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STATE OF ARKANSAS

ARKANSAS GEOLOGICAL COMMISSION

Norman F. Williams, State Geologist

FIELD TRIP GUIDE BOOK

CENTRAL ARKANSAS

ECONOMIC GEOLOGY AND PETROLOGY

LITTLE ROCK, ARKANSAS
1967

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FOREWORD

This publication was first prepared to be used as a guidebook by the Geological Society of America for a field trip held in conjunction with its annual meeting in the fall of 1967. The present edition has been released to enable others interested in the geology of this area to have a usable guide.

In planning the trip and the preparation of the guidebook, a number of individuals were most helpful to the Commission staff. Particular recognition is due the following:

Ralph L. Erickson	U. S. Geological Survey Denver, Colorado
J. S. Hollingsworth	Union Carbide Corporation Hot Springs, Arkansas
Stephen E. Kesler	Louisiana State University Baton Rouge, Louisiana
Charles Milton	George Washington University Washington, D. C.
Hugh D. Miser	U. S. Geological Survey Washington, D. C.
Berton J. Scull	Sun Oil Company Richardson, Texas

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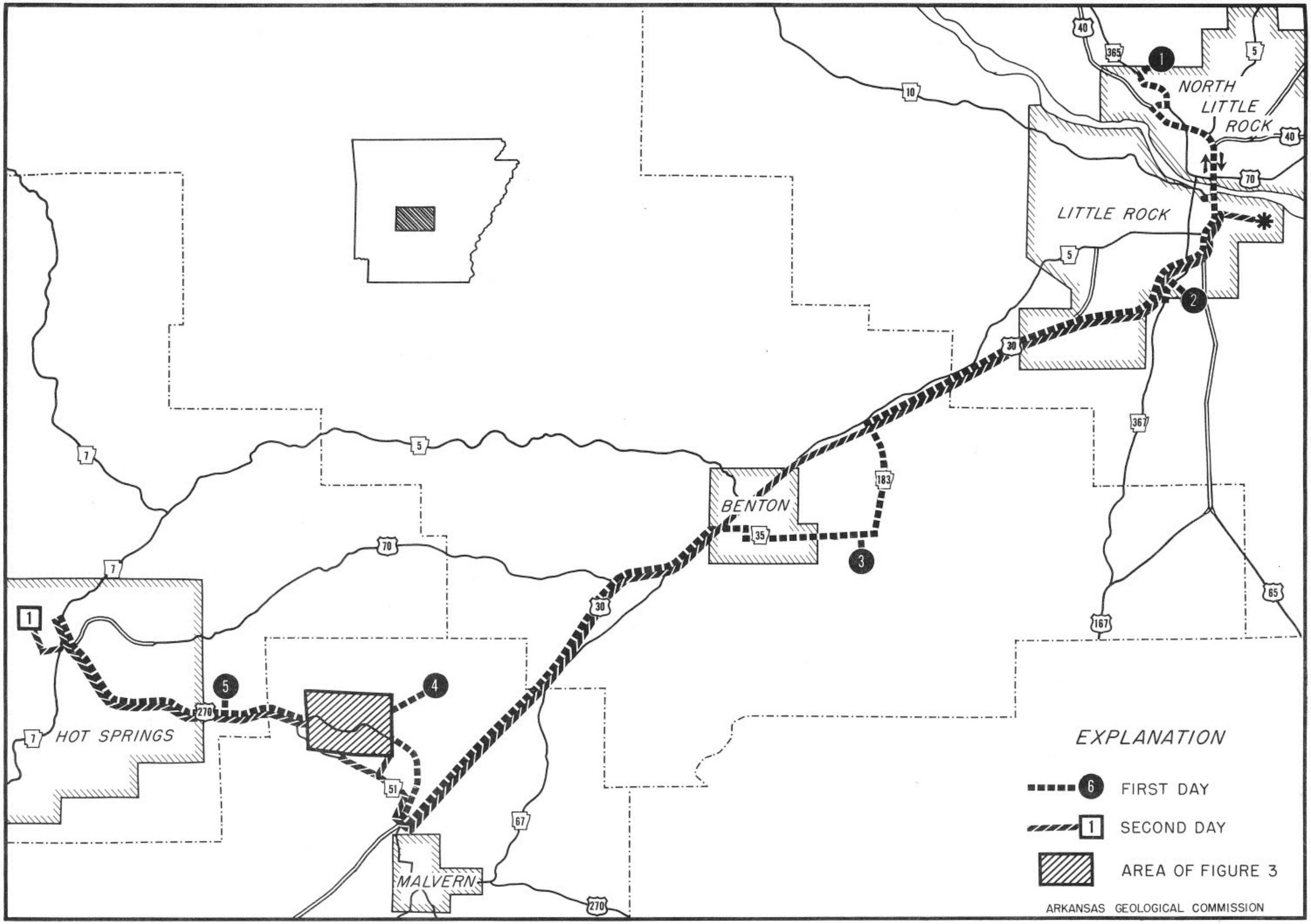


INDEX MAP SHOWING ROUTE OF THE FIELD TRIP

Figure 1

ROAD LOG FOR FIRST DAY

SATURDAY, NOVEMBER 18, 1967

LITTLE ROCK — BAUXITE — HOT SPRINGS

SUMMARY

The first day of the trip will start in the Frontal Ouachita Mountains with the initial stop at the Jeffrey Quarry in North Little Rock, Arkansas. Quartz veins containing rectorite and cookeite fill fractures in the Jackfork Sandstone (Pennsylvanian). The trip will proceed southward to the Big Rock Quarry on Granite Mountain where nepheline syenite of Cretaceous age intrudes Paleozoic formations and is locally capped by Tertiary units. The trip will continue southwestward to the Saline County bauxite area. The trip will proceed from Bauxite southwestward along the Fall Line to the vicinity of Malvern, and then continue northward to the Chamberlain Creek barite deposit. The trip will continue westward through the Magnet Cove intrusive, and then will travel along the northern margin of the Mazarn Basin to the Potash Sulphur Springs intrusive and associated vanadium deposits; and the trip will proceed westward through the Mazarn Basin to Hot Springs, Arkansas.

MILEAGE **DESCRIPTION**

0.0 Marion Hotel—Little Rock, Arkansas. Proceed east on Markham Street. In this general area a thin Tertiary section (Midway clay, marl, and limestone; and Wilcox sand and clay) lies unconformably on Stanley Shale (Mississippian and Pennsylvanian). This is the Fall Line separating the Gulf Coastal Plain (Mississippian embayment) from the Interior Highlands.

0.2 Turn right on LaHarpe Boulevard.

0.3 Turn left on U. S. Interstate Highway 30 East to North Little Rock.

0.8 Arkansas River. About two blocks upstream is the original Little Rock outcrop ("petite roche") at the south end of St. Louis-Southwestern Railroad bridge. It is a large sandstone mass in the upper Stanley Shale.

1.5 North Little Rock, Arkansas.

2.7 Take left lane and enter U. S. Interstate Highway 40 West.

3.9 Hill capped by basal Jackfork Sandstone (Pennsylvanian) near the axis of the east-west trending Big Rock syncline.

4.2 Levy, Arkansas.

5.6 Turn right on Burns Park Road exit.

5.85 Turn right on Arkansas Highway 176. Exposures of somewhat weathered, tightly folded and sheared upper Stanley Shale (Mississippian-Pennsylvanian) near the axis of the thrust faulted Maumelle anticline.

6.3 Turn left on Arkansas Highway 365.

6.45 Cross Missouri-Pacific Railroad tracks.

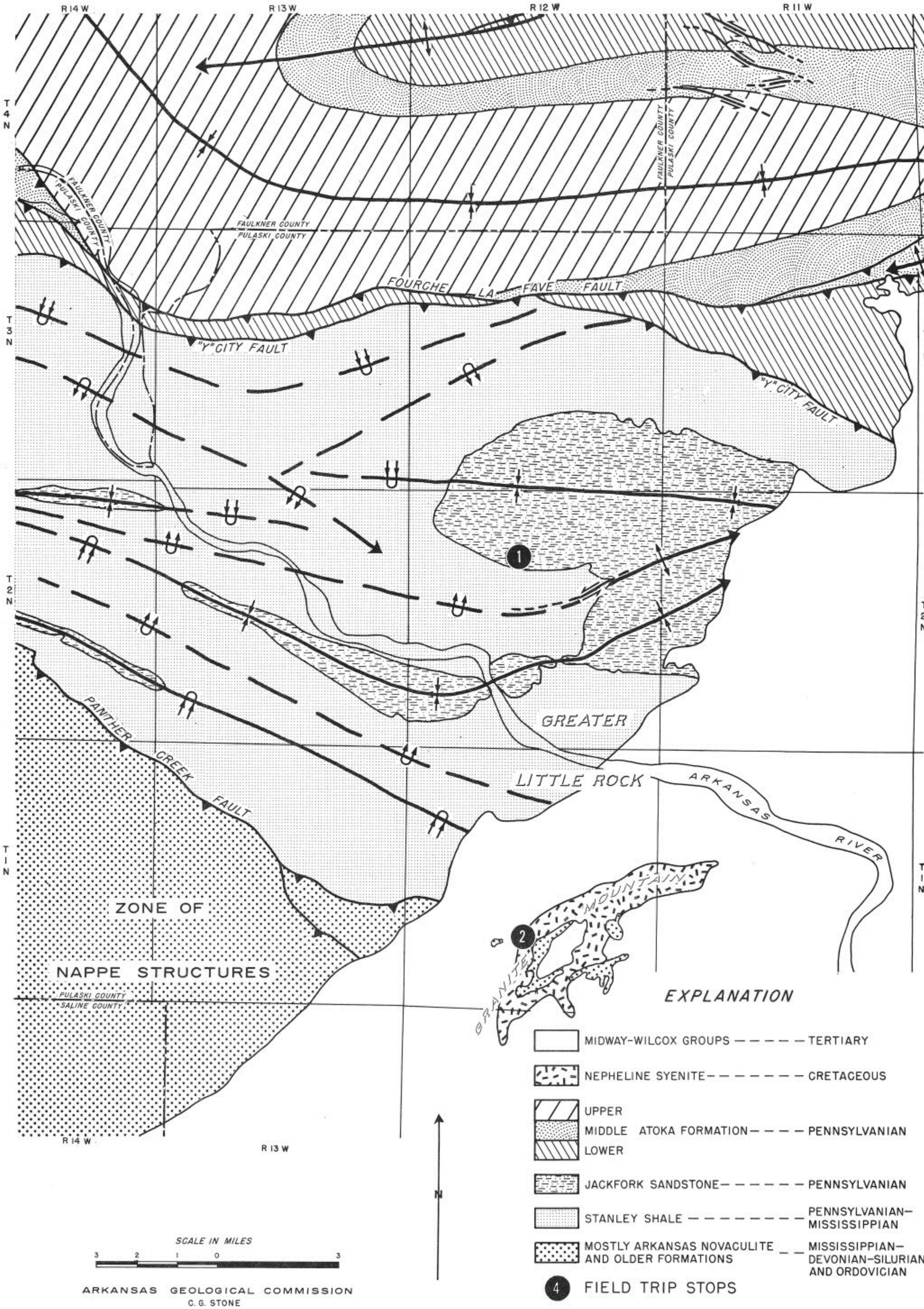
8.35 Turn right to Jeffrey Quarry.

8.6 **Stop 1. (1 hr.) Office Area Jeffrey Quarry.** (Leaders: Hugh D. Miser, Charles Milton and Charles Stone).

Proceed up hill through upper Stanley Shale (Mississippian-Pennsylvanian) to the Quarry area.

These excellent exposures of northward dipping sandstone and shale are in the basal Jackfork Sandstone (Pennsylvanian) on the southern flank of the Marche syncline (Fig. 2). Features suggestive of turbidity current and sediment flow deposition occur in many of the beds. Slickenside surfaces are numerous and usually mark small bedding-plane faults. Three thin basaltic dikes (Cretaceous), now partially altered to clay, cut the sandstone and shale sequence, but have no evident relation to mineralization. The Jeffrey Stone Company Inc., produces large tonnages of quartzitic sandstone from this quarry for crushed aggregate, riprap, and other uses.

Several unusual minerals occur in the milky quartz veins (maximum about 2 feet in width) which fill joints and fractures primarily in the sandstone. Miser and Milton (Ark. Geol. Comm. Bull. 21, 1964), describe beautiful and delicate needle-like quartz crystals, also rectorite (semiliquid and mountain leather varieties), cookeite (lithium mica), and ankerite as being abundant in the veins. Other minerals less commonly found are apatite (hexagonal plates), pyrite, limonite, galena, sphalerite, chlorite and rutile. The late stages of the lead-zinc-silver mineralization at the abandoned Kellogg mines, located about 6 miles northeast



GEOLOGY OF THE AREA AROUND LITTLE ROCK

Figure 2

of the Jeffrey Quarry, are thought to be genetically related to these veins.

Most quartz veins in the Ouachita Mountains contain the mineral dickite and are generally thought to be related to the Pennsylvanian orogenesis leading to the development of the Ouachita folded belt. Miser and Milton (Ark. Geol. Comm. Bull. 21, 1964) suggest that the cookeite-rectorite bearing veins at the Jeffrey Quarry were likely emplaced in Cretaceous time and related to the igneous activity near Little Rock. Investigations in progress indicate that a belt of quartz-cookeite-rectorite mineralization exists in the northeastern Frontal Ouachita Mountains.

8.9 Turn left on Arkansas Highway 365.

10.95 Turn right on Arkansas Highway 176.

11.5 Turn left onto overpass.

11.7 Turn left onto U. S. Interstate Highway 40.

13.5 Levy, Arkansas.

14.1 North Little Rock High School on right.

14.5 Take right lane and enter U. S. Interstate Highway 30 West.

16.4 Arkansas River.

16.9 Little Rock, Arkansas. Poor exposures of Wilcox (Eocene) sand, gravel and clay.

18.3 Veterans Hospital on right. Some exposures of the marine Midway (Paleocene) and nonmarine Wilcox (Eocene) Groups.

18.9 Chicago-Rock Island and Pacific Railroad overpass. View of Granite Mountain to south.

19.2 Junction of U. S. Highway 65 South, proceed right on U. S. Interstate Highway 30.

20.1 View of Big Rock Quarry on Granite Mountain to left.

20.7 Water impoundment for Big Rock Quarry to left.

21.8 Contacts of Arkansas Novaculite (Devonian-Mississippian), large syenite dike (Cretaceous) and Midway Group (Paleocene) in exposures to left along railroad spur.

21.85 Turn right on 65th Street exit.

22.1 Turn left on 65th Street.

22.55 Crossing Chicago-Rock Island and Pacific Railroad tracks.

22.6 Turn left on Arkansas Highway 367.

23.0 **Stop 2. (1 hr.) Office Area Big Rock Quarry.** (Leaders: Charles Milton, Hugh D. Miser and John Barnwell of Big Rock Stone and Material Company).

Proceed across road and up hill to quarry area.

Big Rock Quarry is located in nepheline syenite and pulaskite near the western border of Granite Mountain (Gordon, Tracey and Ellis, Geology of Arkansas Bauxite Region, U. S. Geological Survey Prof. Paper 299). The Big Rock Stone and Material Co. produces large tonnages of pulaskite and nepheline syenite from this quarry for rock aggregate, riprap, roofing granules and other uses.

Most of the rock in the quarry is pulaskite which is a light to dark blue-gray, medium to coarse grained, somewhat porphyritic syenite known locally as "blue granite". A gray, coarse, and granular nepheline syenite with granitic or trachytic texture known locally as "gray granite" occur at the northern end of the quarry. Some exposures of fourchite and other basic dike rocks occur in the southern portions of the quarry. Most of the basic rocks are dark reddish brown to bluish black augite porphyry. Vugs are common near the border phases of the major rock types, and contain many excellent zeolites, as well as several very rare minerals, some possibly new. Recently narsarsukite, a sodium titano-silicate, was found here. Small veinlets of calcite, fluorite, sodalite, chlorite, and other minerals are common along small joints. At several places in the Granite Mountain intrusive, partially metamorphosed shale and novaculite of Paleozoic age are exposed in contact with the syenite. Commercial bauxite deposits resulting from lateritic weathering of the nepheline syenite and pulaskite are being mined a short distance south of this area, primarily in sediments of the Wilcox Group. K-Ar age determinations made by the U. S. Geological Survey on biotite concentrates from pulaskite collected near the center of this quarry (Stone and Sterling, Ark. Geol. Comm. Misc. Rept., 1964) gave an average age of 89 m.y.; establishing that the syenite of Granite Mountain is early Late Cretaceous.

Return south on Arkansas Highway 367.

23.4 Turn right on 65th Street.

23.45 Cross Chicago-Rock Island and Pacific Railroad tracks.

24.0 Turn left on U. S. Interstate Highway 30 West.

24.4 Little Rock Industrial Park covers large area to right.

25.0 Exposure of gray shale of the marine Porters Creek Formation of the Midway Group (Paleocene) on left.

25.3 Bauxite-kaolin facies at base of the Wilcox Group (Eocene) on left.

25.9 Exposures of Wilcox (Eocene) sand, gravel and lignite on left.

28.7 Arkansas State Highway Dept. building at right on Midway (Paleocene) clay and fossiliferous limestone.

29.6 Reddish sand of the Wilcox (Eocene) on right.

30.2 Poor exposures of intensely folded Arkansas Novaculite (Devonian-Mississippian), Missouri Mountain Shale (Silurian), and Polk Creek Shale, Bigfork Chert and Womble Shale (Ordovician).

30.9 Weathered Womble Shale (Ordovician) on left.

31.2 Associated Grocers Warehouse on left. Exposures of intensely folded Womble Shale (Ordovician) overlain with major angular unconformity by nearly flat-lying, highly fossiliferous limestone and clay of the Clayton Formation of the Midway Group (Paleocene). Locally a small lignite bed occurs at the base of the Clayton. Reddish, nonmarine sand of the Wilcox Group (Eocene) occurs above the limestone.

31.7 Old Limerock Dairy on right. Small bluff about 100 yards to north has a large exposure of fossiliferous limestone of the Clayton Formation (Paleocene). Bigfork Chert (Ordovician) crops out in creek bed.

33.15 Enter Saline County, Alexander Mountain capped by Wilcox Group (Eocene) to south. A small exposure of nepheline syenite occurs at the southwestern end of the mountain.

34.7 Exposure of Wilcox (Eocene) sand.

36.3 Turn right on Bryant-Bauxite exit.

36.6 Turn left on Arkansas Highway 183 and proceed south.

37.3 Contact between Midway (Paleocene) and Wilcox (Eocene) Groups.

37.6 Enter Bryant, Arkansas.

38.6 Crossing Missouri-Pacific Railroad tracks. Milwhite Company, Inc., milling operations are about 300 yards to right. Milwhite grinds soapstone and slate for fillers, insecticides, and roofing compound from deposits in northern Saline County. Soapstone is obtained from five open pits along an irregular sill-like serpentine intrusion of probable Paleozoic age. Milwhite also processes barite from Missouri for drilling mud.

39.1 View of portion of Reynolds Metals Company's bauxite mining operations to left.

40.3 Cross Bauxite-Northern Railroad track. Exposure of lignitic sand of Wilcox Group (Eocene).

40.4 View of Reynolds Metals Company's large Hurricane Creek Alumina Plant. Small Delta Ag-Lime, Inc., operation to left, formerly was U. S. Bureau of Mines Pilot Plant for the study of the removal of silica from bauxite.

40.7 Entrance to Hurricane Creek Alumina Plant.

40.9 Cross Chicago-Rock Island and Pacific Railroad tracks.

41.1 Road junction, continue right on Arkansas Highway 183. Exposure of nepheline syenite and bauxite on right.

41.6 Exposure of nepheline syenite on left.

41.65 Cross Bauxite-Northern Railroad track.

41.9 Turn left to Bauxite, Arkansas. Actually much of the town is owned by Alcoa and soon will be incorporated into their mining district.

42.2 **Stop 3. (1 hr. 15 min.) Raw Materials Headquarters of Alcoa–Saline County Bauxite Deposits.**

(Leader: Jack H. McWilliams)

Bauxite, the major ore of aluminum, was first identified in Arkansas by John C. Branner, State Geologist, in 1887, and has been mined commercially both open pit and underground since 1899. Arkansas bauxite output accounted for over 2 million tons in 1965 and for many years Arkansas has produced more than 90 percent of the U. S. domestic bauxite. The primary use of Arkansas bauxite is for making aluminum metal. Other important uses are in chemicals, abrasives, refractories and alumina cements. Alumina is produced by two plants: Reynolds' plant at Hurricane Creek and Alcoa's plant at Bauxite. Aluminum metal is produced at two plants by Reynolds: The Jones Mill Reduction plant on Lake Catherine and the Gum Springs plant at Arkadelphia.

The Arkansas bauxite area covers approximately 275 square miles and is located in Pulaski and Saline Counties, central Arkansas. There are two principal mining districts; in Pulaski County south of Little Rock, and the larger and more productive district around Bauxite in Saline County.

The bauxite deposits are centered around intrusives of nepheline syenite. These nepheline syenites, and related igneous rocks of early Late Cretaceous age, were intruded into highly folded Paleozoic beds. Subsequent erosion exposed some parts of these intrusives to weathering and some parts to burial by sediments of Tertiary age. The bauxite deposits of central Arkansas are the result of a profound lateritic weathering of the nepheline syenite under humid tropical conditions during early Eocene times.

According to Gordon, Tracey, and Ellis (U. S. Geological Survey Prof. Paper 299) the bauxite deposits can be classified into four types:

(1) residual deposits on the upper slopes of partly buried nepheline syenite hills;
(2) colluvial deposits at the base of the Berger Formation (lowermost formation of the Wilcox Group (Eocene);
(3) stratified deposits within the Berger Formation and
(4) conglomeratic deposits at the base of the Saline Formation (formation in the Wilcox Group (Eocene) that overlies the Berger Formation).

Deposits of types 1 and 2 are the most extensive and important commercially.

Bauxite in the various mines differs considerably in its character and physical properties. Most of the bauxite is pisolitic, and ranges from very hard to soft and earthy. Generally, it is hard at the top of a deposit, firm to mealy in the middle, and clayey though not plastic at the base. In color it ranges from a light gray through tan and brown to red. Color is not necessarily an index of grade nor of the amount of iron present, as some of the brick-red bauxite has very little iron. The porosity of bauxite is very high, averaging about 40 percent and exceeding 60 percent in some specimens. The principal mineral in the bauxite is gibbsite (aluminum trihydrate). The chief impurities are silica, iron, and titanium. A significant concentration of gallium is present and is recovered as a valuable by-product. It is possible that, in the future, other by-products of alumina production and other alumina sources within the bauxite area may be utilized.

Briefly these possibilities are:

(1) the recovery of titanium, iron, and columbium from the black sands and red muds which are waste products from the alumina plants;
(2) the recovery of both the iron and alumina from the large deposits of high-iron bauxite and
(3) the recovery of alumina from the vast deposits of high-alumina clays associated with the bauxite deposits (estimated to total over 100 million tons).

Bauxite reserves in the area in 1950 were estimated at about 70.7 million long tons averaging 50 percent alumina and 9 percent silica, but assuming no cutoff on iron. Of this total, about 62.2 million tons occur in Saline County and 8.1 million tons in Pulaski County. It has been estimated that one ton of bauxite will produce about 600 to 1,000 pounds of alumina which yields about 300 to 500 pounds of metallic aluminum.

BRIEF DESCRIPTION OF THE NORTON BAUXITE MINE

The Norton Mine, property of the Norton Company, is a strip pit mine in the Davis area and is located approximately one mile southeast of the town of Bauxite. The mines in the Davis area are owned by Alcoa with this exception.

The bauxite mined from this deposit is moderately low in silica, iron and titanium and was used by the Norton Company in the manufacture of fused-alumina abrasives.

This deposit rests directly on the nepheline syenite and its residual weathering products (kaolinitic underclay). The lower part of the deposit is a residual deposit and the upper part is a conglomeratic deposit or rubble deposit at the base of the Saline Formation of the Wilcox Group. The overlying sediments are the clays, lignitic clays and sands of the Saline Formation.

42.5 Turn left on Arkansas Highway 183.

43.2 Community of Bauxite, Arkansas.

43.8 Fine exposure of lignitic Wilcox (Eocene) sands.

45.7 Cross Chicago-Rock Island and Pacific Railroad tracks.

46.15 Junction of Arkansas Highway 35, proceed west on Arkansas Highways 183 and 35 across Missouri-Pacific Railroad tracks.

47.0 Crossing spur railroad tracks.

47.1 Turn right on Arkansas Highways 183 and 35.

47.25 Sand and gravel beds in Wilcox Group (Eocene) on left.

47.4 Turn left on Ashley Street.

47.55 Turn right on Main Street. Gravel bed in Wilcox Group (Eocene) on right.

47.6 Turn left on South Street. Downtown Benton, Arkansas.

48.5 Proceed right across U. S. Interstate Highway 30.

48.65 Turn left.

48.75 Turn right on access road.

49.2 **Lunch Stop. Pat's Cafe.** Proceed on U. S. Interstate Highway 30 West.

49.7 Holland Gravel Company, Inc. on right. Material obtained from pits in the alluvial bottomlands of the Saline River.

50.1 Saline River. This river drains much of the structurally complex eastern core area of the Ouachita Mountains.

50.8 Womble Shale (Ordovician) exposed on right.

51.1 Highly fossiliferous Clayton limestone of the Midway Group (Paleocene) on left.

51.8 Clayton (Paleocene) clay and limestone in field to left contains abundant shark teeth.

52.1 Unconformable contact of Womble Shale (Ordovician) and Midway Group (Paleocene) on right.

52.6 Igneous sill (Cretaceous) in Womble Shale (Ordovician) on right.

53.1 Exposure on right of Womble Shale (Ordovician) overlain with major angular unconformity by the Cretaceous-Paleocene deposits of Arkansas Novaculite boulders. Notice the small Arkansas Novaculite boulders in the pebbles and silt. The nearest Arkansas Novaculite (Devonian-Mississippian) outcrops are about eight miles toward the southwest. Stone and Sterling (December 1965, GSA, v. 76, p. 1393-1400) have interpreted these deposits as being derived by mud and debris flows from topographically high Arkansas Novaculite outcrops to the southwest during very late Cretaceous or possibly very early Paleocene time.

53.6 Junction U. S. Interstate Highway 30 and U. S. Highway 70 proceed to Malvern on Interstate 30. About ½ mile to right is the abandoned fuller's earth mining district. In the early 1900's high-grade fuller's earth for refining edible oils was mined from small weathered lamprophyric igneous dikes in the area. The fuller's earth deposits are described by H. D. Miser in U. S. Geological Survey Bulletin 530, 1913, p. 207-219.

54.2 Waxy clay of the Midway Group (Paleocene).

55.3 Sand and clay of the Wilcox Group (Eocene).

55.9 Poor exposure of fossiliferous clay and limestone of Midway Group (Paleocene).

56.2 Sand and clay of Wilcox Group (Eocene).

58.0 Abandoned clay pit to left in Wilcox Group (Eocene).

58.9 Quarry in Arkansas Novaculite (Devonian-Mississippian) on right, material was used on U. S. Interstate Highway 30. Contact of Midway (Paleocene) and Wilcox (Eocene) strata on left.

59.3 Enter Hot Spring County.

60.5 Sand and clay of Wilcox Group (Eocene).

61.1 Exposures of Arkansas Novaculite (Devonian-Mississippian).

62.1 Sand and clay of Wilcox Group (Eocene).

63.8 Crossing Chicago-Rock Island and Pacific Railroad tracks.

64.6 Fossiliferous clay and limestone of Midway Group (Paleocene).

65.1 Sand pit to right in Wilcox Group (Eocene).

66.7 Turn right on access road to U. S. Highway 270 and proceed north. Exposure of fossiliferous Midway (Paleocene) clay and limestone on left. Acme Brick Company and Malvern Brick and Tile Company have large plants in the Malvern area. They mine high-quality clay (mostly from the Eocene age Wilcox Group) for building brick, refractory brick and heavy clay products.

67.2 Thick massive beds of steeply dipping Arkansas Novaculite (Mississippian-Devonian). For the next few miles the route will traverse portions of the Trap Mountains. Much of the stratigraphy in this area is taken from Danilchik and Haley (U. S. Geological Survey Map I-405, 1964).

67.3 Contact of steeply dipping Arkansas Novaculite (Devonian-Mississippian) and flat-lying poorly consolidated Wilcox (Eocene) sands.

67.6 Junction of Arkansas Highway 51 and U. S. Highway 270, turn right on 270.

68.1 A reverse fault probably occurs just south of the massive beds of Arkansas Novaculite (Devonian-Mississippian).

68.5 Good exposures of highly folded and faulted, very massive Arkansas Novaculite (Devonian-Mississippian).

68.9 Good exposure of massive Arkansas Novaculite.

69.0 Butterfield, Arkansas. The large abandoned Butterfield Quarry which produced aggregate, riprap and refractory material from the Arkansas Novaculite (Devonian-Mississippian) is about ½ mile to left. Cross Chicago-Rock Island and Pacific Railroad tracks.

69.6 Good exposure of massive Hot Springs Sandstone (Mississippian) and Arkansas Novaculite (Devonian-Mississippian).

70.0 Good exposure of massive Arkansas Novaculite.

70.1 Outlier of Wilcox (Eocene) sand.

70.4 Small exposure of Arkansas Novaculite.

70.7 Partially weathered Hot Springs Sandstone (Mississippian) and basal Stanley Shale (Mississippian-Pennsylvanian) on the southern flank of the Reyburn syncline. Some barite has been mined on the northern limb of this structure about three miles to the east.

71.1 Magnet, Arkansas. Hill to left is a small isolated igneous occurrence (sphene nepheline syenite, monzonite and lamprophyre) surrounded by Stanley Shale (Mississippian-Pensnylvanian).

71.8 Intensely metamorphosed Arkansas Novaculite (Devonian-Mississippian) on right. (see Stop 7, second day).

71.9 Turn right off Highway 270 and proceed on road to barite mines.

72.0 Junction, continue right.

72.6 Missouri Mountain Shale (Silurian) exposed on left.

72.7 Massive lower member of Arkansas Novaculite (Devonian-Mississippian). The route will continue on this Formation to **Stop 4.**

72.8 Junction, proceed right.

73.6 Cross railroad spur. Dumps from barite operations on left.

74.05 Junction, proceed right.

74.2 Cross railroad spur. **Stop 4. (1 hr.) Office Baroid Division of National Lead Company, The Chamberlain Creek Barite Deposit. (Leaders: Berton J. Scull and personnel of National Lead Company.)**

This is the world's largest barite mine. The two companies operating this deposit produced 227,500 tons of barite in 1966. Exploitation of the deposit was started in 1939 when the Magnet Cove Barium Corporation started mining and milling operations, utilizing flotation to concentrate the ore. Their headframe and surface plant may be seen on the opposite side of the pit. The Baroid Sales Division of the National Lead Company, at whose plant site we are located, started mining and milling barite in 1942.

The Baroid Division of the National Lead Company is mining the eastern (shallow) end of the syncline using both underground and open-pit mining methods. The Magnet Cove Barium Corporation has the western or deeper portion of the syncline. They originally removed the shallow ore along the limbs of the syncline by stripping, but the depth of their ore has forced them to go exclusively to underground mining.

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 is used in oil well drilling muds.

The Chamberlain Creek barite deposit is a stratiform deposit of controversial origin at the base of the Stanley Shale (Mississippian-Pennsylvanian). 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 is about 60 percent $BaSO_4$.

Return to Arkansas Highway 270.

76.8 Turn right on U. S. Highway 270 and proceed across Magnet Cove (see second day road log).

78.8 Cove Creek Bridge.

80.35 Junction Arkansas Highway 51 and U. S. Highway 270, continue west on 270.

81.2 Several exposures of Stanley Shale (Mississippian-Pennsylvanian).

81.5 Enter Garland County.

82.6 Garland County Industrial Park on left. Two firms here are aluminum fabricators. View of Zigzag Mountains with resistant Arkansas Novaculite (Devonian-Mississippian) to right.

82.9 Exposure of Stanley Shale (Mississippian-Pennsylvanian) on right.

83.5 Turn right to Union Carbide Vanadium mill.

83.7 **Stop 5. (1 hr. 20 min.) Office—Arkansas Operations, Mining and Metals Division of Union Carbide. Petrology and Vanadium Deposits of the Wilson Springs Area, Garland County, Arkansas. (Leaders: J. S. Hollingsworth and Hugh D. Miser).**

Mining was started at the Wilson Springs vanadium operation in 1966 and it is the only mine in the United States developed for vanadium as the only product. Although the Wilson Springs area was investigated in the 1950's for uranium and columbium, the economic vanadium potential was not determined until 1960. Two open pit mines are presently being developed.

The ores contain approximately one percent vanadium pentoxide which is recovered in this plant by hydrometallurgical methods. The majority of the vanadium produced will ultimately be alloyed in steel.

The ore deposits occur in the vicinity of the contact between the Potash Sulfur Springs alkalic igneous complex and the surrounding Paleozoic sedimentary rocks. The intrusive complex, which was probably emplaced in early Late Cretaceous time has a crude ring structure similar to Magnet Cove. The outer ring is alkali syenite and fenite, and much of the central part of the complex is nepheline syenite. Jacupirangite, melteigite, ijolite, and carbonatite are present, as well as several breccias.

See article in this guidebook for more details of the area.

83.9 Turn right on U. S. Highway 270.

84.9 Road to right formerly led to Potash Sulphur Springs. Several altered igneous dikes may be seen cutting basal Stanley Shale (Mississippian-Pennsylvanian).

85.6 Upper portions of Lake Catherine on Ouachita River to left. The small "V" igneous intrusive with minor fluorite-bearing veins occurs on south shore of lake.

86.3 Crossing Chicago-Rock Island and Pacific Railroad tracks.

86.65 Small fourchite dike with inclusions of ouachitite and shale cutting Stanley Shale (Mississippian-Pennsylvanian) on right (Purdue and Miser, U. S. Folio 215, Description of the Hot Springs District, 1923).

87.1 Lakeside Elementary School on right.

87.45 City limits of Hot Springs, Arkansas.

89.3 Hot Springs Golf and Country Club on left.

89.9 Tightly folded Stanley (Mississippian-Pennsylvanian) shale and sandstone.

91.3 Junction U. S. Highways 70 and 270, proceed straight ahead on Malvern Avenue.

91.9 Turn right on Broadway Avenue.

92.0 Turn left and enter Central Avenue, U. S. Hot Springs Park Museum and Spa Headquarters (note outcrop of Hot Springs Sandstone—Mississippian). Hot Springs Rehabilitation center on right.

92.1 Bathhouse row on right. The hot springs flow from fractures in the Hot Springs Sandstone (Mississippian). The U. S. Park Service controls and regulates the use of the water. About 49 of the original 71 springs produce hot water. According to J. K. Haywood and W. H. Weed (1902) the daily flow aggregates 826,000 gallons with the largest spring yielding a little over 200,000 gallons. The temperature range is from 95.4° to 147° F., with almost half of the water 140° F. or more. The hot spring water is slightly radioactive, apparently caused by radon gas. A soil and vegetation covered gray, calcareous tufa deposited by the hot springs, forms an area of 20 acres and in places is 6 to 8 feet thick.

Several theories have been advanced by Kirk Bryan (1922) and others on the origin of the water, including: (1) deep fractures and faults tapping hot water given off by cooling igenous rocks and (2) deep fractures and faults which encounter hot water in sedimentary rocks, formed by an increase in the geothermal gradient.

92.2 Display hot spring on right.

92.5 Downtowner Motor Inn. Tightly folded Arkansas Novaculite (Devonian-Mississippian) is exposed behind the building.

END OF FIRST DAY LOG.

ROAD LOG FOR SECOND DAY

MAGNET COVE

SUNDAY, NOVEMBER 19, 1967

HOT SPRINGS — MAGNET COVE — LITTLE ROCK

SUMMARY

This portion of the trip begins at the scenic overlook on West Mountain in the Hot Springs National Park where the various geologic and topographic features and the early history of the region will be discussed. The remainder of the day will be spent at the Magnet Cove alkalic igneous complex where stops are arranged to illustrate the many varieties of igneous rocks, metamorphism of sedimentary rocks and associated mineralization.

MILEAGE	DESCRIPTION
0.0	Downtowner Motor Inn. Proceed south on Central Avenue.
0.55	Turn right on Prospect Avenue and continue straight ahead up slope of hill.
1.4	Turn right on West Mountain Drive.
1.9	Junction—proceed left on Scenic Drive.
2.1	Good exposure of overturned Hot Springs Sandstone (Mississippian) on left.
2.3	Scenic overlook on right.
2.5	**Stop 1. (20 min.) Scenic Overlook on West Mountain.** (Leader: Hugh D. Miser) This wonderful view from the novaculite on West Mountain includes: much of the town of Hot Springs; several of the Zigzag Mountains; portions of the Mazarn Basin with Lake Hamilton and the Trap Mountains to south in distance. There will also be a discussion of the early history of the Hot Springs district and a general resumé of the geology of the Ouachita Mountains. Proceed on Scenic Drive.
3.2	Scenic overlook. Bigfork Chert (Ordovician) is exposed in quarries along axis of breached anticline on right. Exposure of Arkansas Novaculite (Devonian-Mississippian) on left. This formation has been the source of crude novaculite for the world famous oilstones and whetstones mined in the Garland County area for several years by Norton Pike Division of Norton Company, Arkansas Oilstone Company and Arkansas Abrasives, Incorporated. Also Malvern Minerals Company quarries and processes silica (tripolitic material) from this formation a few miles to the east. Mazarn Basin underlain by Stanley Shale (Mississippian-Pennsylvanian) is to the south. Portions of Lake Hamilton may also be seen. The Trap Mountains with resistant novaculite ridges are in distance to south. Return down Scenic Drive.
4.4	Junction—proceed on West Mountain Drive.
4.95	Turn right on Prospect Avenue.
5.35	Turn left on West Grand Avenue.
5.7	Proceed ahead on U. S. Highway 70 East.
5.8	Proceed right on U. S. Highway 70 East.
6.25	Junction of U. S. Highways 70 and 270 and Arkansas Highway 7, continue straight ahead on U. S. 70.
6.7	Turn right on U. S. Highway 270 East.
8.7	Hot Springs Golf and Country Club on right.
10.9	Lakeside Elementary School on left.
11.7	Crossing Chicago-Rock Island and Pacific Railroad tracks.
14.1	Union Carbide Vanadium mill on left (see Stop 5, first day).
15.0	Garland County Industrial Park on right.
16.1	Enter Hot Spring County.
17.2	Junction of U. S. Highway 270 and Arkansas Highway 51, continue on U. S. 270.
17.5	Several exposures of contact metamorphosed Stanley Shale (Mississippian-Pennsylvanian) and altered igneous dikes.
17.7	Cross bridge.
17.8	Poorly exposed probable jacupirangite on right. Ground magnetometer surveys indicate a high in excess of 20,000 gammas in this area.
17.95	**Stop 2. (30 min.) Crest of Cook Mountain—West Rim of Magnet Cove.** (Leader: Ralph L. Erickson) This stop is at the crest of Cook Mountain on the western edge of the Magnet Cove complex. From this point, you can see the low ridges that form the outer part of the complex. To the north and northeast there is a single ridge composed of sphene nepheline syenite and garnet-pseudoleucite syenite.

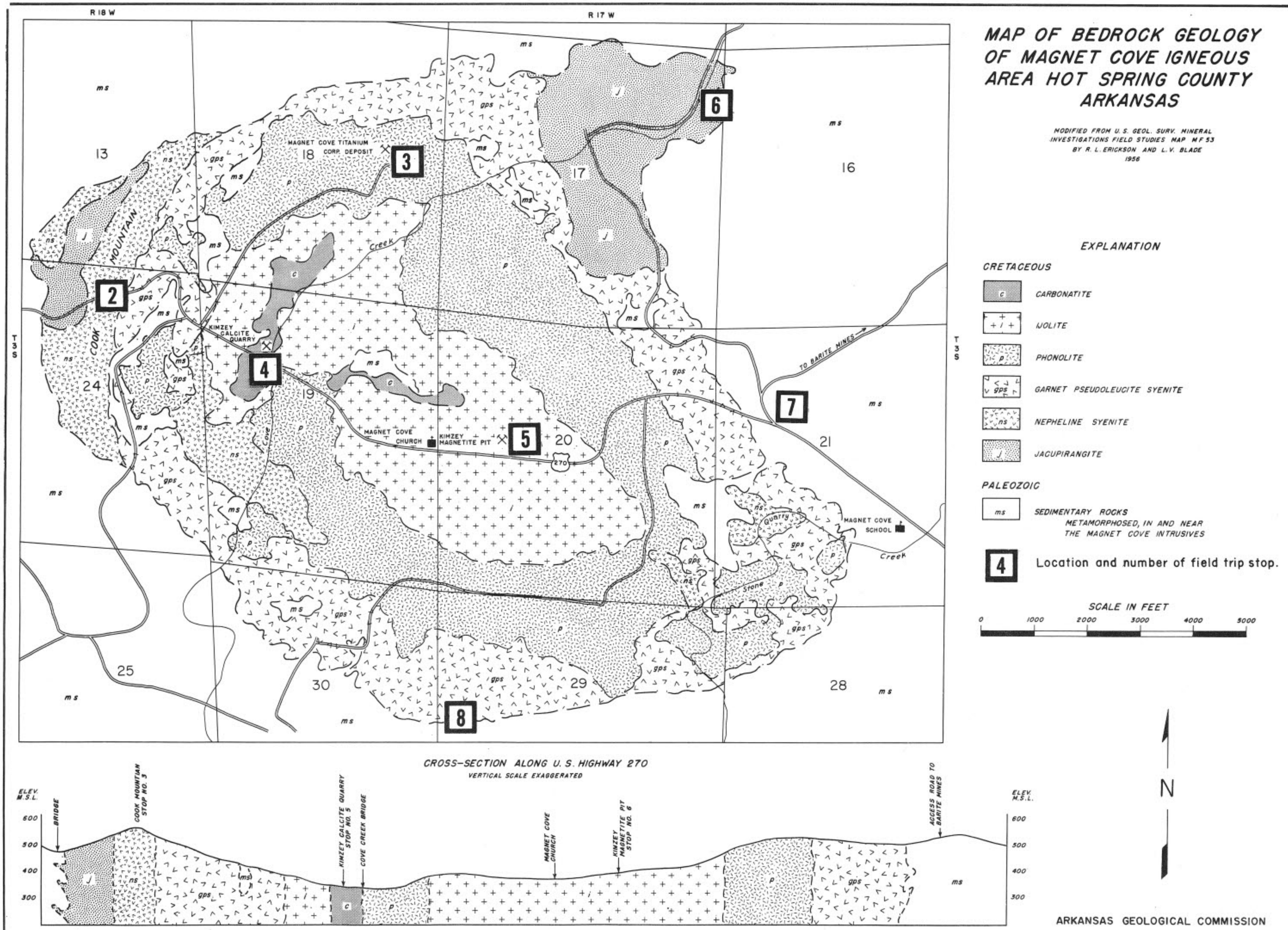

R 18 W
R 17 W
T 3 S
MAP OF BEDROCK GEOLOGY OF MAGNET COVE IGNEOUS AREA HOT SPRING COUNTY ARKANSAS
MODIFIED FROM U. S. GEOL. SURV. MINERAL INVESTIGATIONS FIELD STUDIES MAP MF 53 BY R. L. ERICKSON AND L. V. BLADE 1956
EXPLANATION
CRETACEOUS
CARBONATITE
IJOLITE
PHONOLITE
GARNET PSEUDOLEUCITE SYENITE
NEPHELINE SYENITE
JACUPIRANGITE
PALEOZOIC
SEDIMENTARY ROCKS METAMORPHOSED, IN AND NEAR THE MAGNET COVE INTRUSIVES
4 Location and number of field trip stop.
SCALE IN FEET
0 1000 2000 3000 4000 5000
N
MAGNET COVE TITANIUM CORP. DEPOSIT
KIMZEY CALCITE QUARRY
MAGNET COVE CHURCH
KIMZEY MAGNETITE PIT
MAGNET COVE SCHOOL
COOK MOUNTAIN
TO BARITE MINES
Cove Creek
Stone Quarry
270
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
KINZEY MAGNETITE PIT STOP NO. 6
ACCESS ROAD TO BARITE MINES
ARKANSAS GEOLOGICAL COMMISSION

Figure 3

East and south of this point are two concentric ridges. The outer one is mostly garnet-pseudoleucite syenite and is continuous with the single ridge to the north and northeast. The inner ridge consists of trachyte (Fig. 3).

Contacts are obscured here and only isolated outcrops can be seen. There are good exposures of sphene nepheline syenite in the roadcut along the crest of the hill; and there is a sparsely exposed body of jacupirangite approximately 400 feet to the west. A small body of altered phonolite and breccia which is a xenolith in garnet-pseudoleucite syenite is located about 500 feet east of this point. This garnet-pseudoleucite syenite is exposed about 75 feet farther east. The areas between the outcrops provide a good example of saprolitic residual material. Remnant textures of the sphene nepheline syenite are readily visible in the saprolite, particularly near the crest of the hill.

Sphene Nepheline Syenite

Sphene nepheline syenite comprises about seven percent of the exposed part of the Magnet Cove intrusive (Erickson and Blade, U. S. Geological Survey Professional Paper 425, 1963). At the crest of this hill the syenite is medium grained and exhibits megascopically identifiable pyroxene, hornblende, feldspar, nepheline, and sphene. Most of the syenite is equigranular, but some contains felsic phenocrysts. The syenite has a very heterogeneous texture and contains cognate and foreign xenoliths which are aligned parallel to an apparent flow lineation in places. About 300 feet east of the hills crest is an outcrop of light gray sphene nepheline syenite with a very fine grained groundmass. Phenocrysts of green pyroxene and a few nepheline and alkali feldspar phenocrysts are visible in the rock. According to Erickson and Blade (1963, p. 7) these two varieties of sphene nepheline syenite are probably separate intrusions and the finer-grained rock is younger.

18.3 Exposure of partially weathered garnet-pseudoleucite syenite and metamorphosed sedimentary rocks.

18.45 Turn left through small gate on dirt road to Magnet Cove Titanium Corporation deposit.

18.7 Nichols and Campbell rutile prospects on left.

19.1 Several small exposures of fine-grained ijolite, analcime-olivine gabbro and carbonatite occur in creek bed to right.

19.2 Pass through gate.

19.45 **Stop 3. (1 hr.) Magnet Cove Titanium Corporation Deposit. Site of old mill.** (Leaders: Drew F. Holbrook and Charles Milton)

Approximately 10 million pounds of rutile concentrates were produced from this open pit mine from 1932 through 1944. The rutile mined during this period was utilized in the manufacture of titanium alloys and ceramic raw materials. There has been no production since 1944, but the deposit was core-drilled by the U. S. Bureau of Mines in 1945.

The deposit is comprised of a variety of feldspar-carbonate-rutile veins and vein masses that cut the altered phonolite and breccia country rock. Extensive weathered and hydrothermal alteration to clay of both the veins and the phonolite-breccia country rock and the subsequent reworking of these clays by rainwash have obscured many of the vein-country rock relationships. The knobs of black, fine-grained igneous rock that project from the floor of the pit are phonolite. The most easily recognized type of vein is a hard, buff-colored, porous feldspar-carbonate rock that has abundant coarse pyrite and variable amounts of rutile. The rutile in the veins is characterized by its blue-black luster and striated crystal faces. It is estimated that the average grade of the ore in this deposit is about 3 percent rutile.

A small percentage of columbium is present in the ore and probably is in the rutile. Traces of vanadium, molybdenum and unknown radioactive mineral were found in the ore.

Interest in this deposit continues because of the demand for rutile for white paint pigment and in the manufacture of titanium metal.

Return to U. S. Highway 270.

20.45 Turn left on U. S. Highway 270.

20.7 **Stop 4. (1 hr.) Kimzey Calcite Quarry. Also Lunch Stop.** (Leaders: Charles Milton and Ralph L. Erickson).

This stop is near the center of the Cove, where carbonatite and eudialyte-nepheline syenite pegmatite are exposed. The carbonatite crops out along a north-trending zone about 3500 feet long and 500 feet wide and is best exposed here in the Kimzey calcite quarry (agricultural limestone) which is near the southern end of this zone. Other carbonatite is found in many parts of the central Cove. Erickson and Blade (1963, p. 34) distinguished, during mapping, between carbonatite and residual phosphate, which was derived from the carbonatite by weathering.

The eudialyte-nepheline syenite pegmatite at this stop forms a small arcuate body that is concave southeastward. The pegmatite can be seen on both sides of U. S. 270 between the entrance to the Kimzey calcite quarry and the bridge over Cove Creek.

Carbonatite

Carbonatite occupies 1.8 percent of the exposed igneous complex and is considered to be a late stage of igneous activity (Erickson and Blade, 1963, p. 34). The carbonatite consists largely of medium- to coarse-grained calcite and contains accessory minerals, which ". . . in approximate order of decreasing age, are apatite (light green), monticellite (brown), biotite, magnetite, pyrite, and perovskite (black)" (Fryklund, Harner, and Kaiser, 1954, p. 45). Kimzeyite, a black zirconium garnet, was discovered at this locality (Milton and Blade, 1958, and Milton, Ingram and Blade, 1961, Am. Miner.).

Erickson and Blade (1963, p. 36) note that ". . . inclusions of ijolite a few inches to more than 50 feet across" are found in the carbonatite. These xenoliths have peripheral alteration zones that consist of, from the border of the xenolith inward, magnetite, pyrrhotite, biotite, and idocrase (Fryklund, Harner, and Kaiser, 1954, p. 46).

The accessory minerals in the carbonatite are enriched somewhat in Ti, V, Nb, and rare earths.

Eudialyte-Nepheline Syenite Pegmatite

The eudialyte-nepheline syenite pegmatite covers less than 0.1 percent of the exposed area of the complex (Erickson and Blade, 1963, p. 47). Erickson and Blade indicate that the pegmatite ". . . varies in texture from a fine-grained to very coarse-grained phanerite. The coarse grained parts are well known for beautiful specimens of aegirine crystals up to 6 inches long, and ruby-colored eudialyte crystals up to 1 inch across. Williams (1891) has described in detail the mineralogy of the coarse-grained part. He mentions garnet, ilmenite, magnetite, nepheline, orthoclase, thomsonite, and wollastonite and describes aegirine, astrophyllite, brucite, eucolite, eudialyte, manganopectolite, microcline, natrolite, and sphene."

20.8 Cove Creek bridge on Highway 270.

21.0 Weathered garnet ijolite crops out on right.

21.45 Exposure of biotite-garnet ijolite on right.

21.5 Joe Kimzey's Magnet Cove Mineral Study on left. Mr. Kimzey has an excellent collection of Magnet Cove's rocks and minerals.

21.7 **Stop 5. (30 min.) Kimzey Magnetite Pit.** (Leaders: Ralph L. Erickson and Charles Milton).

This abandoned open pit magnetite mine is located in a zone mapped as lime silicate rock by Erickson and Blade. They believe the deposit to be a local alteration area in the ijolite country rock. The light colored rock in the pit is largely vesuvianite and it contains scattered pods and lenses of magnetite. The mineral thomsonite, which is a zeolitic alteration product of nepheline, is also present. The mine was operated for a short time in 1950-1951 during which time a small tonnage of magnetite was shipped to Birmingham, Alabama. Magnetometer surveys indicate a closure of 10,000 gammas covering a ¼ mile area south of the road.

This Kimzey magnetite pit is of interest because Magnet Cove derived its name from the lodestone and magnetite that are abundent in the soil here.

22.1 Contact of garnet ijolite and trachyte-phonolite.

22.3 Partially altered trachyte-phonolite crops out on right.

22.5 Garnet-nepheline syenite crops out on left.

22.85 Leave U. S. 270 and turn left on barite mine access road.

22.95 Turn left onto dirt road.

23.25 Junction, continue left. Christy brookite deposit on hill to right. (Data from Fryklund and Holbrook, Ark. Geol. Comm. Bull. 16, 1950). This deposit has been prospected as a possible source of titanium, columbium and vanadium ore. The principal titanium mineral here is brookite (TiO_2). Brookite occurs as small black euhedral crystals on smoky quartz crystals or in clay. It is developed in hydrothermal veins that cut a sandstone-like rock that is thermally metamorphosed Arkansas Novaculite. The Magnet Cove intrusive mass is a few hundred feet to the west.

23.7 Exposure of garnet-pseudoleucite syenite and altered phonolite and breccia.

24.3 Cross Cove Creek. Exposure of jacupirangite and related rocks in creek bed.

24.55 The Mo-Ti prospect may be seen to right across creek. Holbrook (Ark. Geol. Comm. Bull. 12, 1948) describes the major molybdenite-bearing veins at the Mo-Ti Corporation prospect as occurring in a fractured jacupirangite country rock and consisting mainly of orthoclase and pyrite with minor amounts of quartz, apatite, plagioclase, molybdenite and brookite. The total length of the deposit is about 400 feet. The average grade of the vein material in the larger veins at the northwest end of the main pit is about 1.07 percent molybdenum sulfide.

24.75 **Stop 6. (40 min.) Jacupirangite at Cove Creek.** (Leaders: Ralph L. Erickson, Stephen E. Kesler and Drew F. Holbrook).

Jacupirangite, with assimilation derivatives of jacupirangite, and various dike rocks are exposed at this stop. Outcrops of the jacupirangite are rare in the complex and the two bodies of this rock that have been mapped were delimited by magnetometer surveys (ground magnetometer surveys show a high in excess of 10,000 gammas in the area) and panned saprolite concentrates (Erickson and Blade, 1963, p. 17). There are two good exposures of jacupirangite along Cove Creek: one location is adjacent to the Mo-Ti prospect approximately 800 feet east of the bridge over Cove Creek and the other location, which is seen at this stop, is about 2000 feet east of the bridge. The contact between the Stanley Shale and meladiorite, an assimilation derivative of the jacupirangite, is exposed in Cove Creek about 1000 feet north of the northern limit of this outcrop.

The jacupirangite is cut by mafic and alkalic dikes. Some of the more noticeable ones at this outcrop include: (1) tinguaite—which forms a six inch dike that runs approximately north-south along the east side of the creek and divides into three smaller dikes near the northern end of the outcrop; (2) pyroxene-biotite ijolite—as a four inch dike that runs east-west across the northern end of the outcrop and is cut by the tinguaite; (3) garnet-biotite melteigite—which is found near the small drill hole (marked No. 1) on the west side of the creek; (4) trachyte-cuts the garnet-biotite melteigite dike near the drill hole; (5) fourchite—is found as a very fresh dike between three and five feet wide which forms a northeast-trending resistant unit in the creek bed approximately 200 feet downstream from the southern limit of the jacupirangite.

Jacupirangite

The jacupirangite covers 10 percent of the exposed area of the igneous complex (Erickson and Blade, 1963, p. 17). These writers describe the jacupirangite as "typically a dark-gray fine-to-medium-grained phanerite that weathers to a dark brown or mottled reddish-brown and olive-green saprolite. Pyroxene is the chief constituent and always comprises more than 50 percent of the rock. . . . The pyroxene crystals (salite) up to 10 mm long appear to have formed as early crystal mush. . . . Magnetite-ilmenite grains as much as 6 mm across comprise about two to 25 percent of the rock . . . Apatite, biotite, sphene, garnet and perovskite are always present, sometimes in proportions greater than 10 percent. Zeolite formed from the alteration of nepheline, calcite and cancrinite is common. Other accessory minerals include pyrite and pyrrhotite."

The Hardy-Walsh brookite deposit lies on the rim of the Cove a short distance to the east. This deposit has been prospected as a possible source of titanium, columbium and vanadium. Brookite occurs with taeniolite in smoky quartz veins in thermally metamorphosed Arkansas Novaculite.

Return to U. S. Highway 270.

26.7 Turn left on U. S. Highway 270. Residential area to right was formerly town of Magnet, Arkansas.

26.8 **Stop 7. (25 min.) Metamorphosed Arkansas Novaculite and Smoky Quartz with Brookite.** (Leaders: Ralph L. Erickson, Drew F. Holbrook, Charles Milton and Hugh D. Miser).

This series of outcrops along U. S. Highway 270 show both the metamorphism and the brookite mineralization in the lower division of the Arkansas Novaculite (Devonian-Mississippian) near its contact with the Magnet Cove intrusive. The novaculite exposed in this cut looks like a very fine-grained sandstone and contains small amounts of taeniolite (a lithium mica), magnetite (?), rutile and brookite. At the "Y" in the highway, and somewhat nearer the novaculite-syenite contact, the novaculite has been recrystallized to a friable quartzite composed of quartz grains ranging from 5 mm to .02 mm in diameter.

There is a good exposure of smoky quartz with abundant brookite developed in the upper division of the Arkansas Novaculite on a small trail to the south about 150 yards. Fryklund and Holbrook (Ark. Geol. Comm. Bull. 16, 1950) state that a thin section shows that rutile needles are common in these quartz veins but not to the extent of darkening the quartz by their numbers. Accompanying the TiO_2 mineralization is an iron oxide, taeniolite, and a clay mineral. The rutile and iron oxide occur in diffuse bands 2-3 mm wide which cut across grain boundaries of the quartz. Typically such a band has an outer zone of abundant rutile, a zone of less intense rutile mineralization, a thin concentrated zone of iron oxide, and a broad zone containing brookite and fresh and altered taeniolite. Acicular rutile is almost entirely altered to leucoxene. The iron oxide occurs as both square and rectangular masses and as a lining of cavities where it has a colloform texture.

26.95 Magnet, Arkansas.

27.7 Turn right on rural road.

28.5 Highly folded exposure of Arkansas Novaculite (Devonian-Mississippian).

28.7 Exposures of massive Arkansas Novaculite (Devonian-Mississippian) and Hot Springs Sandstone (Mississippian).

29.4 Basal Stanley Shale (Mississippian-Pennsylvanian) on right.

29.45 Cross Chicago-Rock Island and Pacific Railroad tracks and Linean creek.

29.5 Turn right on Arkansas Highway 51.

29.85 Cross Chicago-Rock Island and Pacific Railroad tracks and Linean creek.

30.3 Exposures of Stanley shale and sandstone with several altered, reddish igneous dikes.

31.1 **Stop 8. (45 min.) Diamond Jo Quarry.** (Leaders: Ralph L. Erickson and Stephen E. Kesler).

Follow the obscure road on the north side of the highway approximately 1000 feet to the Diamond Jo Quarry. At this stop there are excellent exposures of garnet-pseudoleucite syenite, nepheline syenite pegmatite, and metamorphosed Stanley Shale (Mississippian-Pennsylvanian). Figure 4 shows the distribution of rock types in the quarry area and the numbered points locate features mentioned in the text. The contact between the garnet-pseudoleucite syenite and the nepheline syenite pegmatite can be seen best at point A. Chemical composition and spatial distribution of the two rock types suggest that the nepheline syenite pegmatite is younger (Erickson and Blade, 1963, p. 89). The contact between the pegmatite and the wall rock is well exposed at point B where it appears that the pegmatite was emplaced almost parallel to the bedding of the shale (see photograph facing p. 208, Williams, 1891). Veinlets containing blue sodalite may sometimes be seen filling joint planes. Very little evidence can be found for a chill zone in the pegmatite which suggests that the country rock into which the pegmatite was emplaced had not cooled after emplacement of the garnet-pseudoleucite syenite.

Garnet-Pseudoleucite Syenite

The garnet-pseudoleucite syenite composes 21 percent of the exposed igneous complex and forms a nearly complete ring varying between a few feet and 2000 feet in width (Erickson and Blade, 1963, p. 10). According to Erickson and Blade (1963, p. 11) the "typical fresh rock is light gray, medium

GEOLOGIC MAP OF DIAMOND JO QUARRY
MAGNET COVE COMPLEX, ARKANSAS

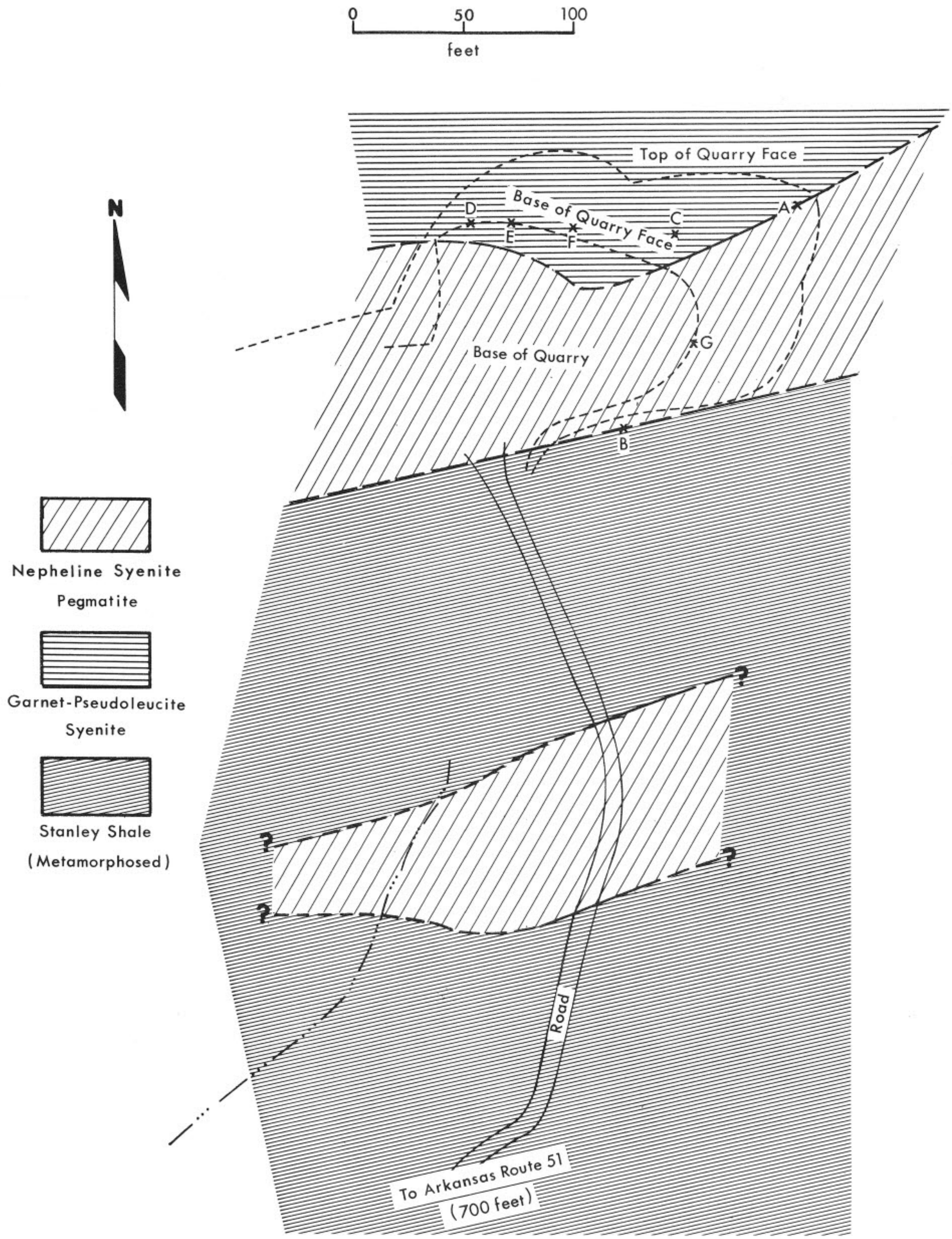


Figure 4

grained, and composed of pseudoleucite, feldspar, black titanium garnet, pyroxene, and nepheline. Inclusions in the rock are abundant and include metamorphosed sediments (point C) and fine-to-coarse grained ijolite (point D) and melteigite (point E) fragments. Miarolitic cavities up to 3 inches across are common (point F—weathered faces) . . . are generally automorphic, and include: tabular white orthoclase, needles of green aegirine, needles of colorless pseudowavellite, and short crystals of apophyllite . . . A coarser grained, more slowly cooled phase of the garnet-pseudoleucite syenite was mapped separately as garnet nepheline syenite and comprises about 3.5 percent of the exposed igneous rocks . . . Earlier workers mapped this rock as part of the sphene nepheline syenite but the presence of macroscopic garnet, absence of macroscopic sphene, and gradational contact with garnet-pseudoleucite syenite mark it as a coarser grained phase of the garnet-pseudoleucite syenite." This garnet nepheline syenite will not be seen on the trip because of accessibility problems. However, a group of samples collected from NE¼ sec. 18 are available at this stop for comparison.

Nepheline Syenite Pegmatite

The nepheline syenite pegmatite occupies 0.2 percent of the area of the complex and forms small, irregular bodies near the outer contact of the igneous complex (Erickson and Blade, 1963, p. 44). The rock contains "... barian sodic orthoclase (... as much as 30 mm long) with minor nepheline and cancrinite (interstitial). Black titanium garnet and zoned pyroxene are the chief mafic minerals and tend to be segregated in patches." (A similar segregation has developed at point G where 10 to 20 cm bands of coarse-grained, comparatively mafic-poor rock alternate with finer-grained, mafic-rich rock.) "Pyrite, calcite, and magnetite are accessory constituents. Blue sodalite and purple fluorite occur as thin skins, one-eighth inch thick, on vertical joint planes (point G)." Erickson and Blade (1963, p. 44) note that the pegmatite, in contrast to the garnet-pseudoleucite syenite, contains no inclusions.

Metamorphosed Stanley Shale

The Stanley Shale (Mississippian-Pennsylvanian) in this area is largely fine-grained, finely-laminated shale and sandstone composed of quartz, feldspar, mica, and iron oxides. Erickson and Blade (1963, p. 56) mapped a 1000 to 2500 foot zone of contact metamorphosed wall rock around the complex. This zone is best developed at the north side of the intrusion. At the Diamond Jo Quarry, the metamorphic assemblage quartz, albite, magnetite, biotite, sphene and hornblende are found in rocks over a range from very near the contact to as much as 700 feet from the contact. Inside this zone, within a few feet of the contact, some rocks contain aegirine, hornblende, biotite, magnetite, oligoclase and sphene. Beyond about 700 feet from the contact, the rock is less obviously changed. It consists of patches of biotite and magnetite in a quartz, biotite, sericite and magnetite matrix. Some of these rocks, especially those nearest the contact show gneissic mineral segregations and close folding but very poor foliation. Little information on contact temperatures can be obtained from mineral assemblages but it is hoped that oxygen isotope studies just begun by E. G. Perry at the University of Minnesota will yield more definite temperature data.

Turn around and proceed east on Arkansas Highway 51.

32.35 Cross Linean creek and Chicago-Rock Island and Pacific Railroad tracks.

32.7 Good exposure of Stanley Shale (Mississippian-Pennsylvanian) on right.

33.4 Excellent exposures of Arkansas Novaculite (Devonian-Mississippian).

33.7 Small lignite bed in Wilcox Group (Eocene) on right.

34.7 Junction of Arkansas Highway 51 and U. S. Highway 270, proceed straight ahead. See first day road log for detail.

35.7 Turn left on U. S. Interstate Highway 30 East.

35.9 Clayton (Paleocene) limestone and clay capped by Wilcox (Eocene) sand.

38.5 Sand and clay pit on right in Wilcox (Eocene).

41.65 Small quarry in massive Arkansas Novaculite (Devonian-Mississippian) on right.

43.5 Enter Saline County. View of large quarry in Arkansas Novaculite (Devonian-Mississippian) to left.

49.4 Junction with U. S. Highway 70, proceed on U. S. Interstate Highway 30 East to Little Rock.

51.5 Exposure of highly fossiliferous Clayton (Paleocene) limestone on right.

52.5 Saline River.

53.8 Benton, Arkansas.

54.3 Intensely folded Womble Shale (Ordovician) overlain by flat-lying Clayton (Paleocene) limestone in small creek on right.

55.3 Gravel and sand pits in Wilcox Group (Eocene) on left.

59.6 Cross Hurricane Creek.

59.8 Small exposure of Womble Shale (Ordovician) on left.

60.9 Bryant-Bauxite exit to right. Join first day road log.

64.7 Enter Pulaski County.

68.8 Arkansas Highway Department building on left.

70.2 Take left lane and proceed on U. S. Interstate Highway 30 East.

73.8 View of Granite Mountain Quarry to right.

76.1 Take left lane and proceed on U. S. Interstate 30 East.

78.2 Turn right on East 9th Street exit.

78.5 Turn right on East 9th Street to airport.

78.9 Cross Chicago-Rock Island and Pacific Railroad tracks.

79.15 Cross Missouri-Pacific Railroad tracks and turn right on Bond Street.

79.5 Turn left on East 14th Street.

80.0 Adams Field Municipal Airport.

END OF SECOND DAY LOG.

THE CHAMBERLAIN CREEK BARITE DEPOSIT

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The occurrence of barite in the Ouachita Mountains of Arkansas has been known since 1890. With the development of the use of ground barite as a weighting agent in oil well drilling muds, interest was shown in the Arkansas deposits, and in 1939 the Magnet Cove Barium Corporation found that an acceptable drilling mud barite could be obtained from the ore by flotation. The company then began producing barite from the Chamberlain Creek syncline deposit near Magnet Cove in Hot Spring County, and in 1941 the Baroid Division of the National Lead Company started mining and milling operations on a portion of the same deposit. Annual production from this deposit expanded rapidly from 2,500 short tons in 1939 to a peak of 468,000 short tons in 1957. Although production has declined since 1957 because of decrease in drilling activity and competitive sources, Arkansas is second only to Missouri in domestic barite production.

The barite region of Arkansas comprises about 2700 square miles in the southern part of the Ouachita Mountain system and the northernmost part of the West Gulf Coastal Plain of Arkansas. The most important occurrence is the Chamberlain Creek deposit.

The Chamberlain Creek syncline deposit is in the Magnet Cove district in the northeast part of the Malvern quadrangle and lies wholly within Hot Spring County. The Paleozoic rocks exposed in the district range from the Ordovician (Bigfork Chert) to the Mississippian (Stanley Shale). The Mesozoic is represented by the Magnet Cove igneous rocks and the Cenozoic is represented by the lower Tertiary Midway Formation, which overlaps the Paleozoic rocks on the southeast side of the district. Structurally, the district incorporates the eastern end of the Mazarn Basin, part of the Zigzag Mountains, the northernmost part of the Trap Mountains, and the Magnet Cove ring dike complex which truncates the Chamberlain Creek syncline on the southwest. The major barite deposit is located in the Stanley Formation in this syncline, one of the southwestward plunging synclines of the Zigzag Mountains.

Local Structure. The Chamberlain Creek syncline from where it is truncated on the southwestern end by the Magnet Cove intrusives in the eastern part of Sec. 17, T. 3 S., R. 17 W. extends northeastward with a subsymmetrical outline for about two miles. Structurally the syncline is decidedly asymmetrical, with the southeast limb being steeper and locally overturned (Fig. 5).

In the rock exposures made available by the underground mining operations, many more local structures can be seen than anywhere in the district. Underground, minor structures in the form of V and chevron folds, rollovers, and normal and reverse faults are common. The displacement along the faults is ordinarily only a few inches. These local structures have no appreciable effect on the concentration of the barite, although there is a slight increase in the grade of the ore along the axes of some of the folds.

Stratigraphic Relations. The barite ore in this deposit lies near the base of the Stanley Formation being separated from the underlying Arkansas Novaculite Formation by a bed of black shale varying in thickness from 2 to 22 feet.

In the area of the mine workings there is a maximum of 600 feet of shale, sandstone, and siltstone of the Stanley Formation overlying the black shale unit. This Formation is probably about 2,000 feet thick near the contact with the Magnet Cove intrusion.

The Ore Bodies. The barite deposit in the Chamberlain Creek syncline is located in the northeastern part of the structure. It has a maximum length of 3,200 feet and apparently is restricted to that portion of the syncline in which the axial trend is nearly eastward. The maximum width of the ore body (1,800 feet) occurs at the west end of the deposit. Because of natural truncation, the width diminishes eastward. The ore body has been completely eroded away at the eastern tip of the structure. The average thickness of the mineralized zone is about 300 feet and the average thickness of commercial concentration is about 60 feet. The maximum thickness of commercial ore occurs just north of the axis of the syncline where it has a thickness of 80 to 100 feet.

The available drill hole information and the exposures in the surface and underground mine workings show that in this thicker portion the mineralized zone is split into two bodies separated

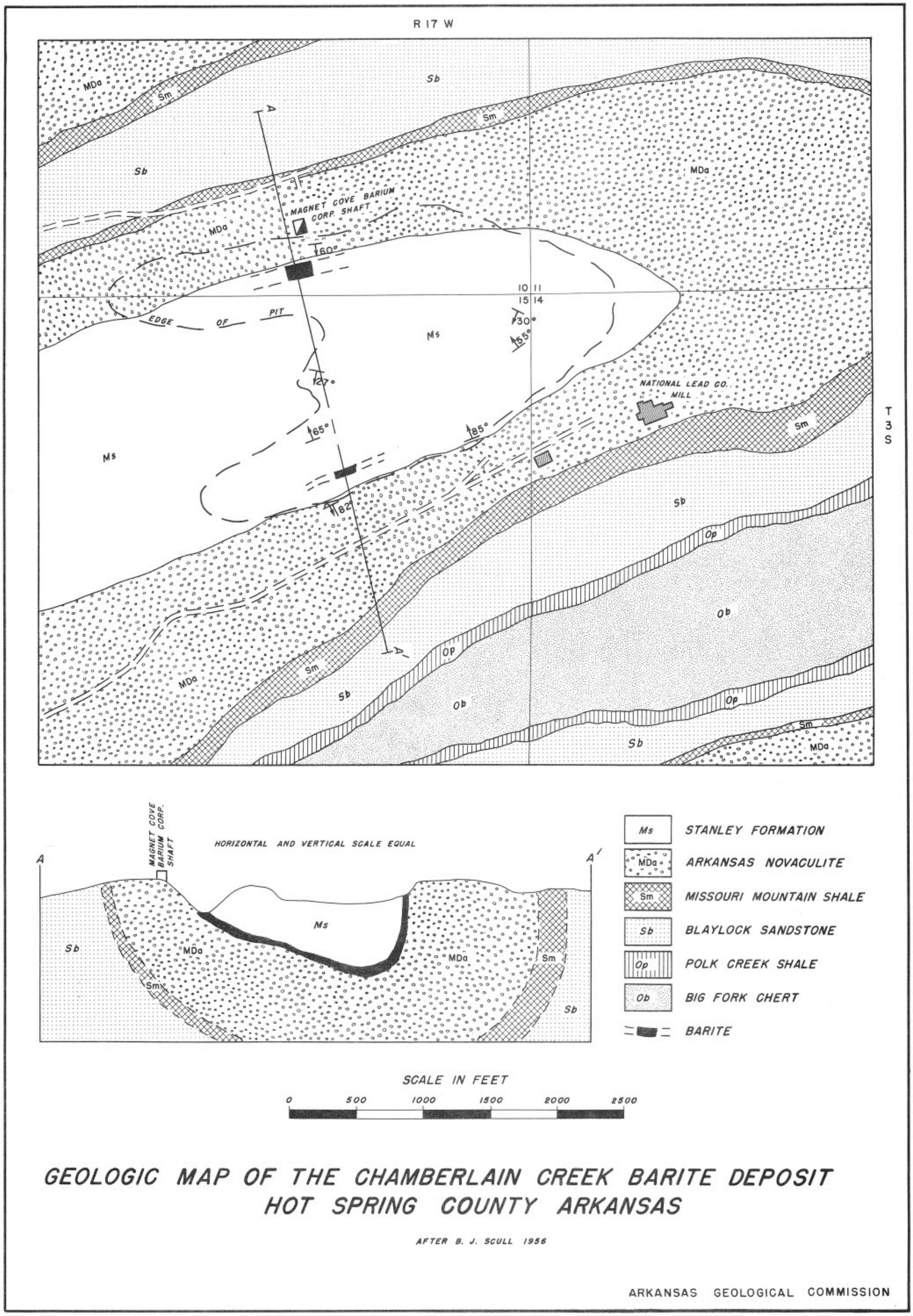

R 17 W
T 3 S
MAGNET COVE BARIUM CORP. SHAFT
EDGE OF PIT
NATIONAL LEAD CO. MILL
HORIZONTAL AND VERTICAL SCALE EQUAL
Ms STANLEY FORMATION
MDa ARKANSAS NOVACULITE
Sm MISSOURI MOUNTAIN SHALE
Sb BLAYLOCK SANDSTONE
Op POLK CREEK SHALE
Ob BIG FORK CHERT
BARITE
SCALE IN FEET
0 500 1000 1500 2000 2500
GEOLOGIC MAP OF THE CHAMBERLAIN CREEK BARITE DEPOSIT
HOT SPRING COUNTY ARKANSAS
AFTER B. J. SCULL 1956
ARKANSAS GEOLOGICAL COMMISSION

Figure 5

by an essentially barren shale lens 5 to 15 feet thick. This is the only place in the commercial ore zone where a persistent barren or non-productive unit occurs.

With respect to texture and structure there are several types of barite ore. The major types in order of decreasing abundance are: finely crystalline in beds and lenses, dense microcrystalline in beds and lenses, nodular, and coarsely granular in lenses. These major types grade into each other laterally, pinch out, grade into low baritic sediments, or grade into non-baritic sediments. The thicker (1 to 3 feet) units ordinarily grade into low grade baritic shales and siltstones or nodule-bearing shales and siltstones. They do not pinch out as true lenses.

The nodular type ore makes up from 3 to 30 percent of the ore body, depending on the section measured. Coarsely crystalline barite is rare in this deposit. Most of the ore is of the gray to dark gray dense variety. Much of it has, superficially, a close resemblance to a dense limestone.

Origin. 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.

GEOLOGY OF THE WILSON SPRINGS VANADIUM DEPOSITS

Garland County, Arkansas

J. S. Hollingsworth
Union Carbide Corporation
Mining and Metals Division
Arkansas Operations

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 and 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 Corporaiton.

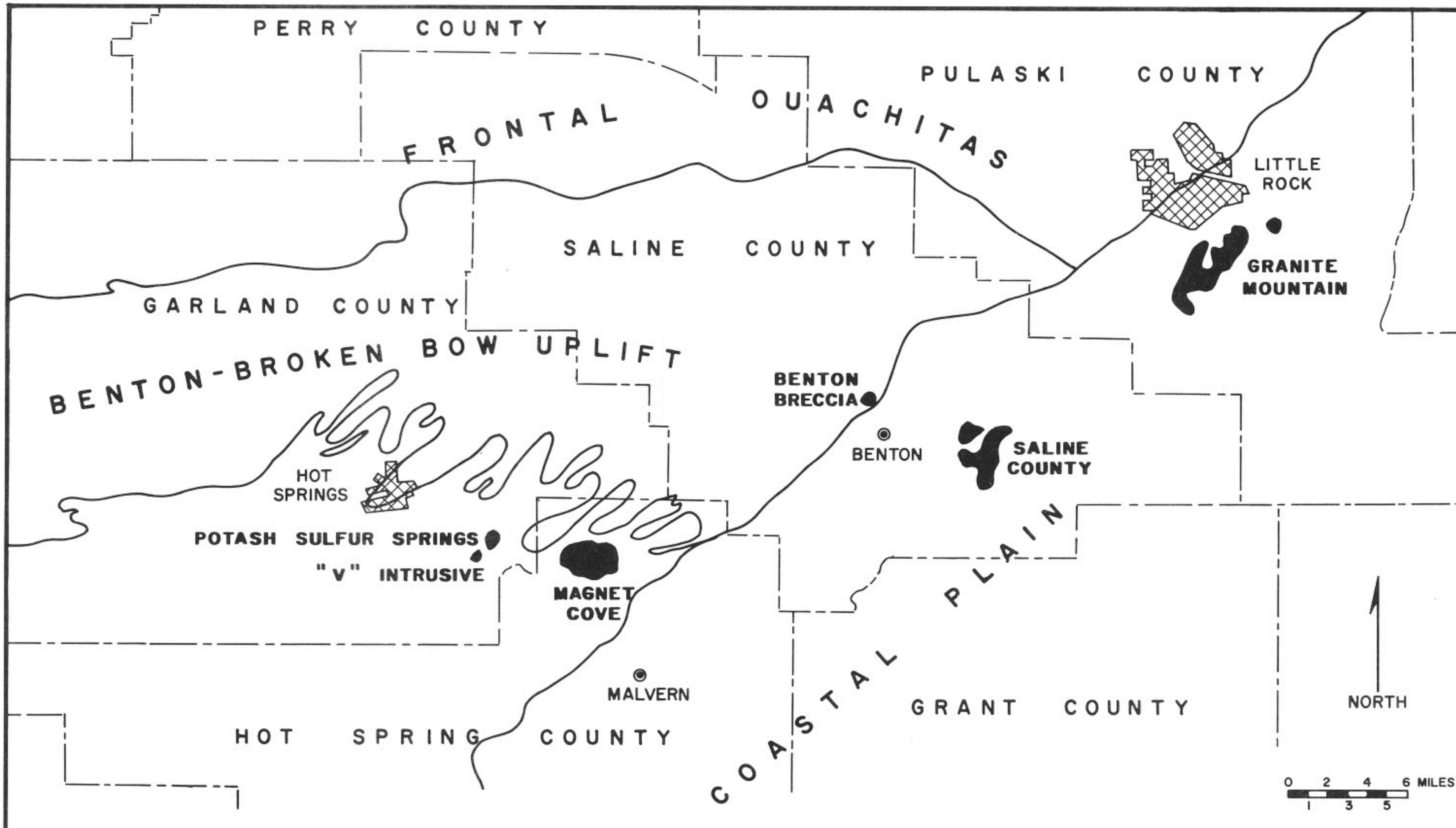
Igneous Rocks

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 intrusive to be 95 $\pm$ 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 alkali 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 feldsphathic 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.

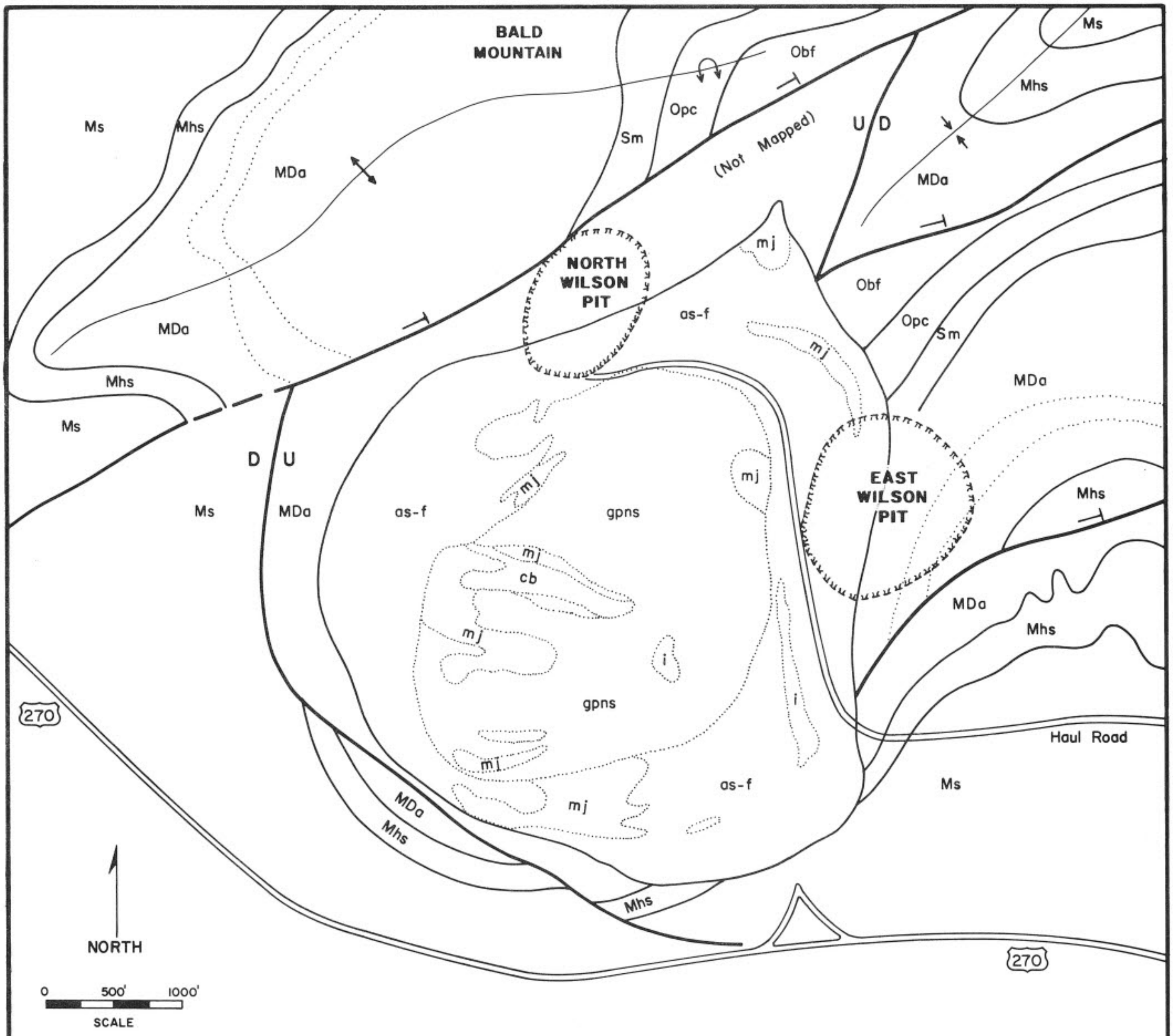
The basic rocks of the Potash Sulfur Springs complex include jacupirangite, pyroxenite, and members of the melteigite-ijolite series. Nepheline content varies from traces in jacupirangite to a maximum of 60 percent in ijolite. Biotite jacupirangite contains small amounts of magnetite and titanite with 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-

[1]The name Potash Sulfur Springs is used throughout geological literature for the intrusive and is retained herein.



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

Figure 6



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

U/D FAULT

ANTICLINE

SYNCLINE

Figure 7

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 fenites.

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

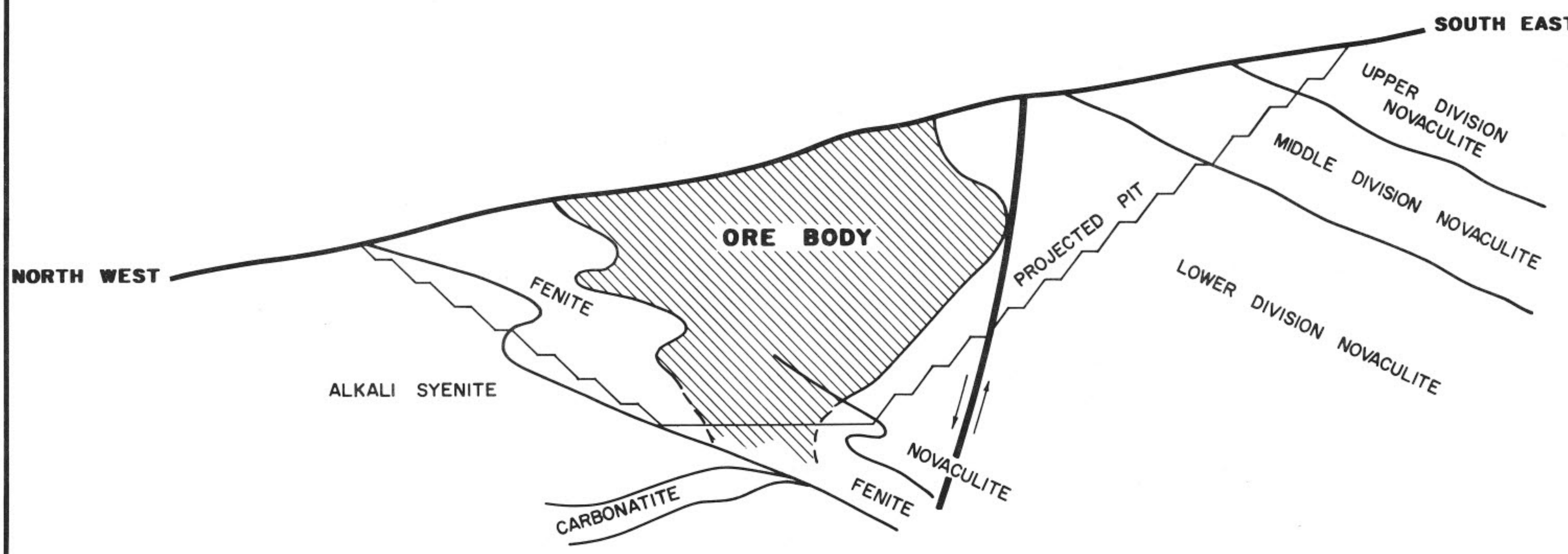
The sedimentary rocks in the immediate vicinity of the Potash Sulfur Springs intrusive range from Ordovician (Bigfork Chert) to Mississippian (Stanley Shale) in age. The approximate observed thicknesses of these units and a brief description are shown in the accompanying table.

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.



DIAGRAMMATIC CROSS SECTION

OF THE EAST WILSON PIT

NOT TO SCALE

Figure 8

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

South North

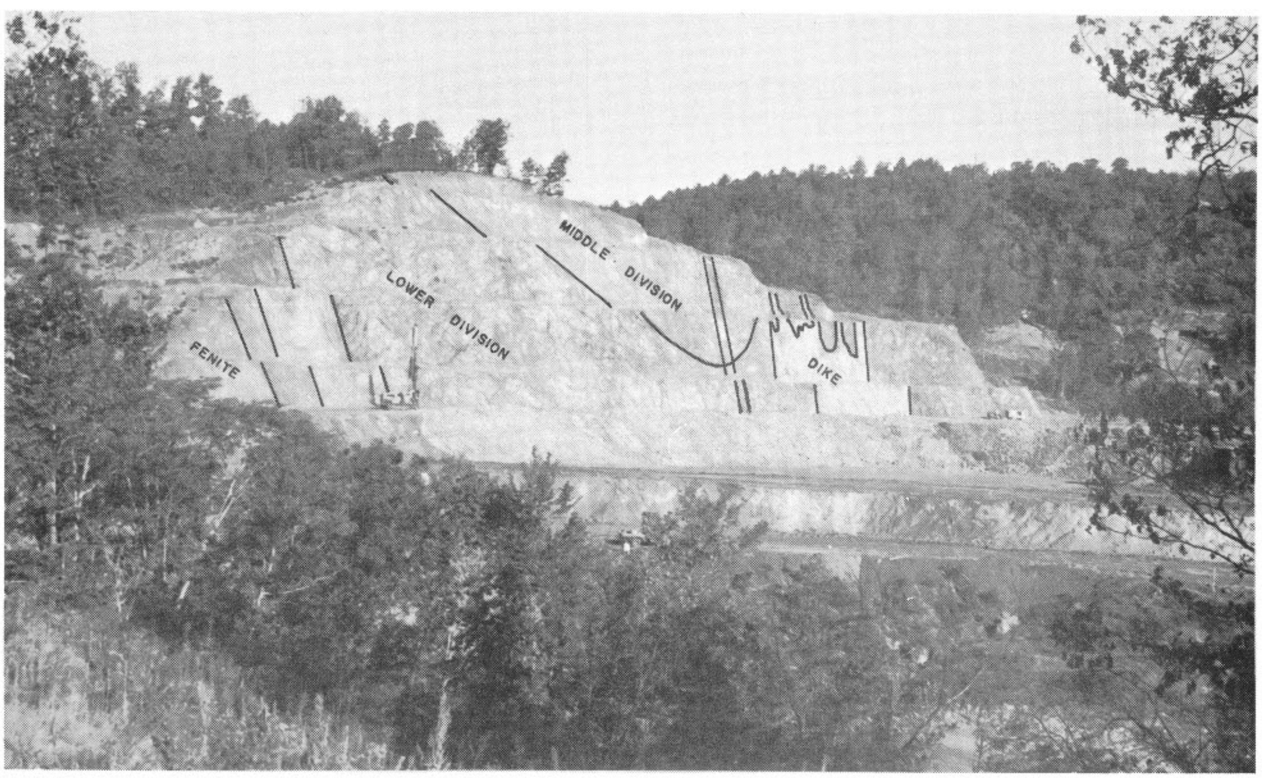


Figure 9 View of the North Wilson Pit looking northwest at the north-south high wall. Description in text.

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.

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.

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