis.

STOP 3 – DUG HILL WAVELLITE PROSPECT

Wavellite and variscite, both aluminum phosphates, occur as fracture and vein fillings in the Bigfork Chert (Ordovician) at Dug Hill. The Bigfork consists of intensely fractured gray to black thin bedded cherts which weather to a brown color. Dug Hill is on the north flank of a syncline which is bounded on the north and the south by faults. The wavellite appears to be restricted to the crest of this ridge, and extends approximately one mile to the east of the road to Avant. Several claims for mineral specimen deposits have been filed on the ridge.

Wavellite occurs mostly as radiating dark green crystal clusters (cats eyes), but it may also be yellow-green, yellow, blue, white or colorless. The intensity of the green coloration is related to both the quantity and valence state of vanadium present in the crystal structure. Rare specimens may display individual wavellite crystals.

Variscite, when fresh, is a brilliant, almost fluorescent green which upon weathering becomes a more subdued pastel green. Crandallite is present as radiating cream, tan or white needle aggregates generally after wavellite. Stone et al. (1979) state that some wavellite and variscite are associated with quartz veins as late-forming minerals not only at this location but at other phosphate localities in the Ouachita Mountains and that the two minerals appear to have been deposited from hypogene fluids. Holt (1972) suggests adjacent strata as a possible source of phosphate with wavellite and variscite being deposited from circulating groundwater.



STOP 3 – Wavellite occurs in the ditch of a Garland County road approximately 1.75 miles north of Avant.

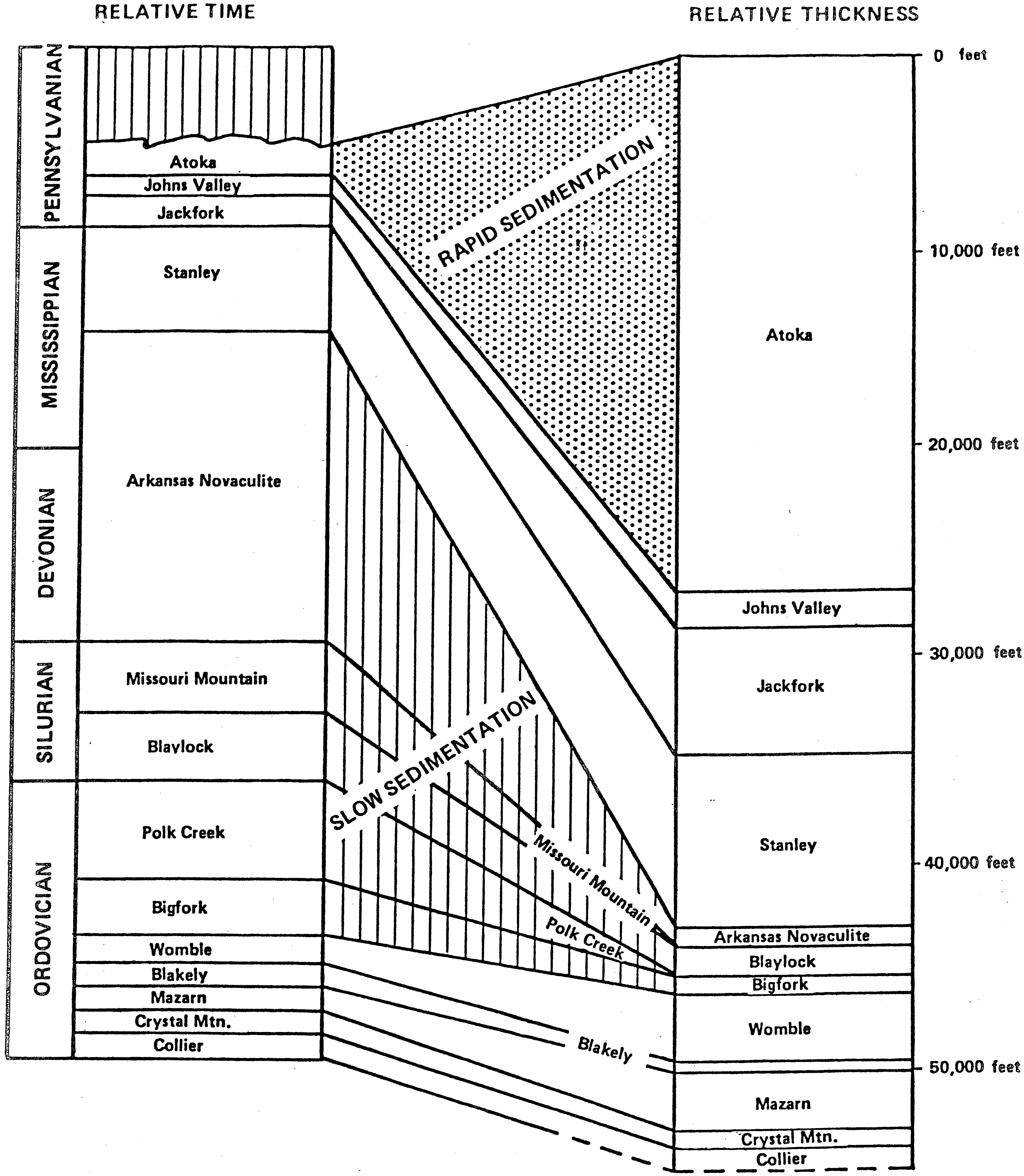


CHART SHOWING SEDIMENTATION RATES OF THE PALEOZOIC ROCKS IN THE OUACHITA MOUNTAINS, ARKANSAS.