THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

ORIGIN AND OCCURRENCE OF BARITE IN ARKANSAS

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

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Norman, Oklahoma

1956

ORIGIN AND OCCURRENCE OF BARITE IN ARKANSAS

APPROVED BY

DISSERTATION COMMITTEE

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

TABLE OF CONTENTS - Continued

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS - Continued

LIST OF ILLUSTRATIONS - Continued

LIST OF ILLUSTRATIONS - Continued

ORIGIN AND OCCURRENCE OF BARITE IN ARKANSAS

CHAPTER I

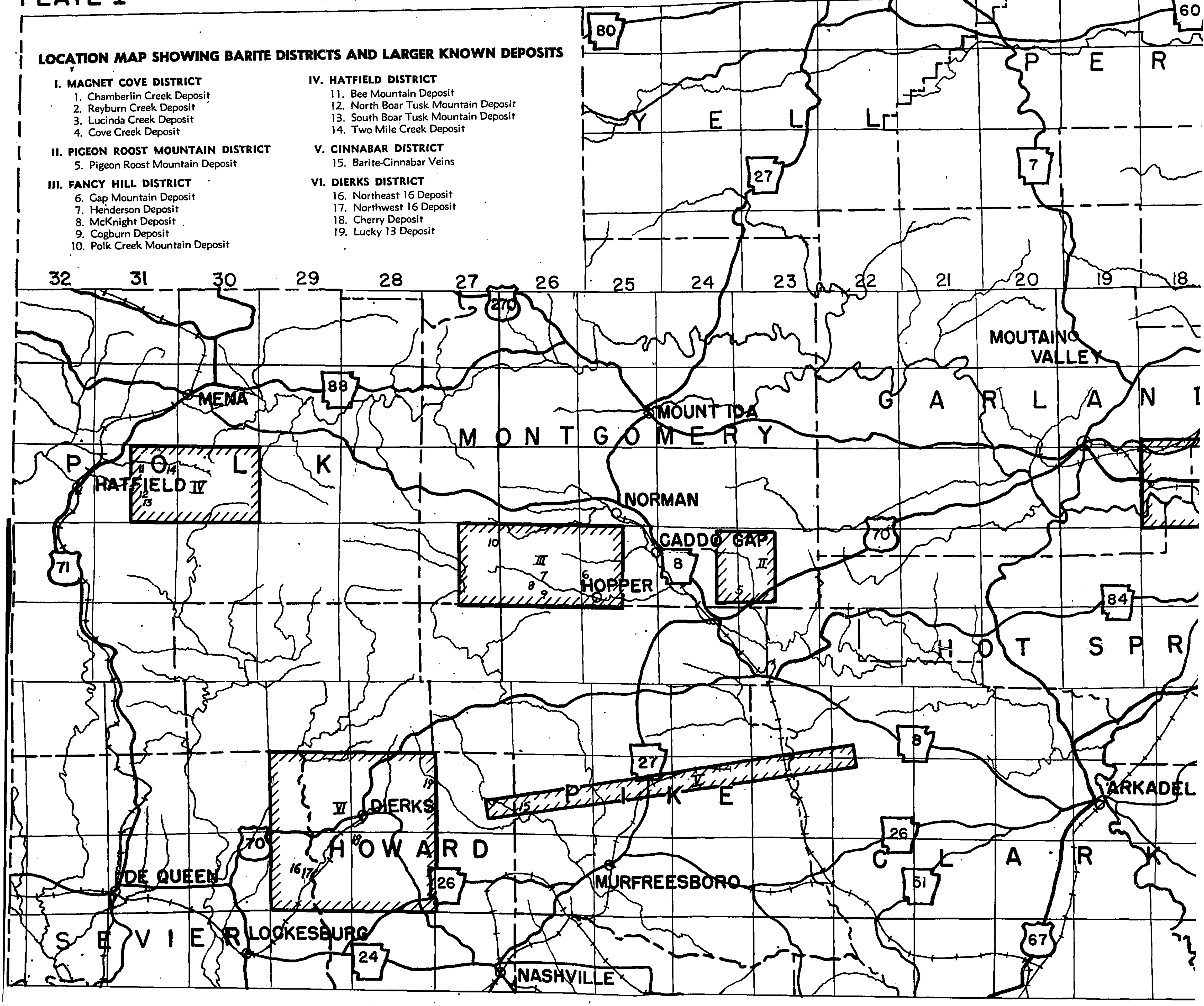
INTRODUCTION

General Statement

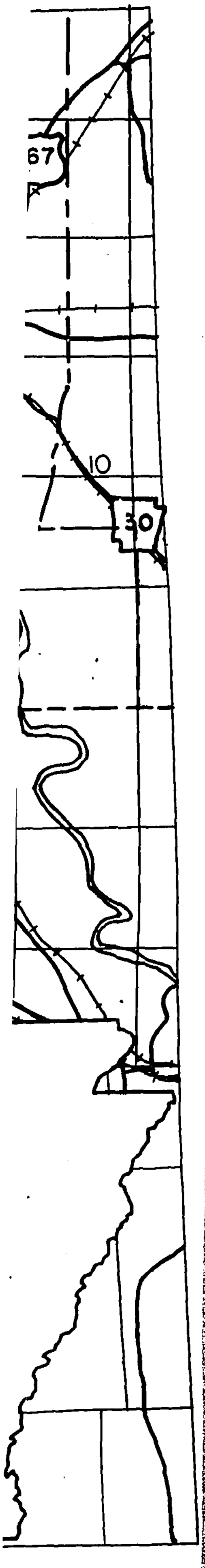
The use of barite as a chemically inert weighting material in the drilling mud of the petroleum industry has increased greatly in the last two decades, and as a result the mining and processing of barite has become a major industry. The barite operations in Arkansas now supply about 50 percent of the domestic production and about 25 percent of the world production.

The presence of impure barite in the Ouachita Mountain region has been known since about 1890, but until 1939, when the Magnet Cove Barium Corporation found that commercial recovery could be made by flotation, the barite of the region, "stinkstone," was mostly considered to be a mineralogical curiosity. This company began operations in a deposit near Magnet Cove, and in 1941 the Baroid Division of the National Lead Company started mining and milling operations in a part of the same deposit. Annual production from this deposit, which is the only one currently being mined in Arkansas,

PLATE I



LOCATION MAP SHOWING BARITE DISTRICTS AND LARGER KNOWN DEPOSITS
I. MAGNET COVE DISTRICT
1. Chamberlin Creek Deposit
2. Reyburn Creek Deposit
3. Lucinda Creek Deposit
4. Cove Creek Deposit
II. PIGEON ROOST MOUNTAIN DISTRICT
5. Pigeon Roost Mountain Deposit
III. FANCY HILL DISTRICT
6. Gap Mountain Deposit
7. Henderson Deposit
8. McKnight Deposit
9. Cogburn Deposit
10. Polk Creek Mountain Deposit
IV. HATFIELD DISTRICT
11. Bee Mountain Deposit
12. North Boar Tusk Mountain Deposit
13. South Boar Tusk Mountain Deposit
14. Two Mile Creek Deposit
V. CINNABAR DISTRICT
15. Barite-Cinnabar Veins
VI. DIERKS DISTRICT
16. Northeast 16 Deposit
17. Northwest 16 Deposit
18. Cherry Deposit
19. Lucky 13 Deposit
Y E L L
P E R
MOUTAIN VALLEY
G A R L A N
MENA
MOUNT IDA
M O N T G O M E R Y
P O L K
HATFIELD IV
NORMAN
CADDO GAP
HOPPER
H O T S P R
P I K E
ARKADEL
DIERKS
H O W A R D
C L A R K
DE QUEEN
MURFREESBORO
S E V I E R
LOCKESBURG
NASHVILLE


67
10
30

increased from 2500 short tons in 1939 to over 300,000 short tons in 1955.

Properties and Uses of Barite

Physical and chemical character. Barite is also known commercially as barytes, baryta, heavy spar, tiff, and cawk. Chemically, the mineral is barium sulfate, ($BaSO_4$), containing 65.7 percent barium oxide, (BaO), by weight, and 34.3 percent sulfur trioxide, (SO_3). Calcium and strontium are the most common impurities, although silica, clay and organic matter are rather abundant in some cases. In many localities barium sulfide, (BaS), or sulfur dioxide, (SO_2), probably in chemical excess in relation to the barium sulfate, is released, producing a fetid odor, when the barite is rubbed or is struck with a hammer.

Barite crystallizes in the orthorhombic system as tabular or prismatic crystals. The tabular crystals may be arranged in crested divergent groups. The mineral also occurs in cleavable, granular, fibrous, or reniform masses. In some cases it is lamellar, nodular, or earthy. Barite has perfect cleavage in three directions, one parallel to the basal pinacoid and the others parallel to the unit prism. The typical cleavage fragment has two right angles and one oblique angle (78° 22'). The mineral is brittle and has an uneven fracture. Its hardness is 2.5 to 3.5 and it can be scratched readily with a knife. The specific gravity ranges from 4.3 to 4.6, making it one of the heaviest of the nonmetallic minerals. The mineral, when pure, is colorless, white, or light gray. When impurities in the form of iron oxide or other matter are present barite may be yellow, blue, brown, red or black. The luster is vitreous to pearly. Barite is soluble in pure water on the order of 1 part in 400,000. The solubility is increased in solutions containing carbon dioxide, alkaline carbonates, or chloride ions.

Distribution. The element barium is widespread in the earth's crust, being present as a trace in nearly all rocks. Clarke (1924, pp. 29, 547, 552) reports 0.055 percent barium oxide in the average igneous rock, 0.05 percent in shales, and 0.05 percent in sandstones. In a sense these percentages are misleading because barium tends to concentrate in particular rock types. In igneous rocks the element is generally present in barium-containing silicates, mostly potash feldspars and micas. Therefore the syenites and allied rocks contain greater percentages of barium than do the more siliceous and mafic rock types. The more arkosic and micaceous sediments ordinarily contain more barium than does the average sediment.

Most barite is deposited from water solutions; however, these solutions and their environments represent a wide variety of conditions. These water solutions may range from hydrothermal solutions with a large content of gas to marine waters in near-shore environments. Many barite

TABLE 1

PRODUCTION STATISTICS - ARKANSAS BARITE

Year	Amount (short tons)	Estimated Value
1939	2,500	
1940	12,000	67,250
1941	31,200	178,760
1942	53,500	321,180
1943	94,700	568,240
1944	159,700	1,038,050
1945	261,400	1,793,240
1946	288,900	2,144,100
1947	376,800	2,411,910
1948	362,400	2,681,780
1949	363,300	6,104,930
1950	343,100	5,973,370
1951	399,500	6,956,550
1952	422,400	7,603,740
1953	381,400	7,437,430
1954	370,600	3,488,480
1955	366,000	3,440,000

From files of Arkansas Geological and Conservation Commission deposits are the result of solution and redeposition through ground water processes, whereas many others are the result of concentration by weathering of a carbonate host rock. The deposits representing deposition from hydrothermal solutions range from simple fracture filling to complete replacement of a favorable stratigraphic unit. Hydrothermally emplaced barite is the gangue material in a large number of metalliferous deposits.

Uses. The chief commercial uses of barite are as weighting material in drilling mud, as source of barium chemicals and in lithopone. However, considerable amounts are used as filler in rubber and paper and in some types of glass. In recent years the use of barite in cement for coating oil and gas lines in swampy areas and as a constituent of rubberized asphalt pavement has created new markets for the mineral. Over half of the domestic production as well as much of the imported material is used to produce weighting material for drilling muds. Barite is ideal for this use because of its chemical inertness, high specific gravity and relative cheapness. Nearly all of the barite processed in Arkansas is sold for this purpose. Barite used in other industries normally brings a higher price, but must be white and almost free from iron.

Scope of the Investigation

This report describes the barite deposits known to occur in the Ouachita Mountains and in the sediments of the adjoining Gulf Coastal Plain. Those deposits considered to be of potential commercial size are described in detail with respect to stratigraphy, structure, nature of the ore and paragenesis, whereas the deposits considered to be of minor importance are treated less thoroughly. The information gathered from the study of each occurrence is integrated to formulate a theory for the origin and paragenesis of the barite of this region.

Methods of Investigation

The geology of the Ouachita Mountains is not well known. Several of the papers concerned with special features or with certain areas within the region are classics among geologic investigations, but parts of the region have not as yet been mapped. In order to complete as much areal mapping as possible within the year spent in the field, the available literature and the field data of U. S. Geological Survey and private parties mapping in parts of the region were used extensively. Where published maps were in obvious error and where suitable maps were not available, the surface geology was mapped on aerial photos on a scale of 500 feet to the inch. The areas so covered were of sufficient extent that the stratigraphic and structural setting of the individual deposits could be established.

The core drill data made available by the operating companies and from reports of the U. S. Bureau of Mines were used to control structural interpretations during the areal mapping, to verify structural and lithologic data obtained from underground mapping, and to establish the extent of mineralization of some of the deposits.

Hand samples were collected from each deposit and in those areas in which trenches, pits, cuts, or core drill holes were strategically located with respect to the ore bodies serial samples were collected. The hand samples were studied under the binocular microscope and from 150 selected samples thin sections for petrographic analyses were made. Forty samples were analyzed chemically, most of them by the chemists of the Arkansas Geological Survey, and twenty samples were analyzed spectographically by the staff of the U. S. Geological Survey.

The structural, stratigraphic, chemical, and petrographic data were systematically combined in order to establish the time and mode of origin of the barite occurring in the region.

Previous Work

The first mention of the occurrence of barite in Arkansas in the available literature is in the Annual Report of the Geological Survey of Arkansas for 1888 (J. C. Branner.) In Volume I of this report a list of the minerals of West

Central Arkansas is included in the gold and silver report of T. B. Comstock. Comstock stated that seams and pockets of "barytes" of a very good quality were common in Montgomery County and predicted that this was an industry worthy of consideration. Volume II contains the report by R. T. Hill (1888) on the Neozoic Geology of Southwestern Arkansas in which the Paleozoic, Cretaceous, and Tertiary areas are defined.

The Magnet Cove intrusives are the only geologic features of the region covered in this report that received any appreciable study prior to the Annual Reports by Branner. These earlier papers were summarized by J. F. Williams (1891) in his classic report on the igneous rocks of Arkansas. A companion report to that of Williams was the study of the Arkansas novaculite by Griswold (1892) in which the structural and geomorphic pattern of the Ouachita Mountains was classified into the units currently used in the region.

Other than these two reports, only the work of Purdue and Miser has been of regional significance. In their reports on the Hot Springs quadrangle (1923) and the De Queen and Caddo Gap quadrangles (1929) these authors developed the stratigraphic terminology now used in the region. Their maps of these three quadrangles are the only areal maps of appreciable extent for areas within the Arkansas portion of the Ouachitas. Considering the complexity of the geology and the physical difficulties involved in mapping these quadrangles, the work is remarkably accurate and established the geologic framework for subsequent students in the region.

Local but useful information was obtained from several papers concerned with the now inactive cinnabar district along the southern border of the Ouachitas. Reed and Wells (1938) and Stearn (1936) present most of the data on stratigraphy, structure, and age relations of the ores that are useful in regional interpretations as related to the barite problem.

Maps and descriptions in the reports of Washington (1900), Holbrook (1947), and Fryklund and Holbrook (1950) show, to a large extent, the distribution and relationships of the various igneous and sedimentary rocks of the Magnet Cove intrusion.

In 1932 Parks and Branner published a report describing the barite deposits near Magnet Cove. The field work was done by Parks, and the mapping in the vicinity of the barite-bearing zone was detailed and rather accurate. The regional map, however, is subject to considerable revision. Two U. S. Bureau of Mines reports by McElwaine and one by Jones were used extensively for orientation, location of known deposits, descriptions of pits and trenches now filled, and other useful data. McElwaine described the deposits in the Magnet Cove area (1946A) and in the Montgomery County area (1946B). Jones (1948) described the deposits known in the western part of the Arkansas Ouachitas.

Current Work

The U. S. Geological Survey has two current projects in the region; one is a detailed study of the Magnet Cove intrusive, and the other is the mapping of several quadrangles. Although these projects are not directly concerned with the barite of this region, the information made available through them has aided materially in the barite study. The projects are of such magnitude that it will be several years before a complete integration of data can be made.

Acknowledgments

This study of the Arkansas barite was suggested by Norman F. Williams, the State Geologist of Arkansas, who rendered full support and cooperation in every phase of the project. Mr. Drew F. Holbrook of the Arkansas Geological Survey was particularly helpful in obtaining photographs for field work.

A report of this nature would be written with difficulty, if at all, without the cooperation of the organizations which control the mineralized lands. Mr. Reginold Rowland, Vice-President, Mr. Ed Farrel, General Superintendent, and Mr. James Chaney, Mine Superintendent of the Baroid Division of the National Lead Company, and Mr. John Tobler, General Superintendent, and Mr. James Stark, Mine Superintendent of the Magnet Cove Barium Corporation granted the writer access to all the holdings of their respective companies and made available the geologic data on file, including core hole information.

Mr. Paul Timbrook and Mr. Al Higgins, Baroid engineers, aided in compiling location maps and in sorting file data.

Mr. Dan Martin, Magcobar engineer, served as a guide in the underground workings and compiled the original data for the underground cross sections.

Mr. Robert B. McElwaine supplied maps of the barite deposits in the Dierks district and served as a geologic guide during that phase of the study.

Mr. Albert Hess, Milwhite engineer, furnished cores from several properties in the region.

Dr. Ralph E. Erickson, Mr. Lawrence V. Blade and Mr. Walter Danilchek of the U. S. Geological Survey gave the writer considerable chemical and field data and aided in the formulation of the more logical interpretations of the origin of the barite.

Dr. Troy Carney, Chief Chemist, Arkansas Geological Survey, made most of the chemical analyses used in the report. Mr. Wallace Griffitts, U. S. Geological Survey, obtained the spectrographic analyses.

Mr. Howard G. Schoenike, Chief Geologist, Baroid Division, helped in a number of ways: in geological and geographic orientation, in obtaining geological data, in acute discussions of geological problems, and, perhaps most

important, as a congenial and competent field companion.

Dr. Hugh Hunter, School of Geology, University of Oklahoma, made several valuable suggestions after visiting the problem area and reading the original manuscript.

The report was written under the helpful guidance of Dr. Clifford A. Merritt, School of Geology, University of Oklahoma.

Geography

The barite region of Arkansas comprises about 2700 square miles and includes portions of Hot Spring, Garland, Montgomery, Polk, Howard and Sevier Counties. The region includes the southern part of the Ouachita Mountain system and the northernmost part of the West Gulf Coastal Plain of Arkansas.

The Ouachita Mountain system, consisting of several ranges and intermontane basins, extends westward from near Little Rock, Arkansas, to near Atoka, Oklahoma. In the mountainous area the major features are narrow ridges and valleys with picturesque transverse water gaps. The ridges trend nearly east or northeast, are characterized by steep debris-covered slopes, and, except for isolated peaks, have even crests. The relief is about 250 feet at the eastern end and gradually increases to about 1800 feet near the Arkansas-Oklahoma line. The up-land latitude increases from about 750 feet near Little Rock to about 2850 feet near the state line.

The various mountain ranges bound wide valleys or intermontane basins. The terrain within these basins is undulating and in places rough with low sharp ridges separating steep-sided narrow valleys. Except for Pigeon Roost (900 feet), the maximum relief is slightly over 250 feet. The general level of the basins rises from about 450 feet above sea level on the east to over 1000 feet near the state line.

The northern part of the Gulf Coastal Plain in Arkansas is essentially a low-lying, gently undulating surface, forest covered and transected by southward flowing streams. Low gravel-covered divides, stream terraces and low cliffs afford the relief of the area. Elevations range from 350 feet in the larger stream valleys to 675 feet on the highest ridges.

Lines of the Missouri Pacific Railroad skirt the mountainous area along the southeastern margin of the region. Branch lines serve Hot Springs and Norman. Lines of the Chicago-Rock Island and Pacific serve Malvern, Butterfield and the barite mines. U. S. Highway 70 and Arkansas State Highways 6, 8 and 27 connect the larger towns within the region (see Plate I).

The region is one of moderate climate. Extreme cold or appreciable amounts of snow are rare and of short duration. The summers are hot and periods of drought are not uncommon. In normal years rainfall is abundant with the maximum during the spring and early summer months. The aggregate precipitation is sufficient to produce a thick forest cover over most of the region. Only cultivated areas along the streams, the soilless steeper slopes and novaculite-capped ridges are free from vegetation. The climate and the cover of vegetation are such that the winter months are the most suitable for field work.

CHAPTER II

AREAL GEOLOGY

General Statement

The Arkansas barite region comprises portions of two geologic provinces; The Ouachita Mountains, including the Athens Plateau, and the Gulf Coastal Plain. The sedimentary rocks exposed in the Ouachitas are well-indurated Paleozoic shales, sandstones, novaculite and chert, with minor amounts of limestone, conglomerate and tuff. They were strongly compressed, in many places overturned, during periods of folding and faulting of Permo-Pennsylvanian age. Syenitic and peridotitic masses and a variety of dikes were intruded into the Paleozoic rocks in the earlier part of Upper Cretaceous time. The Athens Plateau is a dissected piedmont along the southern margin of the mountainous area. Lower Cretaceous sediments, with a low south dip, cover the southern part of the piedmont.

The sediments of the Gulf Coastal Plain are chiefly gravel, sand, clay and marl, with chalk, gypsum, tuff and organic limestone well developed in some areas. They dip southward about 100 feet per mile, but local structures are present. Cretaceous, Tertiary and Quaternary units are exposed in the province, but only Lower Cretaceous and lower Tertiary formations are exposed over appreciable areas within the barite region.

Stratigraphy

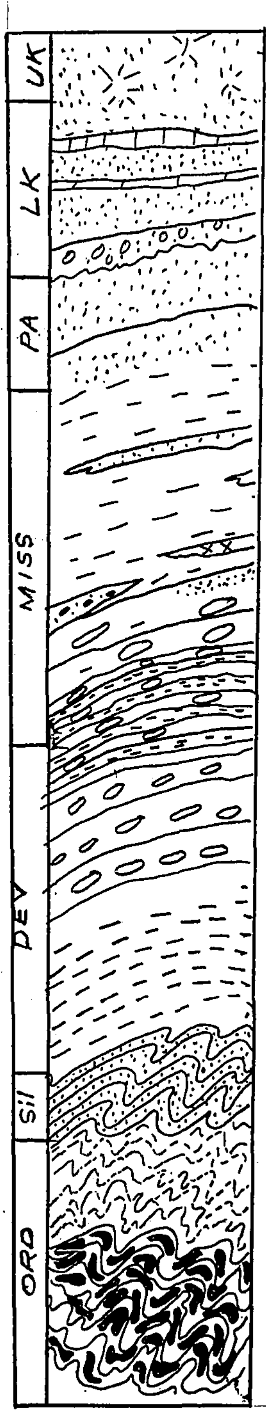
General Discussion

The barite of this region is associated with four stratigraphic units: the Middle Arkansas novaculite, the Stanley shale, the Pike gravel and the lower Trinity sandstones. In order to maintain structural control for these units it was necessary to map units ranging in age from Middle Ordovician (Bigfork chert) to Upper Trinity (De Queen limestone). Rather complete descriptions of the sedimentary rocks of the Ouachita Mountains and the northern part of the Gulf Coastal Plain are given by Miser and Purdue (1923, 1929). The following descriptions are, to a large extent, condensations from their publications, but are modified by more recent paleontological data and other information.

Paleozoic Rocks

Bigfork chert. The type locality of the Bigfork chert (Purdue, 1909, pp. 30-35) is the exposures of the formation in the vicinity of the Big Fork Post Office in the northwest corner of the Athens quadrangle. The formation is composed of chert interbedded with minor amounts of shale and limestone. The chert is brittle and intensely crumpled so that

Fig. 1-Stratigraphic Units
of the Arkansas Barite Region



Woodbine formation - tuffaceous sands and clays.

Trinity formation - Pike gravel member at base, overlain by loosely consolidated sandstones with Dierks and De Queen limestone lentils, some gypsum and celestite beds, maximum thickness 600 feet.

Jackfork sandstone - thick massive sandstone units separated by thinner and less extensive shale units, maximum thickness 6000 feet.

Stanley formation - gray-green weathering dark gray shale with thick siltstone and sandstone members, locally tuff beds near base, maximum thickness 6000 feet.

Upper Arkansas novaculite - tan to gray massive calcareous novaculite, locally quartzitic, maximum thickness 120 feet.

Middle Arkansas novaculite - thin bedded dark colored novaculite and shale, maximum thickness 450 feet.

Lower Arkansas novaculite - white to gray, dense, thick bedded novaculite, maximum thickness 450 feet.

Missouri Mountain shale - black, green and red fissile shale, maximum thickness 300 feet.

Blaylock sandstone - tan to gray fine to medium-grained, thin to medium bedded quartzitic sandstone, intercalated gray to black graptolitic shale, maximum thickness 1500 feet.

Polk Creek shale - Contorted and crumpled black graptolitic shale, maximum thickness 300 feet.

Bigfork chert - Gray to black medium bedded chert, thin black graptolitic shale partings, strongly crumpled, maximum thickness 800 feet.

the true thickness could not be measured. It is black on fresh surface and weathers to various shades of gray. In some places the chert weathers so as to resemble a gray porous sandstone of which hand samples, in isolated exposures, cannot readily be separated from some of the younger sandstones in the region. Along some stream banks and in road cuts the Bigfork chert can be seen to be composed of even-bedded layers of which most are 3 to 6 inches thick, but beds ranging up to 3 feet in thickness are not uncommon. The chert is highly jointed in all exposures examined. Black siliceous and carbonaceous shale layers ranging from paper thin to several feet thick are unevenly distributed through the formation. Because of the closely spaced joints and the shale interbeds, the chert layers have little rigidity and tend to disintegrate into knobs made up of accumulations of small blocks. The Bigfork conformably overlies the Womble shale and grades upward with a diminishing amount of chert into the Polk Creek shale.

Ulrich, as cited by Miser and Purdue (1929, pp. 38-39), classified the Bigfork chert as Middle Ordovician, probably Trenton, in age on the basis of graptolites found in the formation. Decker (1952, pp. 1-145) more definitely established a Trenton age for the formation by correlating the graptolite fauna with that of the Athens shale.

Polk Creek shale. The Polk Creek shale (Purdue, 1909, pp. 30, 36) was named for Polk Creek in the Athens Quadrangle.

It is typically developed along the headwaters of the creek in the Missouri Mountains. The Polk Creek shale, like the underlying Bigfork chert, is so crumpled that the true thickness could not be established. It ranges from a few inches to a maximum of 300 feet in thickness. Where the formation is less than 50 feet thick some evidence of truncation can be found. The shale is black, fissile and carbonaceous; in places, hard, slaty and siliceous; in places, soft and graphitic enough to soil the fingers. In most exposures examined where the cleavage is parallel to bedding planes, the cleavage surfaces are marked by abundant graptolite remains or impressions. Small pyrite crystals are common in fresh exposures of the slaty portions of the formation. Most of the exposures of the formation are composed of weathered gray platy cleavage fragments. Where the shale has weathered to clay the position of the unit was mapped as the topographic low between the Bigfork chert and the Blaylock sandstone. Although the Polk Creek appears to change gradually downward into the Bigfork chert, the graptolitic suites of the two formations indicate a depositional hiatus between their respective periods of accumulation. Because portions of the Bigfork are less cherty toward the top of the formation, the lithologic separation of the two formations is not accurate as mapped in all cases.

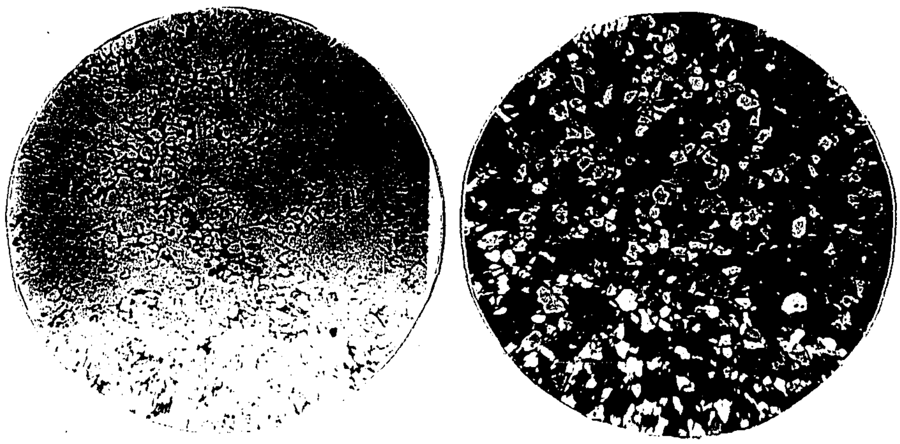
The Polk Creek shale appears to be conformable with the overlying Blaylock sandstone in most exposures. However, as noted by Miser and Purdue (1929, p. 44), in a few places a conglomerate is present at the base of the Blaylock. The Blaylock and Polk Creek were truncated by erosion prior to the deposition of the Missouri Mountain shale.

Decker (1935, pp. 698-700) classified the Polk Creek as Richmond (uppermost Ordovician) on the basis of the graptolites found in the formation.

Blaylock sandstone. The Blaylock sandstone (Purdue, 1909, pp. 30, 36) was named for Blaylock Mountain on the Little Missouri River in the Athens quadrangle. The sandstone, like the underlying units, is so thoroughly crumpled that the true thickness cannot be ascertained. Miser and Purdue (1929, p. 43) estimate the maximum thickness to be on the order of 1500 feet. The formation is thickest to the south and thins rapidly northward. Exposures of Blaylock have not been found north of the Missouri Mountains. A section of the formation exposed on the north side of the Cossatot Mountains in the S 1/2 sec. 29, T. 4 S., R. 26 W., has enough continuity to be measured, although the top and bottom of the section are obscure because of structural features. The formation here is over 600 feet thick; however, less than three miles to the north it is absent (see measured section below).

Sandstone is the chief rock type of the formation, but in some places shale is predominant. The more shaly portions may have been mapped as Missouri Mountain shale in some

PLATE XIX



(A) (B)

(A) Photomicrograph of Blaylock sandstone showing interlocking of grains to give quartzitic nature, nose of anticline north of Chamberlin Creek syncline, sec. 21, T. 3 S., R. 17 W. Plane polarized light; X 13; section 24.

(B) Same view with nicols crossed.

TABLE 2.-Section of the Blaylock sandstone on the north flank of the Cossatot Mountains, S 1/2 of section 29, T. 4 S., R. 26 W.

Lithological Description	Thickness in Feet of Unit	Thickness in Feet To Base of Formation
Faulted zone, Stanley formation in contact with Blaylock sandstone.		
Concealed, mixed sandstone and novaculite float.	87	
Sandstone, tan to gray, fine to medium-grained, medium bedded, highly jointed.	12	607
Shale, gray, micaceous and sandy.	13	595
Sandstone, gray, fine-grained, thin bedded, and intercalated gray shale.	18	582
Sandstone, gray, tan weathering, fine-grained, abundant quartz-lined joint faces.	13	564
Concealed.	18	551
Sandstone, brown, medium-grained, massive, some cross bedding.	8	533
Crumpled zone, thin bedded tan sandstone and dark gray shale, thickness 40 to 150 feet.	50?	525
Sandstone, gray, brown weathering, medium-grained, thin to medium bedded, highly jointed.	6	475
Concealed, stream fill.	18	469
Sandstone, tan to brown, fine to medium-grained, quartz-lined joint faces, quartz crystals abundant in float, thin to medium bedded, some paper thin shale partings.	17	451
Shale, light gray, micaceous, blocky.	5	434
Sandstone, tan to brown, medium to coarse-grained, massive.	3	429
Sandstone, gray, fine-grained; shale, gray, sandy; and shale, dark gray, in thin lenticular beds.	23	426
Sandstone, gray, tan weathering, fine-grained, medium bedded, highly jointed, abundant quartz seams and crystals.	19	403
Concealed.	6	384
Shale, gray, sandy, micaceous, unevenly distributed clay pellets.	9	378
Concealed.	16	369
Shale, black, micaceous, fissile.	18	353

TABLE 2-Continued

Lithological Description	Thickness in Feet of Unit	To Base of Formation
Sandstone, tan, medium-grained, medium bedded, scattered coarse quartz grains.	13	335
Sandstone, gray-green, fine-grained, thin bedded, dark gray shale partings.	28	322
Sandstone, dark brown, fine to medium-grained, medium bedded, some cross bedding, highly jointed.	7	294
Concealed, isolated patches of black fissile shale and thin bedded sandstone.	48	287
Sandstone, light gray, medium-grained, massive.	4	239
Crumpled zone, thin bedded tan to gray sandstone and gray to dark gray shale, thickness 30 to 200 feet.	50?	235
Sandstone, gray, tan weathering, fine-grained, medium bedded, abundant clay pellets 2 to 6 feet above base.	34	185
Shale, gray, finely micaceous, light gray siltstone stringers.	21	151
Overturned and faulted, 5 to 30 feet of section covered.	10?	130
Sandstone, tan, fine-grained, massive, some small quartz pebbles, some cross bedding.	14	120
Sandstone, dark gray to brown, fine-grained, thin bedded, highly jointed, quartz seams along joint faces, some shale partings.	10	106
Concealed, stream fill.	11	96
Sandstone, brown, fine-grained, massive, minor cross bedding.	9	85
Sandstone, gray, tan weathering, fine-grained, highly jointed, abundant quartz seams, some shale lenses.	18	76
Shale, dark gray, sandy, brown fine-grained sandstone and siltstone streaks and lenses.	27	58
Sandstone, tan to brown, fine to medium-grained, medium bedded.	6	31
Shale, dark gray, micaceous, silty.	2	25

TABLE 2-Continued

Lithological Description	Thickness in Feet: of Unit	Thickness in Feet: To Base of Formation
Sandstone, tan to brown, fine-grained, medium bedded, jointed, paper thin shale partings.	23	23
Concealed.	86	
South limb of anticlinal structure, Blaylock highly contorted where exposed.		
Total section measured		717

localities. The sandstone is mostly fine-grained, tan to gray, locally gray-green, and in even bedded layers of which most are 1 to 6 inches thick, but some range up to three feet or more in thickness. Much of the sandstone is hard, quartzitic and closely jointed. Some is soft and laminated. Tan to brown weathered blocky joint fragments mark the surface trace of the formation in most of the region. The joints, most with thin quartz vein coatings on the edges, are of considerable help in distinguishing between the Blaylock and some of the more quartzitic sandstones of the Stanley formation. In a few places the sandstone contains flattened clay pellets which may mark a horizon within the formation, but this could not be proved because of the crumpled condition of the layers. Examinations of thin sections from widely separated areas within the region indicated that the Blaylock sandstone units are rather uniform in composition. Fine-grained, angular, interlocking quartz grains make up 80-85 percent of the rock, with clay minerals the next most abundant. Minor amounts of mica and chlorite are present in each section and all have some plagioclase, orthoclase, zircon, tourmaline, garnet, pyrite, limonite and leucoxene.

The Blaylock was deposited essentially parallel with the bedding of the underlying Polk Creek shale, but the presence of conglomerate locally suggests some degree of unconformity. The Blaylock and Polk Creek formations were considerably eroded before the overlying Missouri Mountain shale was deposited. The maximum amount of material removed during this period of erosion was about 1700 feet. There is conglomerate at the base of the Missouri Mountain in some places, but in most of the region the exposures are such that the stratigraphic relations could not be established.

Ulrich, as reported by Miser and Purdue (1929, p. 45), placed the Blaylock in the Lower Silurian on the basis of the graptolite fauna. Decker (1936, p. 309) correlated the formation with the lower Middle Silurian of England.

The period of deformation and erosion that followed the deposition of the Blaylock sandstone was of considerable importance in the geologic history of the Ouachita Mountain region. The Blaylock and older formations are strongly crumpled and closely jointed. Quartz and calcite veins are more common than in the younger strata. However, the degree of metamorphism, which is slight, is not much greater than it is in the younger formations. The jointing, cleavage and crumpling patterns were probably only moderately developed during this period of deformation and became strongly developed in succeeding and more intense orogenic periods.

Missouri Mountain shale. The Missouri Mountain formation (Purdue, 1909, p. 37) was named for the Missouri Mountains in the Athens quadrangle. In most of the areas mapped during this study, the position of this unit was marked by the topographic low between a high ridge of

Arkansas novaculite and a low ridge of Blaylock sandstone. Novaculite scree is the surface cover in most of these areas. The formation is commonly referred to as slate, but the bulk of it probably should be classed as argillite. Miser and Purdue (1929, p. 46) give a range in thickness from 50 to 300 feet and state that sandstone, quartzite and conglomerate are present near the base and near the top of the formation in some localities. Petrographic studies could only affirm the excellent descriptions of Dale (1914, pp. 63, 64).

The formation, where observed in contact with Blaylock sandstone, appears to be conformable, but the conglomerate at the base and the overlap of the Blaylock and Polk Creek indicate the presence of an unconformity. In all exposures where the contact of the Missouri Mountain formation with the Arkansas novaculite could be studied, the strata were conformable. In some areas the formations appear to have a gradational contact. The massive beds of novaculite are underlain by inter-bedded shale and thin layers of novaculite. Megascopically, and, as far as could be determined microscopically, the shale is not different in any respect from the gray and black or red shale in the upper part of the Missouri Mountain. In other areas, notably in the vicinity of Hot Springs, Arkansas, and in southeastern Oklahoma, a conglomerate separates the two formations.

Miser and Purdue (1929, pp. 48, 49) in discussing the age of the Missouri Mountain formation, state:

No fossils have been found in the Missouri Mountain slate. Its correlation is therefore based upon its stratigraphic position and lithologic character. The position of the slate between the Blaylock sandstone, of early Silurian age, and the Arkansas novaculite, the lower part of which is Onondaga (middle Devonian) age, indicates that this slate is Silurian or Devonian. The nearest exposures of Silurian and Devonian rocks outside the Ouachita Mountains are in the Ozark region in northern Arkansas and northeastern Oklahoma, in the Arbuckle Mountains in southern Oklahoma, and on the southwest flank of the Nashville dome in Tennessee. The rocks of these systems are poorly represented in the Ozark region and Arbuckle Mountains, and no part of them resemble in lithology the Missouri Mountain slate. They are, however, well developed on the southwestern flank of the Nashville dome, where strata of Silurian age are succeeded by strata of Helderberg, Oriskany, Onondaga and later age, in the order named. Although the Silurian rocks of Tennessee consist mainly of limestone, they contain considerable thicknesses of earthy and shaly limestone, which, in the basal part of the strata of Niagara age, changes in color from gray to red as the Mississippi embayment is approached. The rocks of Devonian age earlier than the Onondaga in Tennessee contain no beds with a red color. It seems reasonable, therefore, to assume that the Missouri Mountain slate is equivalent to at least a part of the Silurian rocks in Tennessee.

From a different line of reasoning, the writer would prefer to place the Missouri Mountain formation in the Helderberg (lower Devonian). In most exposures where the contact of the Missouri Mountain shale and the Lower Arkansas novaculite can be studied, the formations appear to be gradational. The Lower Arkansas novaculite contains no diagnostic fossils, but nearly all who have studied the formation place it in the Onondaga of the Devonian on a lithic and stratigraphic basis. The pre-Mississippian rocks in the Arbuckle Mountain region of Oklahoma are predominately carbonate, although thick sandstone and shale members are present. As shown by Decker (1935A, 1935B) and others, many of the zones in the Arbuckle Mountains can be directly correlated on the basis of paleontologic data with more siliceous zones in the Ouachita Mountains. The Haragan marl (Helderberg) of the Arbuckle region changing eastward by loss of carbonate into the Missouri Mountain shale is a less pronounced change than Woodford shale to novaculite or Viola limestone to Bigfork chert.

If the Missouri Mountain formation is more closely related to units in western Tennessee than those in the Arbuckle Mountains, the Olive Hill formation of Helderberg age is the most likely equivalent. The Olive Hill formation consists of clastic and carbonate members and contains zones of oolitic hematite which could be related to the source of the red iron oxide coloring much of the Missouri Mountain.

Arkansas novaculite. The Arkansas novaculite (1909, pp. 30, 45, 46) consists chiefly of an extremely fine-grained siliceous rock which is similar to or a variety of chert. According to Griswold (1892, p. 20), Henry Schoolcraft in 1819 first applied the term novaculite to this rock. The formation contains appreciable amounts of shale, sandstone, and conglomerate. Nearly all the sandstone is quartzitic.

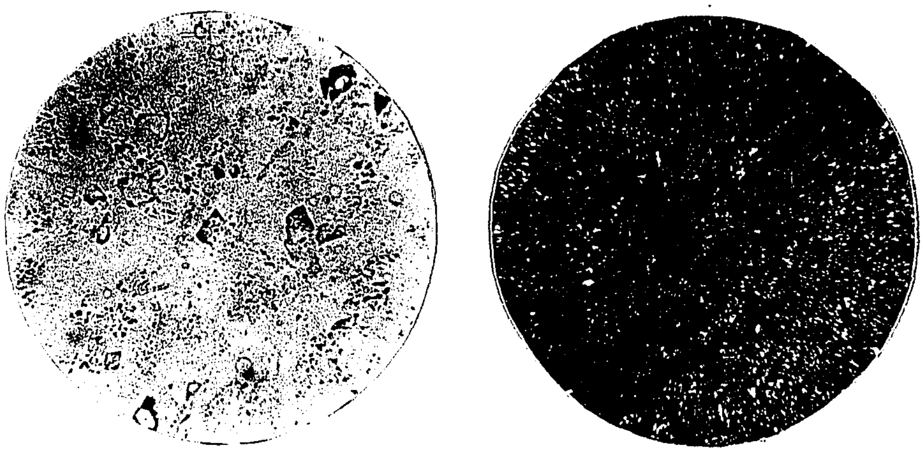
No type locality has been designated for the formation. The exposures at Caddo Gap along the Caddo River and Arkansas State Highway 27 are probably the most suitable to serve as examples of typical development of the formation. The formation is thicker in other places, but the exposures are not as good. Miser and Purdue (1929, pp. 54, 55) present a detailed measured section of the formation at this locality, and Hass (1951) made a comprehensive study of the conodonts found in the formation at this locality.

At Caddo Gap and many other places in the Ouachita Mountains, the formation is readily separated into three members, the characteristics of which are remarkably consistent throughout the region. The formation ranges in thickness from 250 to over 950 feet.

The lower division is made up almost entirely of massive white novaculite, the middle division consists of thin-bedded dark shale and novaculite, and the upper division is mostly massive, calcareous, light-colored novaculite. Each division differs from the others in color and character locally, but when more than one unit is exposed they can be separated readily.

Lower division. In most exposures in the region, the lower division ranges in thickness from 150 to 350 feet, but reaches a minimum of 10 feet in the northwestern part of the Caddo Mountains and a maximum of 450 feet in the Zig Zag Mountains. The upper portion of this unit consists of massive even-bedded layers of white novaculite which are 2 to 10 feet thick. Lentils of shale, sandstone, and breccia are present locally. However, these lithologies make up less than one percent of this part of the formation. In the lower

PLATE XX



(A) (B)

(A) Photomicrograph showing rhomboid cavities lined with limonite (black) formed by leaching of carbonate crystals, lower upper novaculite, south limb of Chamberlin Creek syncline, Magnet Cove district. Plane polarized light; X 46; section 6.

(B) Same view with nicols crossed to show texture of novaculite.

TABLE 3.-Section of the Arkansas novaculite through water gap, Reyburn Creek, SE 1/2 of section 13, T. 3 S., R. 17 W.

Formational Description	Thickness in Feet: of Unit	Thickness in Feet: To Base of Formation
Stanley shale--		
Shale, gray, blocky micaceous.	6	44
Shale, dark gray, platy, silt streaks.	13	38
Concealed, novaculite float and soil.	25	25
Upper novaculite--		
Novaculite, white, medium bedded, blocky fractures.	6	818
Novaculite, gray, thin bedded, with dark gray shale partings, poor exposures.	18	812
Novaculite, white to gray with black streaks, massive, breaks into blocks 3' to 8' in diameter.	42	794
Novaculite, dark gray and shale, dark gray to black, in thin beds (1/2" to 4"), some slickensides.	9	752
Novaculite, gray to buff, massive, breaks into small triangular blocks.	26	743
Middle novaculite--		
Novaculite scree, white, yellow, red and gray.	45	717
Novaculite, light gray, chalcedonic, bedding or pseudo-bedding 1/8" to 1/4" in 2' to 4' units separated by 6" to 18" units of intercalated black shale and dark gray novaculite. Surface is mostly covered with rectangular blocks.	75	672
Novaculite scree, mostly light gray chalcedonic, conchoidal fracture predominate.	28	597
Novaculite, black, dense, 2" to 12" layers with intercalated shale, black, siliceous, platy. Section intensely jointed, surface mostly covered with 2" to 4" rectangular chips.	110	569
Concealed.	12	459
Lower novaculite--		
Novaculite, white, massive, blocky joints, some slickensides.	80	447

TABLE 3.-Continued

Formational Description	Thickness in Feet of Unit	Thickness in Feet To Base of Formation
Lower novaculite-- Continued		
Novaculite, white, dense, medium to thick bedded, some laminated translucent sections.	115	367
Concealed.	32	252
Novaculite, white to light gray, dense, medium bedded, intensely jointed; novaculite breccia float zone probably occurs near the top of this unit; it was not found in place and may come from the overlying concealed zone.	185	220
Novaculite, black, dense, thin to medium bedded, some intercalated shale, black, siliceous, platy.	35	35
Missouri Mountain shale--		
Shale, black, green to red weathering, fissile to slaty; black novaculite stringers near top.	62	62
Blaylock sandstone--		
Sandstone, gray to brown, mostly tan, quartzitic, F to FM, gray shale partings, quartz veins abundant, breaks into characteristic rectangular blocks.	18	18
Concealed.		
Total section measured		923

portion of this division the novaculite beds are, in general, thinner than those of the upper portion. The lower units, in many places, are dark colored with black in predominance, but reds, yellows, and grays are well represented. Shale members up to 15 feet in thickness are also present in this portion of the section.

The most recent discussion of the age of the lower division of the Arkansas novaculite was given by Hass (1951, p. 2534).

> Only one fossil has been reported from the lower division of the Arkansas novaculite. This fossil, as previously stated, is the fragmentary brachiopod that Honess (1923, p. 117, text figure 4-2) discovered near the top of the lower division in southeastern Oklahoma on Boggs Springs Mountain in section 5, T. 3 S., R. 27 E. This specimen is now in the collection of the U. S. National Museum where it bears the catalog number 92762. Honess (1923, p. 117) submitted his fossil to Schuchert who identified it as Leptocoelia flabellites and this determination has been accepted by some stratigraphers as establishing a Devonian age in the lower division of the novaculite. However, G. A. Cooper who recently examined Honess' specimen is of the opinion (Oral Communication, May, 1950) that Schuchert's identification was not justified because the fossil is very poorly preserved. On lithological grounds the lower division of the Arkansas novaculite has been correlated with the Pine Top chert, Ulrich (1927, p. 33), Miser (1934, p. 974), Miser (1944, pp. 134, 135), the Penters chert, Miser, (1944, pp. 132, 134), Kenny (1946, pp. 611, 612), and the Camden chert, Miser (1917, p. 71), Purdue and Miser (1923, p. 5), Miser and Purdue (1929, p. 59), and Kenny (1946, p. 611). All these formations are classified by the U. S. Geological Survey as Lower or Middle Devonian.

Middle division. The middle division of the formation ranges in thickness from about 10 feet to 450 feet. It is composed of thin-bedded, dark novaculite, ordinarily in beds 1 to 6 inches thick and black to dark gray, fissile to slaty shale in beds ranging in thickness from a fraction of an inch to over 75 feet. In a few places the shale is red. In many places beds of conglomerate from 1 inch to 2 feet thick occur in this portion of the novaculite. The matrix and most of the contained pebbles are composed of novaculite, although pebbles of quartzitic sandstone and siltstone are not rare.

Hass (1951, pp. 2535-37) after studying the conodont assemblage in the middle division of the Arkansas novaculite classified the uppermost part of this division as Mississippian (Kinderhook) in age, with the portion below this Kinderhook section being Upper Devonian. The lower 163 feet of this division at Caddo Gap did not yield conodonts, but on lithological grounds Hass considers them to be a stratigraphic continuation of the overlying members, and therefore, Upper Devonian in age.

Upper Division. The upper division is less extensive than the underlying divisions. Where it has not been removed by erosion it is 20 to 100 feet thick. It is light gray to black in color and because of a rather high carbonate content weathers to white or tan porous massive rock. In most exposures there are some layers of white chalcedonic novaculite, which, as seen in thin section, are less calcareous than the darker members. In the Zig Zag Mountains this division contains rather thick beds of quartzitic sandstone interbedded with white massive novaculite. The quartzitic nature of these sandstones is due to the interlocking of angular and irregular grains rather than to siliceous cement.

Hass (1951, p. 2540) on the basis of conodonts collected from this division of the novaculite in a road cut on U. S. Highway 71, 0.5 of a mile south of Hatton, Arkansas, places this division in uppermost Kinderhook or Osage of the Mississippian.

A large number of postulated origins of the Arkansas novaculite are presented in the literature. Branner (1888, pp. 368-371), Miser and Purdue (1929, pp. 55-57), and Harlton (1953, p. 778), review all these postulates and defend some of them. It is the writer's opinion that it would be virtually impossible for silica to replace hundreds of cubic miles of calcareous rock and not leave some evidence of the replacement; therefore, he considers the novaculite to be a primary siliceous deposit.

Stanley shale. The general character of the Stanley shale has been excellently described by Miser and Purdue (1929, pp. 59, 60), who state:

> The Stanley shale took its name from the village of Stanley (formerly spelled Standley), in Pushmataha County, Oklahoma. It consists mainly of shale, though it contains much sandstone and a little tuff and conglomerate. The thickest bed of tuff, which is near the base, has been mapped and is herein described as the Hatton tuff lentil, taking its name from the village of Hatton, in the De Queen quadrangle, where it is excellently exposed. In places shale at the base has been changed to a slate that was formerly called the "Fork Mountain slate," from Fork Mountain, where it is well developed. The Stanley belongs to the Carboniferous system, and represents a part of the Mississippian series. Except the tuff and the conglomerate none of the beds have distinguishable characteristics. On this

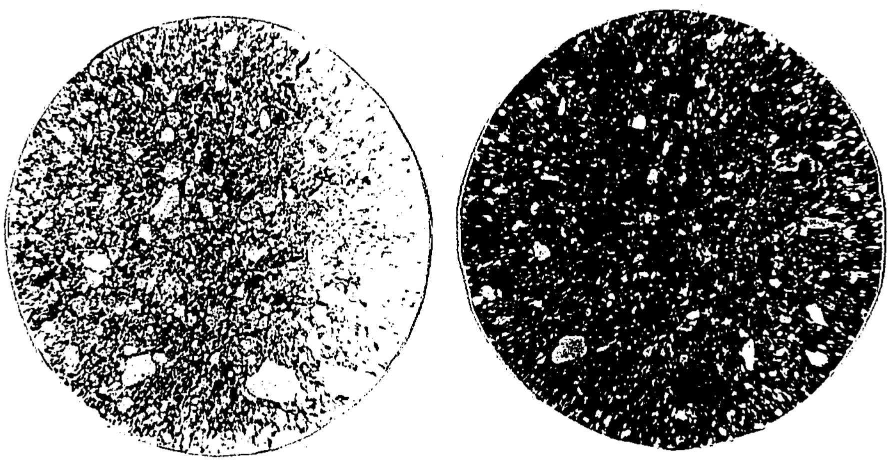
> account and because the formation is much folded, the exact determination of the thickness is impossible, but an approximate thickness of 6000 feet was measured from 1 to 2 miles southwest of Glenwood, in the Caddo Gap quadrangle. The Stanley shale is the surface rock in the Mazarn and Cove Basins, over most of the Athens Plateau, and in the narrow valleys in the mountainous districts--an area of outcrop much larger than that of any other formation. The sandstone of the Stanley weathers so easily that it nowhere produces prominent ridges. In fact, the formation is exposed only in valleys, basins, or low plateaus.

Only the lower 1500 feet of the Stanley was studied in the barite areas, and except where correlatable information was available only the lower 100 to 300 feet could be studied with any accuracy in relationship to thickness and lithological composition. In almost all of these areas the Stanley is predominantly shale, most of it silty, although there are thick sandstones and siltstones and some conglomerate present in the lower part of the formation. This shale, where fresh, is dark gray to black, ordinarily rather micaceous, in places fissile, in places blocky. The shale weathers to a yellowish green which is typical of the Stanley.

The sandstones are light to dark gray and mostly fine-grained, although medium-grained phases are present. Quartzitic, sandy siltstones are more common than sandstones. The sandstones and siltstones less than three feet in thickness ordinarily contain from 20 to 50 percent clay, chlorite, and micaceous minerals. The thicker sandstones and siltstones which range up to 65 feet ordinarily contain less than 10 percent clay, chlorite, and mica. In many places the siltstones and particularly the sandstones are weathered to a punky, porous rock. On the south side of Gap Mountain, sec. 19, T. 4 S., R. 25 W., a conglomerate lentil ranging up to 18 inches in thickness is present 15 feet above the top of the novaculite. It consists of a matrix of black chert and of pebbles of novaculite, slate, and quartzite that range from pea size up to an inch and one-half in diameter. This conglomerate overlies a silt-free clay shale and underlies a very silty shale.

Studies of thin sections show that there are three predominant types of shale in the lower part of the Stanley. These types grade into each other horizontally and vertically, and cannot be used for stratigraphic or structural control. The most abundant type, which makes up perhaps 60-65 percent of the Stanley shale, is a silty variety. It contains 30-40 percent silt-size particles of which about 95 percent are quartz, the rest being feldspar grains. Clay minerals make up 40-60 percent of this rock type, with mica and chlorite each making up 5-10 percent of the rock. Minor amounts of pyrite, magnetite and carbonate are present in all sections examined. Zircon, tourmaline, and rutile are the only consistent accessory minerals. The next most abundant type is called clay shale. It contains less than one percent silt-sized particles, less than 5 percent mica, and less than 5 percent chlorite. The bulk of the rock is made up of clay particles. Magnetite and pyrite are persistent accessory minerals. The third type is called carbonaceous shale. It

PLATE XXI



(A) (B)

(A) Photomicrograph of a sandy siltstone in the lower part of the Stanley formation in southern Montgomery County. Plane polarized light; X 13, section 144.

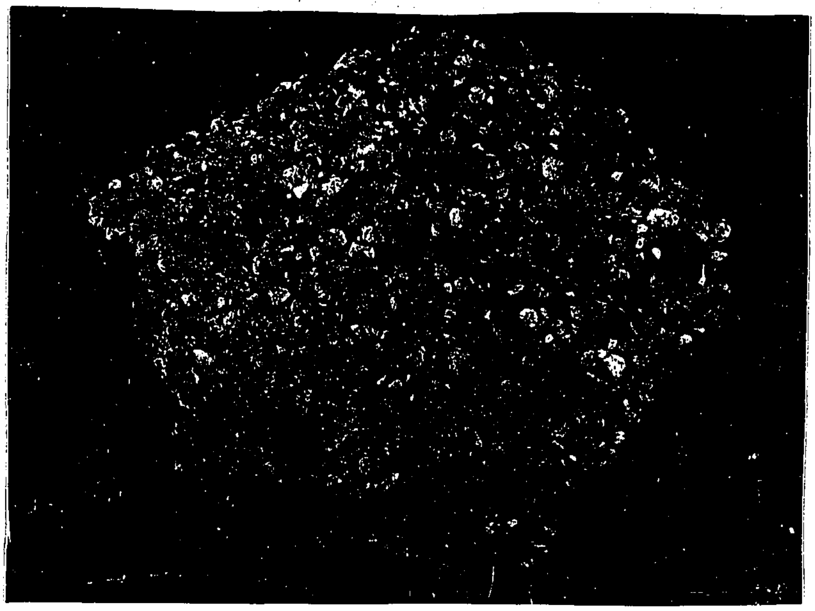
(B) Same view with nicols crossed.

is characterized by enough carbonaceous material to soil the fingers when crushed. It contains up to 15 percent silt-sized particles, less than 10 percent carbonaceous material, and some mica, chlorite, and carbonate. However, most of the minerals are masked by the black carbonaceous material and iron oxides.

Studies of thin sections of the siltstones and sandstones show that these rocks when composed of fine-grained material are characterized by angular to subangular fragments. When only small percentages of mica, chlorite, and clay are present these angular fragments, mostly quartz, are interlocking and give the rock a quartzitic nature. Siliceous cement is present in some of these rocks, but ordinarily clay is the binding material.

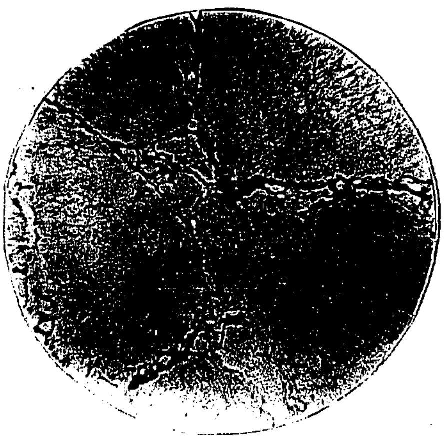
In the southern part of the Arkansas Paleozoic region the Stanley shale, as far as can be determined, conformably overlies the upper member of the Arkansas novaculite. To the north the Stanley was laid down on an erosion surface truncated as deeply as the Bigfork chert prior to the Stanley deposition. The Stanley rests on the Bigfork in the Mount Ida quadrangle, which is near the center of the Ouachita Mountains, and consequently the erosion interval represented by the stratigraphic gap is presumably associated, at least in part, with the post-Blaylock-pre-Missouri Mountain period of erosion.

PLATE XXII



(A)

(A) Photograph of pebbly Stanley sandstone from Mazarn Ridge in the Pigeon Roost District, Montgomery County.



(B)

(C)

(B) Photomicrograph to show the nature of the pebbles in the sandstone shown above. Plane polarized light; X 13, section 145.

(C) Same view as (B) with nicols crossed.

In the Hot Springs quadrangle (Purdue and Miser, 1923) the Stanley overlies the Hot Springs sandstone which is a lenticular unit resting on the novaculite. In this quadrangle much of the basal portion of this unit is conglomerate which is as much as 35 feet thick in places. The Hot Springs sandstone has not been traced east or west out of the Hot Springs quadrangle, and as conglomerate occurs beneath shale and above the novaculite in many other parts of the region, the Hot Springs sandstone is probably a facies of the basal part of the Stanley and should not be considered as a separate formation. The Stanley is conformably overlain by the Jackfork sandstone.

Hass (1950, pp. 1578-84) on the basis of conodonts collected from the Stanley shale at Caddo Gap on Highway 27, places the lower part of the Stanley shale in the Meramec (Mississippian).

Cretaceous Rocks

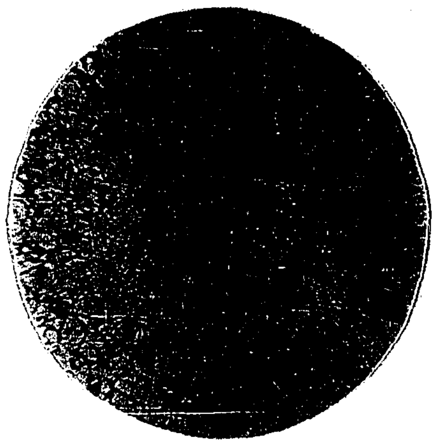
Trinity formation. The Trinity group (Hill, 1888, p. 21) was named for its extensive exposures around the headwaters of the Trinity River in Texas. From this area it crops out in an almost continuous belt northward into southern Oklahoma and eastward into southwestern Arkansas. Miser and Purdue (1929, p. 80), in describing the Trinity, state:

> It consists of clay, sand, gravel, limestone, gypsum, and celestite, the most abundant named first and the least abundant last. The limestone occurs in two beds, the Dierks limestone lentil, the older, near the base, and

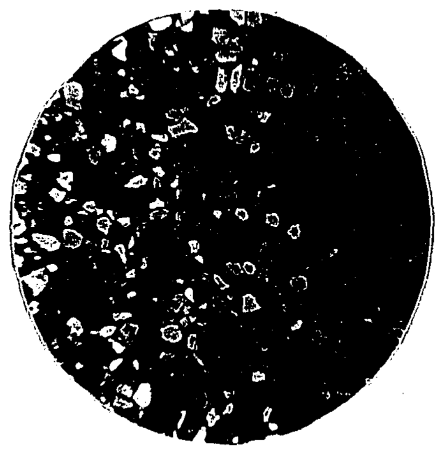
the De Queen limestone member, the younger, near the middle of the formation. The first was named from Dierks, in the De Queen quadrangle, near which it is exposed, and the second was named from De Queen, where it is exposed. The gravel also occurs as two beds, the Pike gravel member at the base, and the Ultima Thule gravel lentil, which is above the Dierks limestone. The Pike gravel was named from the village of Pike, in the Caddo Gap quadrangle, and the Ultima Thule gravel was named from the village of Ultima Thule, in the De Queen quadrangle. These four lentils and members and the interbedded sand and clay of the Trinity dip about 100 feet to the mile toward the south. Although the Trinity lies nearly horizontal, it rests upon the truncated upturned edges of steeply dipping shale and sandstone of Carboniferous age, which, however, form a floor that has only minor irregularities and undulations. A pronounced unconformity, therefore, occurs at the base of the Trinity. A notable though less striking unconformity exists at the top of the formation, as shown by the eastward truncation of its beds, and the resulting overlap of the Woodbine formation and the overlying Tokio formation, both of Upper Cretaceous age.

The Trinity examined for this report crops out in Tps. 7 and 8 S., Rs. 26 to 30 W., in an area roughly bounded on the east by the Muddy Fork River and on the west by the Cossatot River. Within this area the clastic parts of the group are quite variable in thickness, but the carbonates are consistent enough to serve as suitable mapping horizons. The Pike gravel within this area ranges in thickness from 20 to 120 feet and the sand overlying it ranges from 50 to 100 feet in thickness. The Dierks limestone ranges from a minimum of 10 feet in thickness to a maximum of 50 feet. On the average it is about 40 feet thick. Its base is 100 to 200 feet above the base of the Trinity throughout most of the area; however, in a few localities it overlaps Carboniferous sandstone which jutted out into the old Cretaceous sea as a rocky headland. Throughout most of the area the base of the

PLATE XXIII



(A)



(B)

(A) Photomicrograph to show porosity of un-cemented Trinity sandstone, south of Cherry deposit, Dierks District. Plane polarized light; X 13; section 116.

(B) Same view with nicols crossed.

De Queen limestone is about 150 feet above the top of the Dierks limestone. The intervening section consists of various sand and clay lentils and the Ultima Thule gravel. The De Queen limestone is about 70 feet thick and is of particular interest because near its base in certain areas are gypsiferous beds and in a few localities celestite lentils.

As a whole the clastics of the Trinity are bound by clay or are loosely consolidated. In some areas iron oxide cements the gravels and the sands forming a rather resistant rock which stands up as low ridges along the summits of low hills. In a few areas calcium carbonate serves as cementing material. In some localities near Dierks, barite cements the lower sand and the Pike gravel of the Trinity.

Both the Dierks and the De Queen limestones contain brackish water and marine molluscan elements. T. W. Stanton, as reported by Miser and Purdue (1929, p. 85), stated that they occur in the Trinity group of Texas and show a definite relationship to those of the Glenrose limestone of that state.

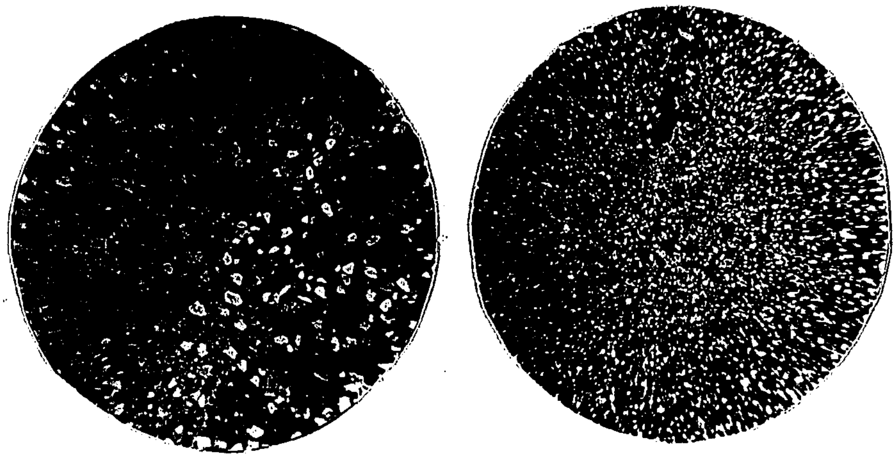
Woodbine formation. The Woodbine formation (1901, p. 293) was named for exposures at Woodbine, Cook County, Texas. At the type locality and northward in Texas and in parts of southern Oklahoma, the formation is predominantly sand, but eastward in southeastern Oklahoma and southwestern Arkansas tuffaceous material make up a large part of the formation. Woodbine is the basal unit of the Upper Cretaceous in the area studied and unconformably overlies the

Lower Cretaceous Trinity. A rather complete description of the formation is given by Miser and Purdue (1929, pp. 86-90). Although the Woodbine crops out south of the known barite deposits of the region discussed in this report, it is of considerable importance because its volcanic component is one of the factors used in determining the age of the barite mineralization.

Igneous rocks. Igneous rocks occupy only a small area in the Arkansas barite region; however, these rocks form one of the most interesting suites of igneous rocks in the world. They have an unusual chemical and mineralogical composition and contain well formed mineral crystals, many rare, that for the last 150 years have been sought by collectors.

Intrusive igneous masses crop out in five well-defined areas in southwestern Arkansas: the Pulaski County region immediately south of Little Rock; the Saline County region a few miles east of Benton; the Magnet Cove region in Hot Spring County a few miles west of Malvern; the Potash Sulphur Spring region in Garland County, a few miles east of the town of Hot Springs; and the Pike County area southeast of Murfreesboro. In the first four areas, the rocks are predominantly syenitic and mafic varieties, although the rock types in each area are somewhat distinctive from those in other areas. The syenites in Pulaski and Saline Counties are the parent rock from which the Arkansas bauxite deposits were derived. In the Murfreesboro area the igneous rocks are

PLATE XXIV



(A) (B)

(A) Photomicrograph of barite cemented Trinity sandstone, Northwest 16 deposit, Dierks district. Crossed nicols; X 13; section 112.

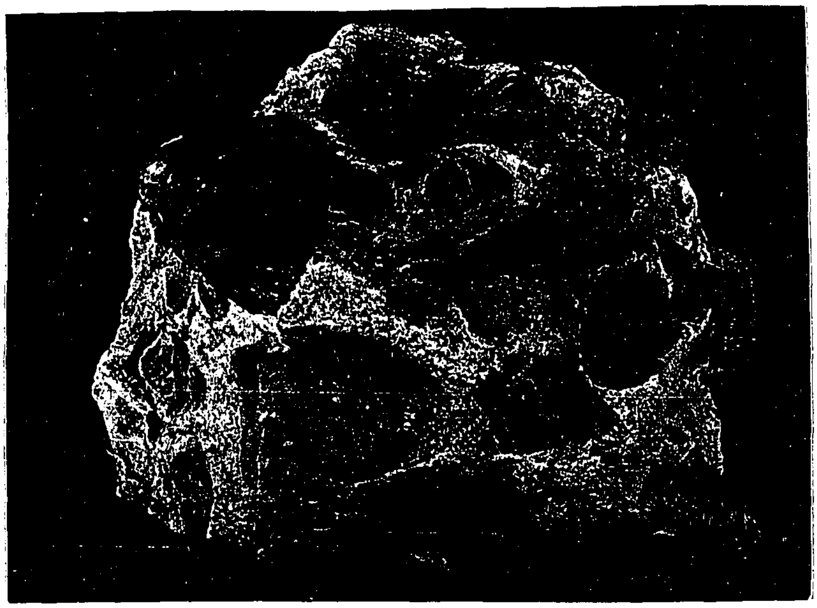
(B) Photomicrograph of saccharoidal gypsum, De Queen limestone member of Trinity formation, north of Martha Post Office, Dierks district. Crossed nicols; X 13; section 134.

peridotitic plugs which are particularly noted for the diamonds they contain. Outside of these five typical areas there are numerous dikes which as far as their petrographic character is concerned could be associated with any or all of the plutonics. The rocks in the syenitic areas and the dikes undoubtedly have a common source. It cannot be definitely demonstrated whether they are related to the plugs at Murfreesboro. As all of these rocks are Cretaceous in age, it is probable that they are genetically related.

In the subsurface of southern Arkansas, northern Louisiana, and eastern Texas, wells drilled by the petroleum industry have encountered igneous rocks that can be demonstrated in many cases to be of Cretaceous age. In Texas, at least as far southwest from Murfreesboro as Austin, igneous rocks are exposed at places at the surface. Mineralogically, and chemically, these rocks in Texas appear to be genetically related to the syenites of Arkansas. The writer believes that all the surface and subsurface igneous rocks of Cretaceous age in Arkansas represent one period of igneous activity. The rocks are all of a silica-deficient variety (Moody, 1949; Williams, 1891), are characterized by a rather high titanium content, and nearly all contain more carbonate than the average igneous rock.

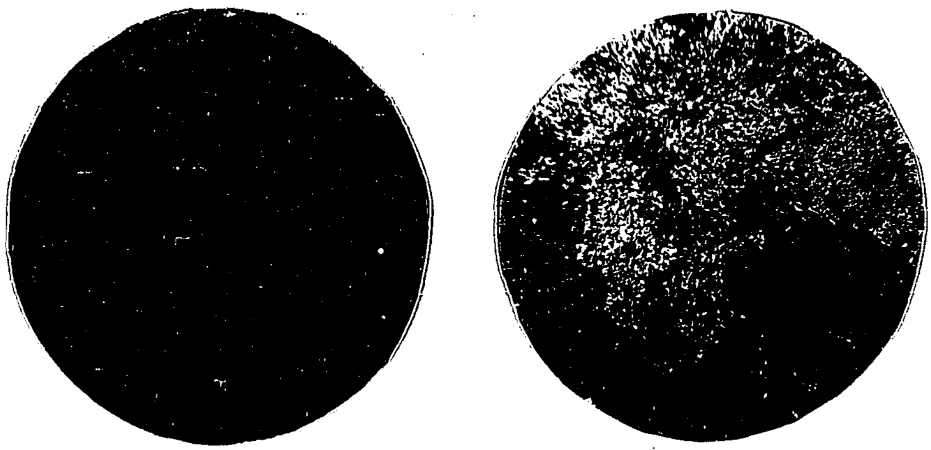
For more detailed information on the igneous rocks of Arkansas the reader should consult Williams (1891) for references to those rocks cropping out at the surface; Miser and

PLATE XXV



Photograph of calcite cemented Pike gravel, Dierks district, natural size. (Photographer, Harry Smith, Jr.)

PLATE XXVI



(A) (B)

(A) Photomicrograph of a part of a Carlsbad twin of orthoclase in the Diamond Joe type syenite, south rim of Magnet Cove. Plane polarized light; X 13; section 26.

(B) Same view with nicols crossed to show alteration of feldspar to zeolites and carbonate.

Ross (1923) who have described the peridotite of Pike County; and Moody (1949), who has described many of the igneous rocks encountered in the subsurface in this area.

Regional Structure

General Statement

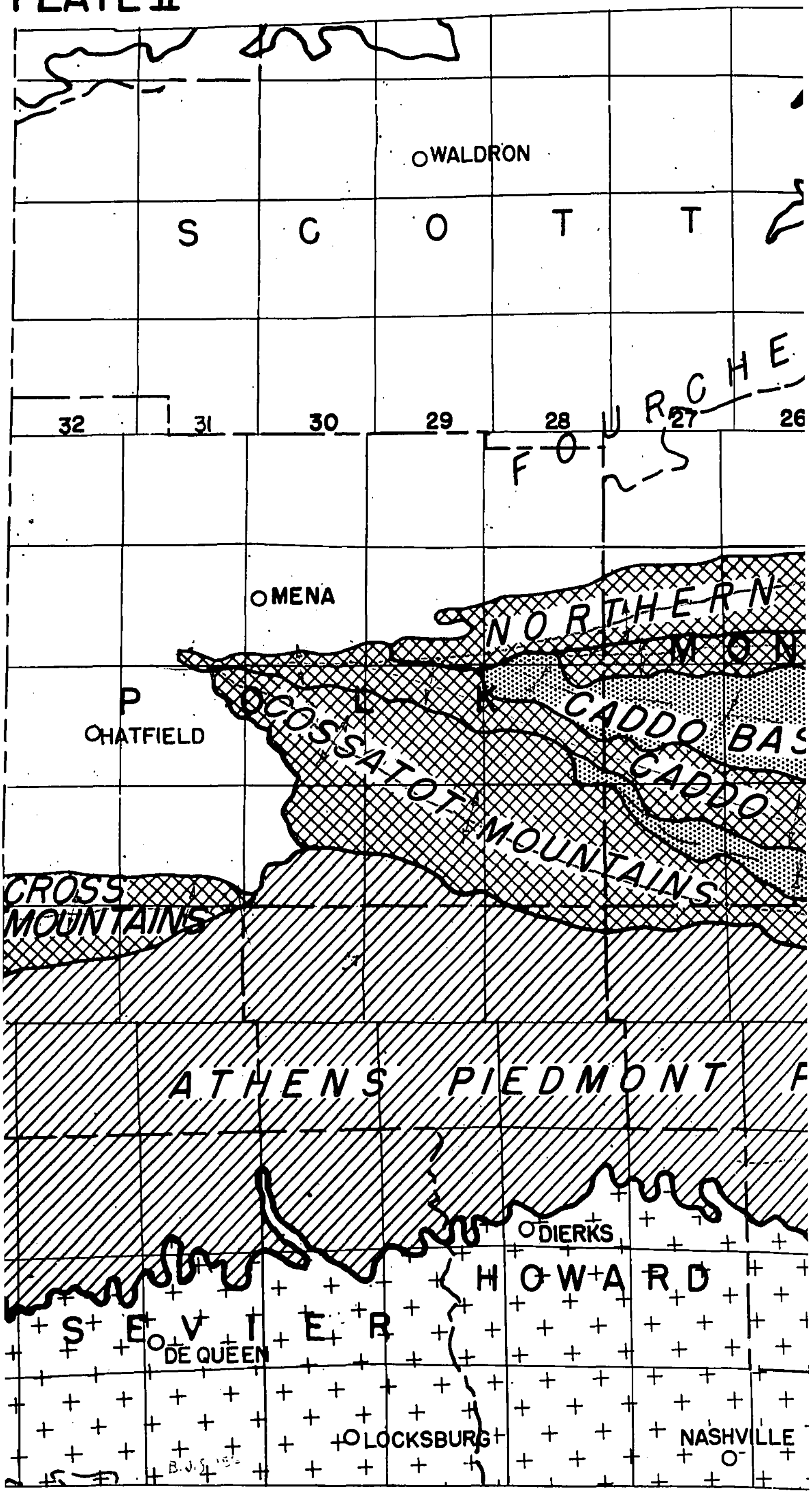
The region under consideration comprises elements of the Ouachita Mountains and the Gulf Coastal Plain. The barite region is arbitrarily defined and contains the southern part of the Ouachita Mountain system and the northernmost part of the Gulf Coastal Plain.

Ouachita Mountains

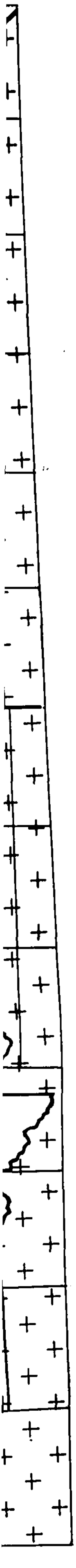
General discussion. The structural configuration of the Ouachita Mountain system has been described by Griswold (1892), Purdue (1909), Purdue and Miser (1923), Honess (1923), Miser and Purdue (1929), Croneis (1930), and van der Gracht (1931). In all these reports the structural pattern of the Ouachita Mountain system is described only in a general manner because the details of the structure of this region have not as yet been mapped.

The deformational history of the Ouachita Mountain system has been such that primary, secondary, and tertiary orders of folding can be recognized. The primary or central axis of the deformation has been variously called the Ouachita anticline, the Ouachita Mountain anticlinorium, and the Novaculite uplift. The writer prefers the term Ouachita

PLATE II



GENERALI



Mountain anticlinorium because of the geographic connotation and the implication of relationship to subsidiary structures. This axis of deformation extends from near Little Rock to the Arkansas-Oklahoma border where it plunges to the west, then rises again to form the Ouachita Uplift of the southeastern Oklahoma mountainous area. To the north and south of this main axis are various mountain ranges which in themselves are anticlinoria or synclinoria. These comprise the second order of folding. The individual synclines and anticlines in these mountainous areas are the tertiary order of folding.

The barite region of Arkansas as defined (Plate II) contains elements of the Crystal, Caddo, Cossatot, Cross, Zig Zag, and Trap Mountains, and portions of the Caddo, Cove, Mazarn, and Saline basins. The Athens Plateau is stratigraphically and structurally related to these other features.

Mountain systems. Cross Mountains. The Cross Mountains are an extension of an anticlinorium rising in McCurtain County, Oklahoma. The anticlinorium as a whole has a length of about 30 miles, of which the eastern 11 miles is in Arkansas. Its greatest width is about 4 miles in the Arkansas portion of the mountains. The Blaylock sandstone is the oldest formation exposed; however, in McCurtain County, Oklahoma, the Bigfork chert is exposed at the core of the mountains. These mountains are formed by anticlinal ridges which along much of their flanks are overturned to the south so that the beds dip to the north on both sides of the ridge.

The Athens Plateau forms the southern boundary of the Cross Mountains and the Cove Basin forms the north boundary.

Cossatot Mountains. The Cossatot anticlinorium extends north and west 45 miles from Glenwood in T. 5 S., R. 24 W. The greatest width of the anticlinorium is about 7 miles in the central part where the amount of uplift was the greatest. The axis of maximum uplift is just north of Pryor, Blaylock, Brushheap, and Raspberry Mountains. The Bigfork chert, the oldest strata exposed in this system, crops out in a belt along the axis. The belt of Bigfork exposure is about 14 miles long and a tenth to a half-mile in width. Although the rocks in the Cossatot anticlinorium are intensely folded (see Miser and Purdue, 1929, Pl. 6, p. 20, fig. 6, p. 122), their regional position is essentially as tightly folded wrinkles on the south flank or monocline of the Ouachita Mountain anticlinorium. There are several high-angle thrust faults within the Cossatot Mountains. They strike parallel to the ridges and therefore parallel to the anticlinal axes. The strike length of these faults ranges from 1 to 15 miles. The stratigraphic displacement along most of them can be measured in hundreds of feet. However, the physical displacement cannot be accurately ascertained as the formations within the mountain system are repeated numerous times because of the intense folding. Displacement along some of these faults may be measured in thousands of feet. The Cossatots are bounded on the south by the Athens Plateau and on the north by a westward extension of the Mazarn Basin. However, in their northwestern portion they abut against the folds of the Caddo Mountains.

Caddo Mountains. The Caddo Mountains trend a little south of east from T. 2 S., R. 31 W., to Caddo Gap, from where they trend northeastward to the Ouachita River in T. 2 S., R. 21 W. These mountains have a total length of 65 miles and range in width from 2 to 10 miles. West of the Caddo River they are aligned in parallel ridges. On the east side of the Caddo River they are en echelon or zig-zag arrangement. The Bigfork chert is the oldest formation exposed within these mountains, and the Stanley, which crops out in some of the closely folded synclines, is the youngest. The western one-fourth of the Caddo Mountains are structurally aligned along the westward plunging axis of the main Ouachita Uplift. The other parts of this range are anticlinoria on the south flank of the main uplift. The western end of the Caddo Mountains, like the Cossatots, is overturned in such a way that the overall picture of these structures is that of a fanfold. In the western part of the Caddo Mountains there are a great number of high-angle thrust faults, most of which are less than 2 miles in strike length. The fault at Caddo Gap is one of the most readily recognized faults in the area. All the ridges in this mountain range have cores of the resistant Arkansas novaculite. Most of the longer ridges have a simple anticlinal structure, although many are monoclinal or synclinal throughout their entire length or part of it. Many of the higher peaks are of a complex structure, with as many as five folds being present.

Crystal Mountains. There is considerable confusion in the literature concerning the Caddo Mountain and Crystal Mountain topographic units as related to their structural relationships (Griswold, 1892, pp. 196-200; Croneis, 1930, pp. 338-44; Miser and Purdue, 1929, pp. 118-22). The Crystal Mountains as a topographic unit extend from the northernmost part of T. 3 S., R. 27 W., slightly south of east to T. 3 S., R. 24 W. From there the trend is northeastward to the middle fork of the Saline River in T. 1 N., R. 18 W. Throughout this length the structure is a single anticlinorium whose axis coincides with the axis of the main Ouachita Mountain anticlinorium. The Caddo Mountains where they are separated from the Crystal Mountains by the Caddo Basin have a major axis and form a separate anticlinorium. At their western end, however, because erosion has not stripped back this portion of the younger sediments from the anticlinorial structure of the older sediments of the Crystal Mountains, the Caddo Mountain anticlinorium coincides in this area with the Crystal Mountain anticlinorium. This is the area where the Ouachita Mountain anticlinorium plunges to the west.

The sedimentary rocks exposed in the Crystal Mountains are all older than the Bigfork chert and are not involved in the barite problem. The Collier shale, the oldest known formation in the Ouachita Mountains, is succeeded in ascending order by the Crystal Mountain sandstone, Mazarn shale, Blakely sandstone, Womble shale. The Mazarn, Blakely, and Womble are Ordovician in age, and the Crystal Mountain and Collier are probably also Ordovician, although on the state geologic map the Collier is shown as Cambrian.

Zig Zag Mountains. The Zig Zag Mountains adjoin the Caddo Mountains near Mountain Pine in T. 2 S., R. 20 W. They extend eastward to the Gulf Coastal Plain in R. 16 W. The range is bounded on the north by the Saline Basin and on the south by the Mazarn Basin. The individual anticlines and synclines in this range trend northeastward almost at right angles to the general trend of the Ouachita Mountain anticlinorium. The Bigfork chert (Ordovician) is the chief formation exposed in the Saline Basin and the Stanley shale (Mississippian) is the chief formation exposed in the Mazarn Basin, indicating that the Zig Zags stand as transverse structures on the flank of the Ouachita anticlinorium. Tongues of Bigfork chert extend southwestward along the crests of the truncated anticlines, and tongues of Stanley shale extend northeastward in the synclinal structures. Most of the folds are isoclinal with axial plane vertical or overturned to the south. Some of the overturning reported in older papers is the result of slumping of nearly vertical massive beds of Arkansas novaculite and not wholly the result of structural deformation. The Zig Zags at their southeastern extremity may merge with the Trap Mountains on the south.

Trap Mountains. The Trap Mountains may have structurally, that is by thrust faulting, overridden the Zig Zag Mountains. The Trap Mountains at their eastern end, in Tps. 3 and 4 S., R. 17 W., are overlapped by the Tertiary sediments of the Gulf Coastal Plain. This mountain range extends 35 miles slightly south of west from the coastal plain to the northernmost part of T. 5 S., R. 22 W. The mountains consist of about 30 steeply folded, elongate, narrow anticlinal ridges, with narrow steep intervening synclinal valleys. Many of the folds are overturned to the north, but many others are fanfolds. In the northeastern portion of the range a few of the anticlines are broken by thrust faults. The amount of displacement is not known. In a few places small patches of Bigfork chert and Polk Creek shale crop out. The Blaylock sandstone and the Missouri Mountain shale are exposed in the more deeply eroded anticlines. Nearly all of the ridges are held up by the Arkansas novaculite; however, a few toward the western end are composed of resistant sandstones of the Stanley. The Trap Mountains are bordered on the north by the Mazarn Basin and on the south by the eastward extension of the Athens Plateau.

<u>Basins</u>. Cove Basin. Cove Basin, like the Cross Mountains, extends into Arkansas from the area of its maximum development in Oklahoma. The Cove Basin is bounded on the south by the Cross Mountains and on the northeast and east by

the Cossatot Mountains and Athens Plateau. Its narrowest portion, the southeast extension between the Cross and Cossatot Mountains, has a minimum width of 6 miles. Structurally, the basin is a synclinorium with low, narrow, steep-sided, eastward-trending ridges in which sandstones of the Stanley formation are the chief components. As there is no marker bed suitable as a mapping datum in this formation, detailed delineation of local structures is difficult. However, on the larger anticlines, erosion has been sufficiently deep to expose the tuffaceous beds that occur near the base of the formation. These tuff beds are excellent datum planes for mapping local structure.

Caddo Basin. The Caddo Basin lies between the Caddo Mountains on the south and the Crystal Mountains on the north-east and the Northern Mountains of the northwest flank of the Ouachita Mountain anticlinorium on the northwest. The rocks exposed in the Caddo Basin belong to the intensely crumpled Ordovician formation. The topography is more diverse and somewhat more rugged than in the surrounding areas where the long narrow ridges of novaculite control the erosion pattern. The Caddo Basin lies along the main axis of the Ouachita Mountain anticlinorium in its western portion, along the south flank in the eastern portion.

Saline Basin. The Saline Basin lies north of the Zig Zag Mountains. It is bordered on the north by the Northern Mountains on the north flank of the Ouachita Mountain uplift.

As in the Caddo Basin, the surface rocks belong to the Ordovician formations, and as in that basin they are highly crumpled. The main axis of deformation is the main axis of the Ouachita Mountain anticlinorium. The eastern end of the Saline Basin is overlapped by the Tertiary sediments of the Gulf Coastal Plain.

Mazarn Basin. The Mazarn Basin is a large synclinorium on the south flank of the Ouachita Mountain anticlinorium. It is bounded on the north by the Caddo and Zig Zag Mountains and on the south by the Cossatot and Trap Mountains. The basin is completely surrounded by novaculite ridges except on the south side where for about 7 miles the Stanley shale is the surface formation between the Cossatot and Trap Mountain systems. The length of the basin is about 60 miles and its greatest width is about 10 miles. The surface is marked by low parallel sandstone ridges and narrow valleys, most of which trend slightly north or south of east. Except for novaculite in Pigeon Roost, a prominent anticlinal mountain in T. 4 S., R. 23 W., and the alluvium of the stream valleys, the Stanley shale is the surface formation throughout the basin. The beds of Stanley are closely folded and ordinarily lack any distinguishing features which would make it possible to map structures. Locally, persistent quartzitic siltstones can be traced for several miles and recognized in adjoining folds. The major structural axis of the Mazarn synclinorium is of the same order, secondary, as the axes of the various mountain ranges. South of this axis, the axial planes of the tertiary folds are overturned to the north; north of it they are overturned toward the south.

Athens Plateau. Miser and Purdue (1929, pp. 123, 124), in discussing the Athens Plateau state:

> The general structure of the Athens Plateau is that of a southward-sloping monocline corrugated with many minor folds. These folds are nearly parallel and have a general south of west trend. Toward the west their trend and that of the Ouachita anticline diverge and they pass on both sides of the eastward-plunging Cross Mountains anticline. The most conspicuous and easily distinguishable folds are formed by the Jackfork sandstone and the Atoka formation. Although each of these formations is about 6000 feet thick, the beds stand at steep angles, having dips that commonly exceed 50°, and in some places they are overturned. The usual direction of the overturning is from the south.
>
> Although the Stanley shale, which is also exposed on this plateau, has a thickness of 6000 feet, it is folded many times and doubtless much faulted and overturned in its wide beds of outcrop, but the lack of distinctive beds, except the Hatton tuff lentil and the associated beds of tuff, makes the determination of the folds nearly impossible. Although the dips and strikes differ somewhat, most of the strikes have an eastward trend, and most of the dips are 40° or more.

These writers (p. 125) describe a cross fault in T. 6 S., Rs. 23 and 24 W., with a displacement, probably mostly horizontal, of several thousand feet. After the discovery of quicksilver in 1930, Branner (1932, p. 11), in discussing these deposits, named the Amity fault. During the 1930's there were a number of papers written concerning the quicksilver district of Arkansas. Most of these are summarized individually in Reed and Wells (1938, pp. 18-20). This mineralized belt extends along the strike of the sediments, essentially south of west except at its eastern end where it makes a southeastward bend along the Amity fault. A major thrust, first recognized by Stearn (1936) and named the Cowhide thrust by Reed and Wells (1938, p. 33), extends from one end of the district to the other. The quicksilver district, as defined by these authors, extends from sec. 13, T. 7 S., R. 27 W., in eastern Howard County, to sec. 5, T. 7 S., R. 22 W., in Clark County. The belt has a maximum width of six miles. Throughout the length of this thrust zone, the sediments are broken by tear faults and several prominent sets of fractures. Cross folds also are numerous. Much of this district is now under the waters of the Narrows Lake formed by the impounding of the Little Missouri River.

Age of the Ouachita Orogeny

A review of the literature concerned with the Ouachita orogeny would take a great number of pages and entail the citing of a great body of literature. Much of the material in these papers can be relegated to the realm of speculation. They are, for the most part, based upon data available in the literature, and the writers clearly were not familiar with the stratigraphic units and structural conditions of this mountainous area. Much of the literature concerned with the dating of the Ouachita orogeny is based on conscientious and thorough studies of limited areas and should be used with caution in making regional applications of the local conditions. The writer has spent most of the last four years studying the rocks of the Ouachita Mountain region and those of the adjoining geologic provinces. During this period, surface mapping, both reconnaissance and detail, subsurface studies in mines and of the samples and electric logs of drilled wells, the measurement and construction of two geologic cross sections (jointly with K. D. White, Continental Oil Company) from the Gulf Coastal Plain northward across the Ouachitas and the Arkansas Valley to the Ozark Platform, and extensive and critical review of the available literature concerning the region has led the writer to the formulation of definite opinions on the age of the Ouachita orogeny. These opinions are tempered by information from discussions with geologists such as E. B. Brewster, B. H. Harlton, H. D. Miser and C. W. Tomlinson, all of whom are authorities on one or more facets of the Ouachita problem.

If we assume that the rocks which make up the Atoka formation in the northern or frontal Ouachitas were deposited at a fairly uniform rate, and, lacking other criteria, divide this section of rocks into lower, middle, and upper divisions, it can be stated that the initial uplift of the Ouachita orogeny occurred at least by the upper part of lower Atoka time. The nature and distribution of upper middle Atoka sediments were affected locally by structures which involved the lower Atoka sediments. By the end of Atoka time the Ouachita Mountain area was completely emergent.

The Hartshorne sandstone, which overlies the Atoka in the area immediately north of the present Ouachita Mountains, is in its southern exposures composed chiefly of sand grains derived from the Jackfork sandstone. There are only minor amounts of coarse clastic material in the middle and upper Atoka units and in the Hartshorne sandstone, indicating a low magnitude of uplift and consequently a low order of erosional truncation of the uplifted area. The Jackfork sandstone is the only post-novaculite formation in which the sand grains are of sufficient size to have been the source material for the Hartshorne. The Hartshorne is succeeded by a sequence of shales and sandstones of Middle Pennsylvanian age which contains no appreciable amounts of coarse material. These formations are thickest in their southern exposures and thin rather rapidly to the north. The lack of coarse clastics and the general thickness patterns indicate that the Jackfork and Stanley were the chief sources of material deposited to form these formations. Paleozoic formations younger than Middle Pennsylvanian are not present in Arkansas, and in Oklahoma the debris from the Wichita and Arbuckle Mountain uplifts dominates the coarse clastic phase of the later Paleozoic rocks in which a Ouachita facies has not been conclusively isolated. It is doubtful that at any time during the Pennsylvanian the Ouachita Mountains were uplifted high enough to be a source of much coarse clastics; there is no flysche or molasse that can be associated with the Ouachita orogeny during the Pennsylvanian time. During this period of the orogeny, lasting longer than twenty million years, the amount of uplift and accompanying erosion was on the order of 15,000 to 20,000 feet. Probably there was no appreciable topographic relief until the resistant beds of the Arkansas novaculite were exposed.

Only negative evidence can be used to support further discussion of the history of this orogeny. Some of the more salient points are: (1) Novaculite pebbles up to 8 inches in diameter are found in present-day stream channels at least 25 miles from the nearest possible source. (2) Trinity formation is the only post-Atoka formation that contains appreciable amounts of conglomerate composed in part of cobbles and boulders of Arkansas novaculite. The upper Paleozoic and Jurassic beds known only in the sub-surface of the Gulf Coastal Plain contain little or no coarse clastic material along their northern limits. (3) There has been a minimum of 4000 feet of pre-Stanley beds removed from the core of the Ouachita Mountains. These features suggest that the slow spasmodic movement of the Ouachita area continued well up into the Permian and perhaps later, but at no time was the area sufficiently elevated to empower the streams to carry coarse cobbles of novaculite any appreciable distance. These opinions are supported, to a large extent, by the metamorphic character, or rather the lack of it, of the rocks in the Ouachita Mountains. The aggregate uplift at the core of the mountains has been 3 to 5 miles and the lateral compression is on the order of 50 percent. The rate of uplift and compression was sufficiently slow so that the individual mineral grains were maintained by physical adjustments. Physical-chemical adjustments (metamorphism) are restricted to a few local areas where they represent the lowest grade of metamorphism.

From the records available in the rocks, one can say that only during the Lower Cretaceous, when the downwarping of the Gulf Coastal Embayment increased the gradient of the streams draining the Ouachita Mountains, were these streams able to carry coarse material some distance from their source area. Therefore, with respect to the age of the Ouachita orogeny, it can be said that it was initiated probably in Morrow time, but no later than the lower Atokan. The downwarping of the Athens Plateau during the initial Trinity deposition and zones of weakness invaded by the lower Upper Cretaceous igneous rocks may indicate that the last stages of the Ouachita deformation are as young as Lower Cretaceous time. It is more likely that these features are more related to the subsidence of the Gulf Coast, but this cannot be proved with the information available at present. There is no evidence indicating a maximum period of deformation.

Gulf Coastal Plain

The structural history of the Gulf Coastal Plain includes at least three periods of movement. The initial movement in this area was part of a regional subsidence in the region now called the Gulf Coastal Plain. For a long period of time prior to this subsidence, the Paleozoic rocks in this area had been beveled by erosion almost to a peneplain. The advent of this subsidence was followed by the deposition of the sediments of the Trinity formation on the beveled surface. The lower member of the Trinity, the Pike gravel, is made up mostly of pebbles from one-half to one inch in diameter. Cobbles and boulders are abundant in this member, as are extensive lenses and facies of clay and sand. The fossils in this member consist of wood fragments and vertebrate remains. These non-marine fossils and poor sorting of the gravel, as shown by the sand and clay, indicate (1) that the seas advanced rather rapidly and did not winnow out the fine debris from the pebbles, and (2) that the gravels were deposited as a blanket when the gradients of the streams were altered by the encroaching seaways. This latter possibility is substantiated somewhat by the presence of cobbles and boulders of novaculite in the gravel.

The writer believes that there must have been some uplift in the mountainous region of the Ouachitas to empower the streams to carry this coarse debris, even though their length, and consequently their base level, was being altered by the encroaching marine water. The subsidence of the Paleozoic floor of Trinity deposition was sufficient for 600 feet or more of this formation to be laid down. The various sandstones, gravels, oyster-bearing limestones and possibly evaporites in this formation indicate considerable oscillation of the seaways. Following the deposition of the Trinity and the overlying Lower Cretaceous units, a more wide-spread subsidence occurred in the Texas-Arkansas area. There are two phases of this second period of subsidence, which were first discussed by Veatch (1905, p. 22).

> As a result of this submergence (Upper Cretaceous) the low-lying area in western North American became a great mediterranean sea, which connected the Gulf of Mexico and the Arctic Ocean. In the Texas-Arkansas area the depression was at first greatest to the southwest, but during the latter part of the Cretaceous the movement was reversed and the western region was gradually elevated as the area near the Mississippi was depressed. This resulted finally in the development of the Mississippi embayment and in the severing of the connection between the Gulf and the interior sea, which was thus converted into a series of great inland lakes which persisted through much of the Tertiary. Because of this east-west and then west-east tilting the lower portion of the Upper Cretaceous, which in central Texas is characterized by thick limestone and light-colored marl beds, is in Arkansas and Indian Territory composed entirely of near-shore sands with no marine fossils; while the upper portions, which in Texas are dark-colored calcareous clays, contain in Arkansas, Mississippi, and Alabama a large percentage of chalk and chalk marls.

In the region covered in this report, the westward tilting of the early Upper Cretaceous is indicated by the unconformity at the base of the Woodbine. Toward the east end of the region the Woodbine overlying the unconformity rests on the lower sandstone member of the Trinity. From this area westward the Woodbine lies on succeedingly younger members of the Trinity and at the west end of the region almost the entire 600 feet of the Trinity is preserved beneath the Woodbine. The eastward tilt of Upper Cretaceous is indicated by the southeastward dip of the Paleozoic floor, and isopachous maps of the Cretaceous (Caplan, 1954). There was a general withdrawal of the seas in the Arkansas area and adjoining states at the end of the Cretaceous. This may have been the result of eustatic uplift of the continent or a general deepening of the ocean basin.

Another period of subsidence accompanied the opening of the Tertiary; however, Tertiary sediments are present only at the eastern end of the barite region. They overlap the eastern end of the Athens Plateau, the Trap Mountains, the Zig Zag Mountains, and the Saline Basin.

Sometime after this early Tertiary subsidence, either in late Tertiary or the Quaternary, perhaps extending through both of them, the general Ouachita Mountain area was uplifted from 350 to 500 feet. This is indicated by the valleys of the major streams in the area. In the mountainous area many of the valleys are over 350 feet deep, with streams still actively eroding the valley floors with little terrace or flood plain development along them.

Igneous Structure

Peridotite. The peridotite necks and pipes that occur near Murfreesboro in the Caddo Gap Quadrangle appear to be the result of three distinct but closely related stages of igneous activity (Purdue, 1908, p. 526; Miser and Ross, 1923, pp. 279-322; Miser and Purdue, 1929, pp. 140-41). The first phase consisted of intrusion of ultramafic magma into the Paleozoic and Lower Cretaceous rocks. The second phase was volcanic explosions that resulted in the accumulation of fragmental material in the form of volcanic breccia. This breccia consists of peridotite, shale, sandstone, and novaculite fragments. A second period of volcanic eruptions added fragmental volcanic material to marine sediments accumulating in the adjacent seas. Miser and Purdue (1929, p. 141), in discussing the age of this period of activity, reasoned:

> That the several phases of volcanic activity took place after Trinity (Lower Cretaceous) time and during or before Tokio (Upper Cretaceous) time is shown by the facts (1) that the peridotite has penetrated and cut across the nearly flat-lying beds of the Trinity formation (figs. 4 and 5), (2) that it is overlain at places by the Tokio formation (fig. 5), and (3) that pebbles of it occur in the lower part of the Tokio. The pebbles of the peridotite in the Tokio were probably ejected as fragmental material during the volcanic eruptions, and if so the eruptions took place during the time when the Tokio was being deposited. The several phases of volcanic activity probably accompanied the diastrophic movements that produced the downwarping of the Mississippi embayment early in Upper Cretaceous time.

Magnet Cove. The Magnet Cove area includes a roughly elliptical basin 2 by 3 miles in extent, almost completely enclosed by a rim which rises 200 to 300 feet above the basin floor. The area is located near the center of the state of Arkansas in northern Hot Spring County, occupying the west central part of T. 3 S., R. 17 W., and the east central part of T. 3 S., R. 18 W., in the northeastern part of the Malvern quadrangle. Magnet Cove is one of the most interesting areas of mineralization on the North American continent. It compares with the Franklin Furnace area in New Jersey and the Crestmore area in California for number and variety of unusual rocks and minerals present. The Magnet Cove igneous rocks were intruded into the extreme eastern end of the Mazarn Basin. The northern part of the intrusions truncates southwestward-trending folds of the Zig Zag Mountains. The southern arc intrudes, in part, into the northernmost ridges of the Trap Mountains. The structure of the Magnet Cove intrusives has been subjected to quite divergent interpretations. Williams (1891, p. 342), in discussing the structure of the area, states:

> The igneous rocks of Magnet Cove are divided into three genetically distinct groups whose structure and mode of occurrence show that they were formed during three distinct periods of igneous activity.
>
> The oldest of these consists of the basic, eleolitic, abyssal rocks which constitute a large part of the interior Cove basin. The large masses of these rocks are holocrystalline granitic in their structure and were cooled slowly and under pressure. About the edges of this mass a porphyritic variety of these rocks often occurs and in some cases cracks in the surrounding rocks are filled with materials from this basic magma thus forming basic, eleolitic, porphyritic and lamprophyric dikes.
>
> The next period of igneous activity is one which corresponds to the dike forming epoch of the Saline County region. During this period the rock in and about the Cove which had been disturbed and heated by the intrusion of the masses of abyssal rocks cooled, and cracks opened in all directions. These cracks are filled with monchiquitic rocks of all varieties which appear as the basic, dark, non-eleolitic dikes, so numerous in the neighborhood of the Cove and in fact everywhere throughout that part of the state. (See chap. XIII).

The third and last period of igneous activity is that in which the eleolitic and leucitic rocks of the "Cove ring" were formed and during which the numerous tinguatic dikes of all varieties were intruded. The rocks of this period are all of an intrusive character, a fact which is shown both by their structure and mode of occurrence.

These youngest rocks cut both the abyssal rocks (p. 188) and the dikes of monchiquite (p. 174), and are therefore proved to be younger than either of those groups.

All the igneous rocks are younger than the surrounding Paleozoic rocks and have forced their way into them. They were formed after the folding and bending and after some of the erosion of the Paleozoic rock had been accomplished, probably during late Cretaceous time.

Washington (1900, p. 392) believed that the igneous mass was a laccolithic intrusion, which had differentiated in place to produce the various igneous rock types. Landes (1931, pp. 313-26) presented evidence to show that the igneous mass was not concordant, but cut across the structure of some of the sedimentary rocks. He interpreted the mass to be a stock which differentiated in place. Ross (1941, p. 24), after examining the rocks of some of the rutile deposits within the Cove area reached the conclusion that at least part of the Magnet Cove area is composed of volcanic material. Fryklund and Holbrook (1950, pp. 35, 36) cast considerable doubt on Ross' interpretation. Erickson and Blade (1955) are completing a detailed study of the Magnet Cove igneous rocks. Their findings should answer many of the problems connected with this highly mineralized area.

Summary of Geologic Events

The Ouachita Mountain region from Cambrian or earliest

Ordovician time until early Silurian time was a geosynclinal area receiving thick deposits of mud and lesser amounts of sand and carbonate. Minor changes of the seaways or land masses caused local changes in the character of the sediments. These sediments were lithified and now comprise the formations ranging from the Collier shale to the Blaylock sandstone. After the deposition of the Blaylock sandstone, in Silurian time, and before the deposition of the Missouri Mountain formation in uppermost Silurian or lower Devonian time, the region now forming the central part of the Ouachita Mountains was uplifted sufficiently for erosion to remove several hundred feet of sediments. There may have been some folding associated with this period of uplift, but it was minor. This period of uplift and erosion was followed by a new advance of the seaways over the area. Other than small patches of conglomerate, only fine muds, which became the Missouri Mountain shale, were deposited in the new seaway as initial sediments. Toward the end of the period of deposition of muds which make up the Missouri Mountain formation a considerable change took place in the source of material of the sediments; near the top of the Missouri Mountain siliceous material now transformed into novaculite was laid down with the muds. Several hundred feet of this siliceous material was laid down on top of the Missouri Mountain and lithified into the Arkansas novaculite. This period of deposition was not everywhere continuous. There is considerable range in thickness of each of the three members of the Arkansas novaculite and there is considerable difference in their composition. The lower member is chiefly novaculite, the middle member is about equal parts of novaculite and shale, and the upper member is highly calcareous novaculite. Locally, there is conglomerate and breccia at the tops or bottoms of each of these members and at places in them.

This period of predominantly silica deposition lasted from uppermost Silurian or lower Devonian to lower Mississippian, at which time the seas withdrew over much, but not all, of the region.

This period of withdrawal was followed by a period of great subsidence lasting from the middle Mississippian to middle Pennsylvanian during which the area was downwarped a minimum of 18,000 and a maximum of 24,000 feet. Over much of this period of time the accumulation of debris from the land masses adjoining the downwarped area was so rapid that the seaways were not able to maintain themselves, except in local embayments. This is indicated by the tremendous accumulation of non-marine clastic rocks, which locally contain coal and plant remains, and the paucity of marine fossils in these sediments. The only known marine fossil horizons found in the strata deposited during this period of accumulation are found in the frontal Ouachitas where sedimentation was not rapid enough to block spasmodic marine invasions.

In the middle Pennsylvanian this process of downwarping was reversed because of compressive forces from the south. During this deformation period, the Ouachita orogeny, the Ouachita Mountain region was folded and faulted into its present configuration. The time span of this orogenic period has not been established. However, as there is no thick accumulation of coarse clastics of upper Paleozoic age along the flanks of these mountains, it is presumed that the uplift was spasmodic and slow and probably continued well up into the Permian, or later, This diastrophic period was followed by a long period of erosion, perhaps including part of the Permian, all the Jurassic, and Triassic periods.

Early in the Cretaceous period the beveled surface of the Ouachita structural province was downwarped to the south, and encroaching marine waters received the sediments of the Trinity and succeeding Lower Cretaceous formations. The seas withdrew at the end of the Lower Cretaceous and after some south of west tilting re-entered early in the Upper Cretaceous. At the same time a period of igneous activity was initiated with both intrusive and volcanic rock being formed and cutting through the Paleozoic and Lower Cretaceous formations. Alkalic tuffs are present in the Woodbine, the lowest Upper Cretaceous formation, with ultramafic tuffs forming part of the overlying Tokio formation. The ultramafic plugs near Murfreesboro cut the Trinity and are overlain by the Tokio and, therefore, are effectively dated. The age of the igneous rocks at Potash Sulphur Springs, Magnet Cove, Bauxite, and Little Rock are less accurately known.

Toward the middle of Cretaceous time, the initial westward tilt of the coastal region was reversed to the east. Later, toward the end of the Cretaceous, the seas withdrew from the region and readvanced in lower Tertiary time. The Tertiary sediments overlapped much of the Cretaceous and the eastern end of the Ouachita Mountains. Following, or perhaps causing, the withdrawal of the Tertiary seas, the Ouachita Mountain area was uplifted 250-500 feet, as indicated by the topography of the major streams of the Ouachita Mountain region.

CHAPTER III

ORIGIN, PARAGENESIS, AND AGE OF THE ARKANSAS BARITE DEPOSITS

General Discussion

The discussion of the origin of the barite requires frequent reference to the various districts in the region. The districts are defined strictly on the geographic basis and are not necessarily comparable geologically, in area or with respect to the type or amount of barite present (Plate I). The Magnet Cove district is in northern Hot Spring County and includes the area in Tps. 3 and 4 S., Rs. 17 and 18 W. The Pigeon Roost district is in the southeast townships of Montgomery County, T. 4 S., Rs. 23 and 24 W. The Fancy Hill district is in the southwest quarter of Montgomery County and includes the barite deposits in T. 4 S., Rs. 25, 26, and 27 W. The Hatfield district is in the central part of Polk County and includes the barite prospects in Tps. 3 and 4 S., Rs. 29, 30, and 31 W. The Cinnabar or Quicksilver district strikes across Howard, Pike, and Clark Counties as discussed in the previous chapter. The Dierks district includes the barite deposits of western Howard County and eastern Sevier County in Tps. 7 and 8 S., Rs. 27, 28, and 29 W. There are numerous isolated barite prospects throughout the southwest part of the Ouachita Mountains, but present information does not indicate sufficient barite in these localities to warrant a district name.

In the Magnet Cove, Pigeon Roost, and Fancy Hill districts the barite occurs as a replacement zone in the basal part of the Stanley formation. In the Hatfield district the barite occurs as veins in the middle division of the Arkansas novaculite. In the Cinnabar district barite occurs as a gangue material in the mineralized zone at a few places in the western part of the district. In the Dierks district the barite occurs as a cement in the Pike gravel and Trinity sands.

Character of the Barite

Replacement Deposits

Although the districts in which the replacement type of deposits occur are many miles apart, the barite ore is remarkably similar in all of these deposits. The individual bodies of barite contain several types of ore. The most abundant type is a massive gray to dark gray, finely crystalline ore which is referred to as the limestone-appearing ore in some reports. Where weathered, this ore has a lighter color and appears to be faintly to strongly banded. Much of the banding parallels the bedding, but some of it is caused by differential oxidation and hydration of iron oxides along joint and cleavage surfaces. The replacement nature of this finely crystalline barite is best seen in thin section. However, the well-preserved bedding planes of the host rock and isolated patches of non-mineralized shale are indicative of the replacement. In thin section, the metasomatic effects are readily discernible. Incompletely replaced shale "islands" (Plate XXVII) are not uncommon; partially breached bedding planes were observed in a few sections (Plate XXX), and replaced embayments in individual grains were noted in nearly all thin sections of this type of ore that were examined (Plate XXIX A).

A second type of ore is gray, extremely fine-grained, and has a texture ranging from earthy to extremely dense. At a few places it resembles gray novaculite from which it can be readily distinguished because it is easily scratched and is much heavier. This ore type like the one discussed above was emplaced without destroying bedding planes. However the replacement was so complete that identifiable host rock constituents are rare (Plates XXIX B, XXXII A). A third ore type is massive, dark gray to black, and its granular nature can be detected with the unaided eye. This is the least abundant ore type, but it has a higher tenor where it does occur. This type of barite either replaced massive beds or the bedding planes were obliterated during the mineralization.

PLATE XXVII

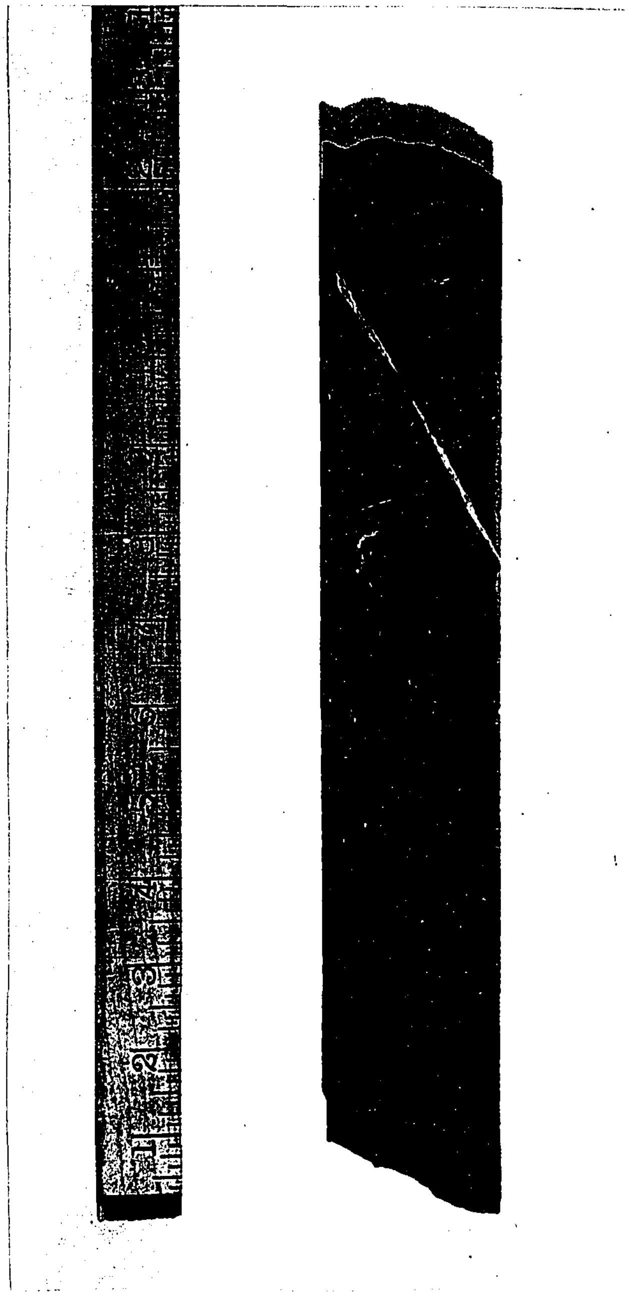
(A)

(B)

(A) Photomicrograph of barite (light gray) replacing shale (gray), near east end Baroid pit at Magnet Cove. Plane polarized light; X 13, section 17.

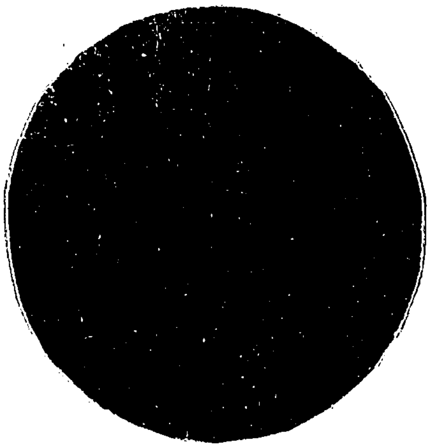
(B) Same view with nicols crossed showing vermicular nature of the barite.

PLATE XXVIII

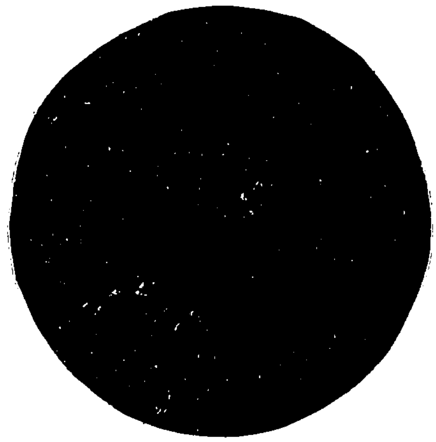


Photograph showing the nature of the nodular ore, Magnet Cove district. Black barite nodules in gray baritic shale, cut by carbonate seam (white).

PLATE XXIX



(A)

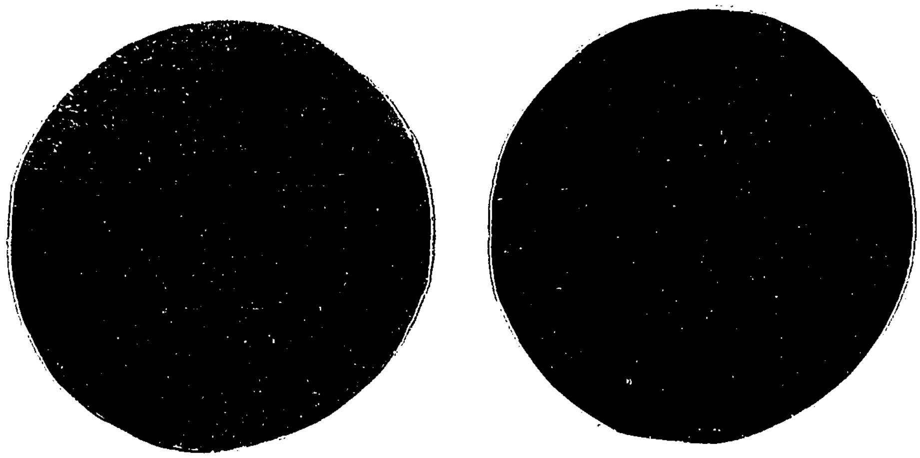


(B)

(A) Photomicrograph of partially replaced quartz crystal (in relief, near center) in massive barite bed, near base of mineralized zone, underground workings, Magnet Cove district. Plane polarized light, X 208; section 59.

(B) Photomicrograph of quartz remnants (in relief) in massive barite bed, near top of mineralized zone, underground workings, Magnet Cove district. Crossed nicols; X 625; section 54.

PLATE XXX

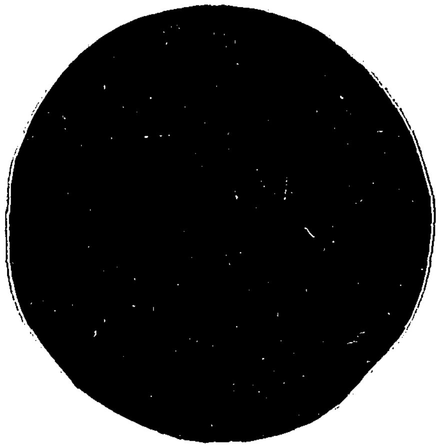


(A) (B)

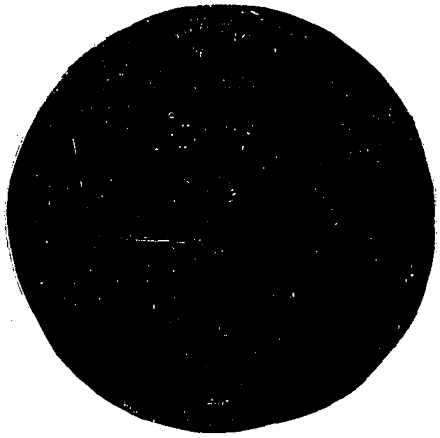
(A) Photomicrograph of barite replacing shale, Henderson property, Fancy Hill district. Plane polarized light; X 46, section 86.

(B) Same view with nicols crossed.

PLATE XXXI



(A)

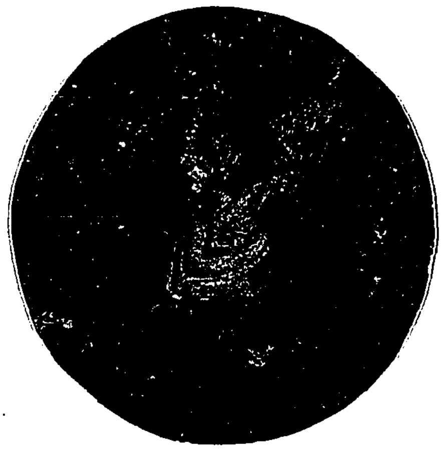


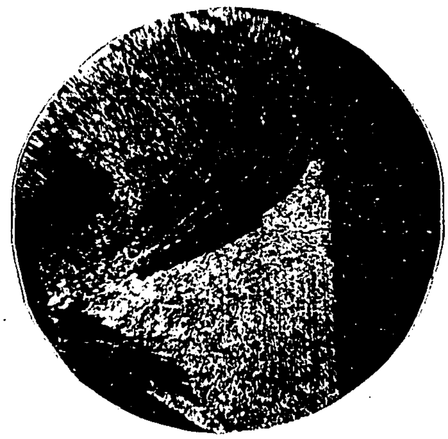
(B)

(A) Photomicrograph of radial barite developed around clay pellets in the Stanley shale above the highgrade ore zone, Baroid pit, Magnet Cove district. Crossed nicols; X 13; section 44.

(B) Photomicrograph of barite (black) replacing novaculite, pebble zone at base of Stanley, Chamberlin Creek syncline, Magnet Cove district. Crossed nicols; X 625; section 17.

PLATE XXXII





(A) (B)

(A) Photomicrograph showing the zonal growth of a barite crystal in a massive ore bed, McKnight property, Fancy Hill district. Crossed nicols; X 46; section 104.

(B) Photomicrograph of a barite nodule in which the accretion lines extend uninterrupted across the various barite blades, Pigeon Roost district. Crossed nicols; X 13; section 139.

In all thin sections of the granular ore some lineation is apparent (Plate XXIV). However, in only a few of the sections was the lineation parallel to the bedding of the adjoining stratigraphic units.

The fourth type is nodular ore in which the nodules range from one-tenth of an inch to two inches in greatest diameter (Plate XXVIII). The average diameter of these nodules is approximately one-half inch, with the nodules of any particular horizon tending to be rather uniform in size. Some if not all these nodules were clay pellets in the Stanley shale before the invasion of the barite-bearing solutions. The studies of thin sections of several of these pellets show that the degree of replacement ranges from a minute quantity of barite dispersed through the clay minerals to a complete replacement of the nodules by barite (Plate XXXI A, XXXII B). Granular and radial forms of barite occur in these nodules. In some the central portion is granular and the outer portion is radial. These textural differences, especially where the granular and radial types occur in the same nodule, suggest that the granular textured nodules were formed by the replacement of clay pellets and that the nodules of the radial type grew from a central point, possibly a small opening in which the barite mineralization was initiated, or some nucleus whose chemical makeup initiated the precipitation of the barium sulfate.

PLATE XXXIII

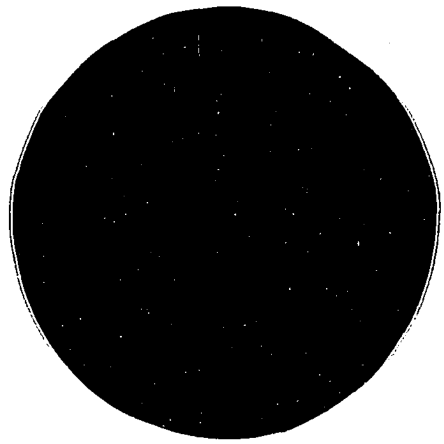
(A) (B)

(A) Photomicrograph of high-grade barite from Henderson property, Fancy Hill district. Compare with high-grade ore from Magnet Cove district, Plate XXXIV. Plane polarized light; X 13; section 88.

(B) Same view with nicols crossed.

PLATE XXXIV

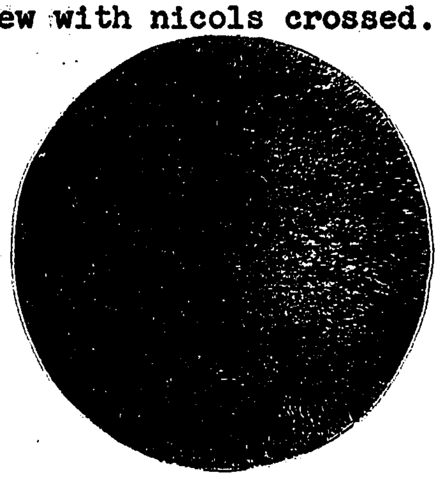
(A)



(B)

(A) Photomicrograph showing the types of barite in a high-grade (87% $BaSO_4$) ore zone in the underground workings of the Magnet Cove Barium Corporation. Plane polarized light; X 13; section 60.

(B) Same view with nicols crossed.



(C)

(C) Same section as (A) and (B), different field. Note pyrite cubes, black. Plane polarized light; X 13.

Vein Deposits

The vein deposits of barite in the Ouachita Mountain region can be subdivided into two types. Type I is characteristic of the Hatfield district, but also occurs in other localities of the region. These veins formed in and parallel to the bedding of the middle member of the Arkansas novaculite. They consist of dark gray to black, fine to coarsely crystalline barite, and generally are less than two feet thick. Only a few of the veins can be traced more than 60 feet along the strike length. They are classified as concordant veins in this report.

The other type, the discordant veins, is exemplified by the white, coarsely crystalline barite in the peridotite area of Murfreesboro and the colorless extremely coarse crystalline barite veins at the west end of the Cinnabar district. It is doubtful if either of these types of veins has any commercial significance.

Barite as Cement in Sediments

The third type of barite occurrence in this region is in the Dierks district where barite is present as cementing material in the Pike gravel and in the lower sands of the Trinity formation. The barite cement of these units was deposited from solutions in such a manner that large crystals incorporating a number of sand grains were formed. Many of these crystals have a maximum dimension of 3 or 4 inches.

In many of these individuals the force of crystalization was sufficient to isolate the individual sand grains from each other (Plates XXXV, XXXVI). At some places in these deposits the barite crystals were deposited as radial aggregates. When these aggregates are freed from the enclosing rock by weathering and erosion, they have the form of sand barite "roses" similar to the barite roses from the Permian of Oklahoma.

The barite-bearing zones in the Trinity are lenticular and the tenor of ore changes quite rapidly horizontally and vertically.

In the conglomerates the solutions from which the barite was precipitated dissolved the rims of some novaculite and quartzite pebbles. In the sandstones there is little evidence that the quartz grains were attacked by the solutions.

The study of the thin sections of these barite cemented sediments yielded no evidence that the barium sulfate replaced a previous cementing material, and as much of the Trinity sand is not cemented, the writer believes that the barite was deposited in open pore spaces.

Origin and Age

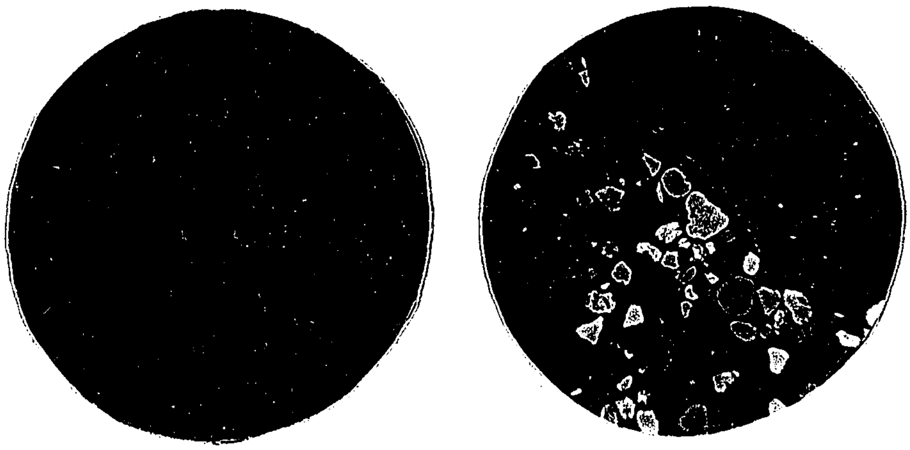
Replacement Deposits

The replacement type barite deposits in Arkansas, the Magnet Cove, Pigeon Roost, and Fancy Hill districts are judged by the writer to have formed in the same manner and at essentially the same time. The ore bodies within these districts have the same relationships to major and minor structures, are limited to the same stratigraphic horizon, have the same types of ore, and are closely related chemically and physically.

Relation to structure. The three districts named above lie within the confines of the Mazarn Basin or along its margins where more intense folding and subsequent stratigraphically deeper erosion has exposed folded Arkansas novaculite. Every deposit within these districts lies on the flanks of or extends across a syncline. Within these synclines, minor folds and faults, as well as the stratigraphy, are ordinarily the controlling factors of the exact localization of the barite ore. The role of these minor features is discussed under the description of the individual deposits in Chapter IV.

Relation to stratigraphy. The replacement barite bodies of these districts are confined to the lower 300 feet of the Stanley formation. In most deposits a black shale, ranging in thickness from 1 to 30 feet and having a basal conglomerate from one-half to 4 inches thick, overlies the Arkansas novaculite. This black shale forms the foot wall of the barite mineralization zone (Plate XXVII B). There is no definite hanging wall in some deposits. In most cases, the vertical range of the mineralization is less than 100 feet, although it extends in a few places to 300 feet. Ordinarily 20 to 65 feet of the mineralized zone can be considered commercial ore.

PLATE XXXV

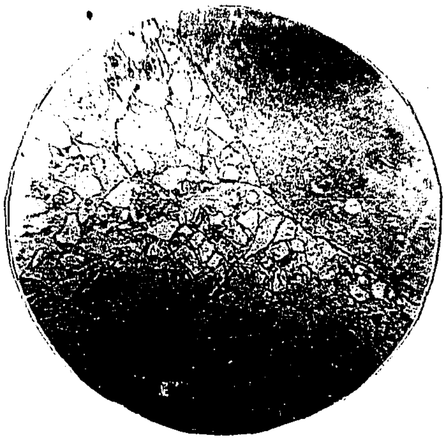


(A) (B)

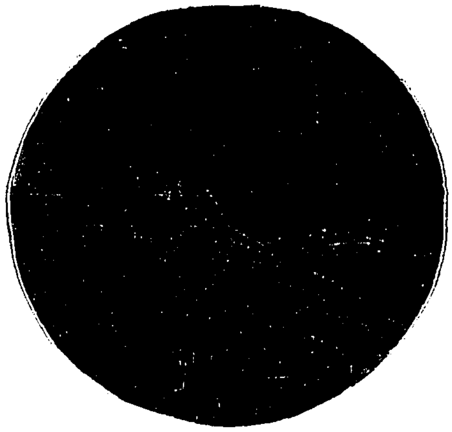
(A) Photomicrograph of barite (gray, higher relief) cemented gravel containing novaculite pebbles (light gray, upper and lower left parts of picture) and quartz grains (light gray, lower relief). Cherry deposit, Dierks district. Plane polarized light; X 13; section 113.

(B) Same view with nicols crossed. Optically continuous barite is at extinction (black).

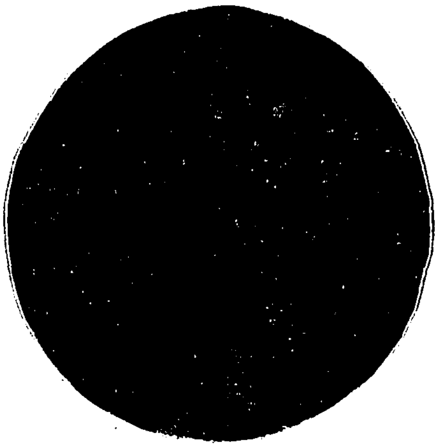
PLATE XXXVI



(A)



(B)



(C)

(A) Photomicrograph of novaculite pebble (mottled gray) and quartz grains (whitish gray) cemented by barite. Lucky 13 deposit, Dierks district; plane polarized light; X 13; section 123.

(B) Same view with nicols crossed to show optical continuity of barite.

(C) Same view with nicols crossed and barite at extinction position.

Modes of emplacement. The barite was deposited in three different ways: capillary replacement (metasomatic), cementation, and fracture filling. Metasomatism is most marked in the silty shales, cementation in the clean siltstones and sandstones, and fracture filling in the clay shales along fractures and bedding planes.

Metasomatism, in the broad sense, can be considered to be the volume-by-volume replacement of one mineral or a mineral aggregate by another mineral or mineral aggregate. The process of adsorption, a type of metasomatism in which the replacement is effected by solutions moving along capillary openings, is governed by the physical and chemical nature of the solution and the texture and the mineralogical and chemical composition of the invaded rock. The surface of any given matter differs physically from the main mass because the outer layer of ions or atoms is affected by external forces that do not affect the ions or atoms within the mass. Turner and Verhoogen (1951, pp. 396-401) in their discussion of kinetics of surface phases note that the growth in solution of crystals in contact with solvents, vaporization of liquids, and the eutectic melting of two or more solids are processes essentially concerned with surfaces rather than with internal structure.

Solutions with respect to surface phenomena are heterogeneous in that they are affected by internal and external forces. The composition of the surface of the solution is governed by the free surface energy. The component with the smaller free surface energy, or tendency to maintain itself as a homogenous unit, will concentrate in the outer surface of the solution. In the ordinary solution of barium sulfate and water, the water molecules, because they have a weaker attractive field of force than the barium sulfate, form a layer a few angstrom units thick and comparatively free from solute at the surface of the solution. This surface layer of water forms only a minute part by volume of the solution. However, when a solution of this type enters a capillary opening a few tens of angstrom units in diameter, the surface layer becomes a major part of the solution. After the solution enters the capillary opening and the comparative volume of the film forming the outer surface is greatly increased the kinetic and chemical potentials of the solute-free surface layer are much stronger. The ensuing kinetic and chemical reactions are not clearly known.

The interpretation of the processes involved in the metasomatic replacement by barite of the lower beds of the Stanley formation must take cognizance of the role of the strongly reactive surface film of the capillary fluids and the innate ionic disorder of the replaced minerals. Mineral particles or crystals have, within limits, a definite chemical composition and essentially an organized ionic arrangement. Minor amounts of impurities, present in nearly all minerals, tend to disrupt and weaken the ionic bonding so that the mineral particle is more subject to chemical reaction. The surface layers of nearly all mineral particles are in a state of ionic disorder because the ions of these outer layers are not bonded in all directions and because of heterogeneous surface effects as discussed above.

The ionic disorder in mineral particles bounding capillary openings is probably increased when fluids enter the openings. Capillary forces acting on the fluid and, perhaps, an initial hydrostatic pressure, tend to form an unilateral pressure gradient. In a system of unilateral pressure gradient the minerals are under stress which tends to disrupt the space lattice and weaken the ionic bonds.

Niggli (1954) emphasizes the fact that many of the laws of thermodynamics are not directly applicable to mineralization processes. The ideal states of gas, liquid and crystalline solid with constant thermal, hydrostatic and gravitational gradients are rarely, if ever, obtained in natural mineralizing solutions. The phase of the solution, or at least its behavior, may change as the degree of saturation is changed. An undersaturated solution that reacts as a true liquid may assume the properties of a pseudo-crystalline state as the solution becomes saturated (Niggli, 1954, p. 469). The internal changes and external factors such as the heterogeneous nature of the wall rock, constrictions of passageways and interstitial fluids of the wall rock limit the applicability of thermodynamic analyses of mineralization processes.

The petrographic and chemical studies of the host rock remnants in the mineralized zone and the rock units adjoining this zone indicate that quartz, mica, clay, and pyrite are the replaced minerals. The replacement processes were comparatively simple because, other than minor amounts of brookite (rutile) and pyrite, barite was the only replacement mineral.

The writer believes that the following processes were the most effective during the metasomatic activity. As the mineralizing solutions pervaded the capillary openings, the first reaction was between the minerals of the wall rock and the solute-deficient surface film of the solutions. The reaction principally was hydrolysis of the wall rock minerals along the ionically disorganized surfaces of the mineral particles, resulting in some dissolution of the mineral particles and disorganization of the newly exposed surfaces. The hydrolysis, disorganization and dissolution of the wall rock minerals allowed dispersion of Ba^{++} S^{--} into these minerals. Chemical reaction between the ions of the invading solutions and those of the invaded particles resulted in precipitation of barium sulfate and removal in solution of the host material. Penecontemporaneous precipitation of barium sulfate in the capillary openings occurred because the invading solutions became supersaturated with barium salts when the surface film of water was adsorbed during the hydrolysis of the host minerals. These reactions continued until the host minerals were completely replaced, precipitated barite plugged the capillary openings, or the supply of mineralizing solutions was exhausted.

An idealized reaction series for the replacement of quartz is given below. A similar series for clay and mica would be more complicated, and for pyrite less complicated.

$$SiO_2 + H_2O \rightarrow 2H^+ + SiO_3^{--} \quad \text{hydrolysis}$$

$$Ba^{++} S^{--} \rightarrow S^{--} + Ba^{++} \quad \text{dispersion}$$

$$\downarrow \quad \downarrow$$

$$H_2S + BaSiO_3$$

$$H_2S + 4H_2O \rightarrow 2\,H^+ \cdot SO_4^{--} + 4\,H_2\uparrow$$

$$BaSiO_3 \rightarrow SiO_3^{--} + Ba^{++}$$

$$\downarrow$$

$$H_2SiO_3 + BaSO_4\downarrow$$

$$H_2SiO_3 \rightarrow H_2O + SiO_2$$

The quartz veins cutting the mineralized zone and the overlying strata may represent the end product of this series (Plates XLII, LIX). Dispersion effects are shown by the zoning in some of the larger barite units (Plate XXXII). Replacement ordinarily proceeds from the exterior of the host particle toward the interior.

The effectiveness of replacement along capillary openings is well illustrated by the nature of the host rocks of the Arkansas barite. The silty shales are more completely replaced than any other type of rock within the region. The silt grains disrupt the layerings of the clay minerals sufficiently to form capillary openings. The mineralizing fluid attacked both the clay minerals and the silt grains. In the clay shales the only paths of migration available to the mineralizing fluids were bedding planes and fractures. The sandstones that contain only a small percentage of clay were not subject to grain replacement because the size of openings available to the barium sulfate-bearing solutions were too large for the surface layers of the solutions to react strongly with the wall rock minerals, which mostly are rather insoluble quartz. The sandstones that contain appreciable amounts of clay were subjected to the capillary processes, and much of the quartz was replaced by barite.

For the most part in these Arkansas deposits, the barite did not preserve the outlines of the individual grains of the country rock, but the larger structures such as nodules and bedding planes are readily identified.

In the cemented siltstones and sandstones the barite is present mostly as pore filling. There is no evidence that barite replaced a previous cementing material. There is only a minor amount of replacement of quartz grains, and this only around the outer rim. Pyrite and novaculite grains in these rocks were subjected to more replacement than the quartz grains. As in the quartz grains, the replacement is restricted to the outer margins.

The shales that are composed almost entirely of clay minerals are relatively free of barite. In these shales the barite occurs only in fractures and along bedding planes where it is present as veins of radiating or fibrous aggregates. The habit of the barite and the width of the veins, up to 10 millimeters, suggest that the force of crystallization of the barite was sufficient to force apart, at least to a small extent, the wall rock of the veins (Plate XXXIX B).

Chemical character. The barite deposit in the Chamberlin Creek syncline of the Magnet Cove district lies within a mile of the nearest exposed igneous rock. The chemical composition of this barite body, and therefore its mineralogy, is more complicated than it is in the barite deposits of the Pigeon Roost and Fancy Hill districts, where presumably the igneous source of the barite is more remote from the areas of deposition. The chief difference is that the barite deposits in the Magnet Cove district have been partially replaced by carbonate, whereas those of the other districts have not (Plate XL).

Within the exposed boundaries of the Magnet Cove intrusion there have been at least four stages of carbonate introduction. The older masses are coarsely crystalline calcite, invaded and metamorphosed by later igneous rocks and veins. The later phases are chiefly feldspar-carbonate veins associated with the period of titanium mineralization in the Cove (Fryklund and Holbrook, 1950, pp. 26-35). In the Pigeon Roost and Fancy Hill districts barite and pyrite are the only metasomatically introduced minerals. The barite in all these deposits has a remarkably uniform suite of trace elements (Table IV).

Origin and age. The Chamberlin Creek syncline is shaped much like a spoon with the point at the northeastern end, and the posterior part truncated by the Magnet Cove intrusion (Plate IV). The barite ore body, as discussed above, is a replacement or metasomatic type. The structural relations and the nature of the mineralized zone strongly suggest that the Magnet Cove intrusions were the sources of the solutions from which the barite was deposited. If this deposit were the only one of its kind in the region, most geologists would require little or no supporting evidence in order to accept the idea that the nearby intrusions were the source of the mineralizing solutions. The occurrence of almost identical barite bodies 35 to 60 miles to the west and an unknown distance from any igneous bodies which could have been the source of supply for the barium sulfate necessitates bringing more evidence to bear to show that the igneous intrusions of the Cretaceous period are the parent bodies for the hydrothermal solutions which deposited the metasomatic barite.

There is one major fact concerning the relationship of the replacement-type barite, the igneous rocks, and the zone of replacement for which the writer has only a speculative explanation. This type of barite deposit has been found only in the basal part of the Stanley shale, primarily in synclines. The ore zones have a definite foot wall but no definite hanging wall. How and why the barium-bearing solutions were concentrated in the basal part of the Stanley formation cannot definitely be established with the information now available. The writer believes that differential slippage of the Stanley units over the more massive novaculite during deformation created openings that allowed the migration of the mineralizing solutions. The migration, for the most part, occurred along the Stanley-novaculite contact in synclines, as these downfolded structures were the first available to the ascending hydrothermal solution (see interpretive sketches below). The barium-bearing solutions migrated essentially vertically into the basal Stanley units along fractures and joints. The capillary processes effected the metasomatic replacement of the Stanley by barite.

Of the igneous rocks the syenitic types tend on the average to have a higher barium content than other types because the syenitic rocks are relatively rich in potassium. The potassium ion is comparatively large, as is the barium ion, so to a limited extent the two can substitute for each other in mineral structures. In potassium feldspars, the most abundant mineral of syenitic rocks, as much as four percent barium may be substituted for potassium. Barium may also substitute for potassium in potash feldspathoids, zeolites, and micas. Except for a few rare types, the igneous rocks in the Magnet Cove intrusions contain from about 0.17

to about 2.25 percent barium with the greater percentages occurring in the more coarse-grained rocks. As far as igneous minerals are concerned the rocks of Magnet Cove are essentially saturated with barium and, of importance to paragenesis, with titanium.

The body of literature concerned with the geochemistry of barium is not extensive. The excellent monograph of Von Engelhardt (1936, pp. 186-246) has been the source of the geochemical data given in the subsequent writings dealing with the subject. The data obtained by Von Engelhardt show clearly that barium in igneous rocks tends to be concentrated in the earlier crystallizing potash feldspars and micas. The potash minerals formed during the end stages of the fractional crystallization of the magma, particularly the pegmatites, are extremely deficient in barium oxide.

Barium is able to enter the space lattice of the feldspar crystals at the higher temperatures because the kinetic energy of the ions forming the crystal particles is higher, which makes the ionic arrangement less stable. Under these less stable conditions the barium ion (1.46A°), which is larger than the potassium ion (1.33A°), can be accepted into the ionic arrangement. At lower temperatures where the kinetic energy is lower and therefore the ionic arrangement more stable, the barium ions because of their larger size and because of their bivalent charge are not readily accepted into the feldspar structure. This substitution pattern is

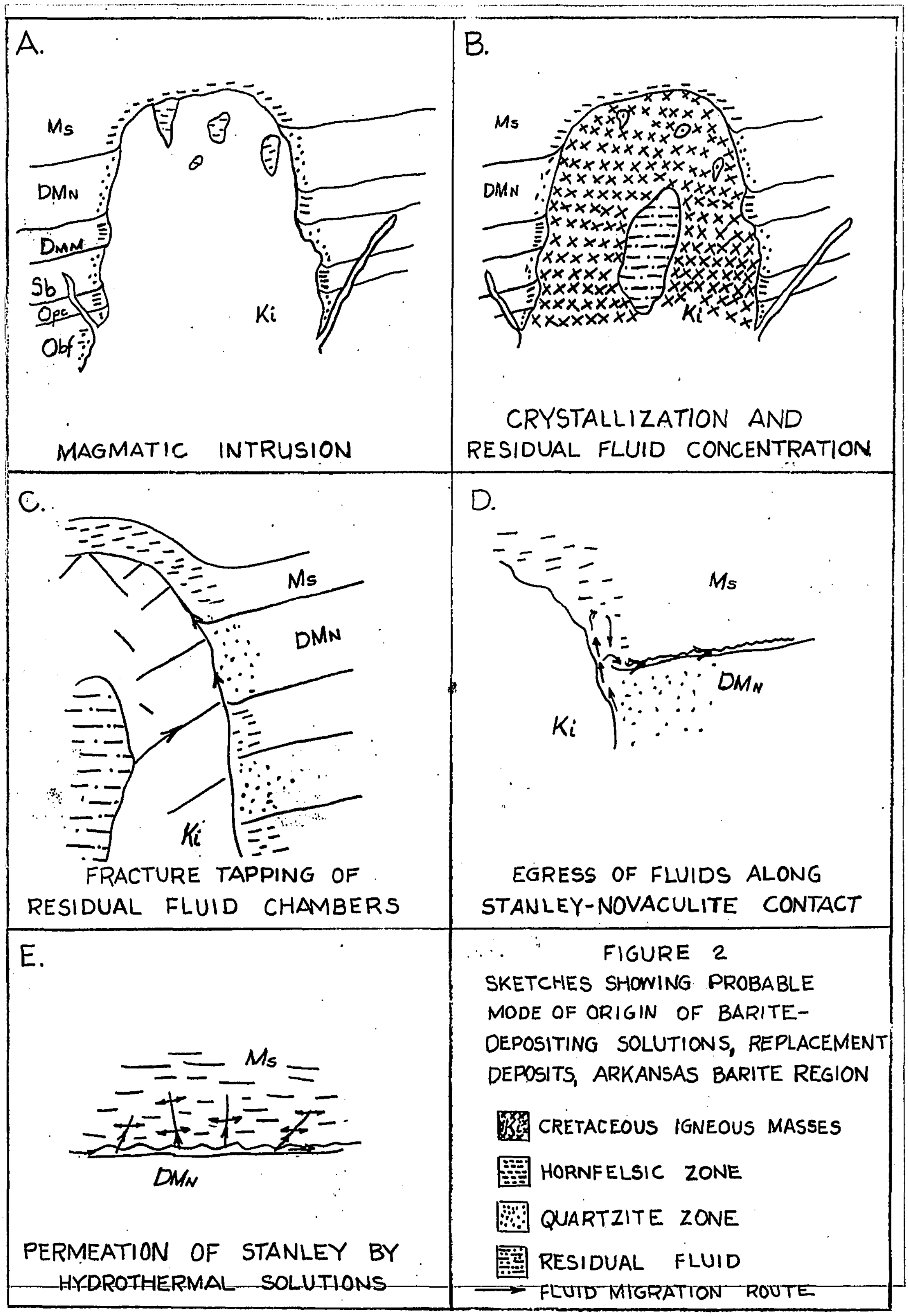


FIGURE 2
SKETCHES SHOWING PROBABLE MODE OF ORIGIN OF BARITE-DEPOSITING SOLUTIONS, REPLACEMENT DEPOSITS, ARKANSAS BARITE REGION

similar to the calcium-sodium relationship in the plagioclase feldspars. Apparently barium can substitute for potassium in mica and zeolites at somewhat lower temperatures than it can in feldspars because the ionic grouping of these minerals is not as completely a closed system. However, as in the potash feldspars, the late-stage zeolites and micas are comparatively free of barium.

If barium is present in the magma, and if its quantities cannot readily be accepted by the potash minerals, the surplus accumulates in the residual fluids and is expelled from the magmatic chamber in hydrothermal solutions in the form of barium sulfide, oxide, chloride, carbonate, or fluoride. Because barite is a common gangue mineral in metalliferous deposits it is presumed that barium leaving the magmatic chamber ordinarily is ionically bound to sulfur rather than the other anions. Barium sulfide is rather soluble but unstable. The barium sulfide may be converted to the insoluble barium sulfate through the agency of meteoric waters, interaction with the wall rock, or aeration.

The earlier students of the Magnet Cove rocks and minerals failed to discover the presence or importance of barium in the Magnet Cove suite. Erickson and Blade found that some of the feldspar in the Cove rocks was saturated with barium (Erickson and Blade, 1954). Much of the feldspar containing less than the maximum amount of BaO probably crystallized at temperatures and pressures that inhibited maximum acceptance of the barium ions into the space lattice.

Erickson and Blade also noted that barite was present in the "tufa" or sinter domes in the Cove.

As stated before, the Gulf Coastal Cretaceous igneous province is rich in barium and in titanium. It was expected that the igneous rocks of this province would contain an unusual suite of trace elements. This, however, is not the case. The available data show that Co, Mn, Ga, Cr, V, Sc, Y, Yb, La, Zr, Nb, Be, Sr, Ti, and Ba are present in nearly all varieties of igneous rocks in this province. Mo, Pb, Co, and Ni are less widespread trace elements. With the exception of the barium and titanium none of these elements is present in percentages greater than those given for the average of igneous rocks, particularly the syenitic and peridotitic types. With respect to the trace elements the barite ore bodies differ from the igneous rocks only in that lanthanam is not present and boron is much more widely distributed, although in minute amounts. In both the igneous rocks and the barite deposits, disregarding Ba, Sr, and Ti, the trace elements are present in amounts ranging from 1 to 100 parts per million. The method of semi-quantitative spectrographic analysis used to obtain this data was sensitive to concentrations of one part per million.

Goldschmidt (1954 pp. 409-411), in discussing the abundance of titanium in rocks, points out that the averages given by the earlier assayers are too high because of

TABLE 4

SPECTROGRAPHIC ANALYSES FOR TRACE ELEMENTS IN SELECTED SAMPLES FROM THE ARKANSAS BARITE REGION

SAMPLE NO. / ELEMENT	1	14	25	32	47	49	76	85	87	89	171	121	#22	204
Nb	0	0	0	0	0	.0X	0	0	0	0	0	0	0	0
Cu	.0X	.00X	.000X	.000X	.0X	.0X	.00X	.00X	.000X	.00X	.00X	.000X	.000X	.000X
Ag	0	.000X	0	0	0	0	0	0	0	0	0	0	0	0
Mo	0	.00X	0	0	.00X	0	0	.00X	0	0	0	0	0	0
Pb	.000X	.000X	0	0	.0	0	0	0	0	0	0	0	0	0
Mn	.00X	.0X	.000X	.X	.0X	.0X	.0X	.00X	.000X	.00X	.00X	.00X	.00X	.00X
Co	0	.000X	0	0	.000X	.00X	.000X	0	0	0	.00X	0	0	.00X
Ni	0	.00X	0	0	.00X	.00X	.00X	0	0	0	0	0	0	0
Fe	X.	X.	.X	.00X	.X	X.	X.	X.	.0X	.X	.X	.X	.X	.0X
Ga	.00X	.00X	0	0	0	.0X	.00X	.00X	0	.000X	0	0	0	0
Cr	.0X	.0X	.000X	.000X	.00X	.000X	.00X	.00X	.000X	.00X	.000X	.000X	.000X	.000X
V	.0X	.0X	.00X	.00X	.00X	.0X	.00X	.00X	.000X	.00X	0	.00X	.00X	0
Sc	.00X	.00X	0	0	.000X	.00X	.00X	.00X	.000X	.00X	0	0	0	0
Y	.00X	.00X	0	0	0	.00X	.00X	.000X	0	0	0	0	0	.0X
Yb	.000X	.000X	0	0	0	.000X	.000X	.000X	0	0	0	0	0	.0X
La	0	0	0	0	0	.0X	0	0	0	0	0	0	0	0
Ti	.X	.X	.0X	.00X	.0X	X.	.X	.X	.00X	.X	.0X	.X	.X	0
Zr	.0X	.0X	.00X	0	.00X	.0X	.0X	.0X	0	.00X	0	0	0	0
Be	.000X	.000X	0	0	0	.000X	0	0	0	0	0	0	0.	0
Mg.	.X	X.	.X	.X	.X	X.	X.	.X	.0X	.X	.00X	.0X	.0X	.00X
Ca	.00X	.00X	.0X	M.	.X	X.	X.	.0X	.0X	.X	.0X	.00X	.00X	.0X
Sr	.00X	.00X	.X	X.	.X	.X	.X	.X	X.	X.	X.	.X	.0X	X.
Ba	X.	X.	M.	M.	M.	X.	M.	M.	M.	M.	M.	M.	M.	M.
B	.0X	.0X	0	0	.0X	.00X	.0X	.0X	.00X	.0X	0	0	0	0

Tested for but not found: Au, Hg, Ru, Rh, Pd, Ce, Ir, Pt, W, Re, Ge, Sn, As, Sb, Bi, Te, Zn, Cd, Tl, In, Tb, Ta, U, Li, Na, K, P.

X. = 1-10%
M. = over 10%

Analyses Courtesy of U.S. Geol. Sur. in agreement with Ark. Geol. & Cons. Com.

SAMPLE DESCRIPTION

1 STANLEY SH. - 20' ABOVE NOV. - SOUTH SIDE LUCINDA CREEK SYNCLINE - SE, NW, SW SEC. 10, 3-S, 17-W

14 FOOTWALL BLACK SH. - EAST END - CHAMBERLIN CREEK SYNCLINE - NE, NW, NW, NW SEC. 14, 3-S, 17-W

25 STANLEY SH. - 34' ABOVE NOV. - NORTH RIM REYBURN CREEK SYNCLINE - NE, SE, SE, SEC. 13 3-S, 17-W

32 CARBONATE DIKE - FOOTWALL RAMP BAROID PIT - NW, SW, SW, SEC. 10, 3-S, 17-W

47 MASSIVE BARITE ORE - SOUTH RIM CHAMBERLIN CREEK SYNCLINE - SE, NE, NE, SEC. 15, 3-S, 17-W

49 ALTERED DIKE - BAROID PIT "A" CHAMBERLIN CREEK SYNCLINE - SW, NE, NE, SEC. 15, 3-S, 17-W

76 MASSIVE BARITE ORE - KIMZEY DRIFT MAGCOBAR UNDERGROUND MINE - CHAMBERLIN CREEK SYNCLINE - NW, SEC. 15, 3-S, 17-W

85 NODULAR BARITE - HENDERSON PROPERTY FANCY HILL DISTRICT - NW, NW, NW, SEC. 29, 4-S, 26-W

87 MASSIVE BARITE ORE - McKNIGHT PROPERTY FANCY HILL DISTRICT - SE, NE, SEC. 30, 4-S, 26W

89 MASSIVE BARITE ORE - GAP MOUNTAIN DEPOSIT - SW, SE, SE, SEC. 24, 4-S, 26-W

171 MASSIVE BARITE ORE - PIGEON ROOST DISTRICT - SW, NW, SEC. 30, 4-S, 23-W

121 BARITE CEMENT - TRINITY FMTN. - LUCKY 13 DEPOSIT - DIERKS DISTRICT - SE, NW, SW, SEC. 13, 7-S, 28-W

122 BARITE CEMENT - PIKE GRAVEL - LUCKY 13 DEPOSIT - DIERKS DISTRICT - SE, NW, SW, SEC. 13, 7-S, 28-W

204 "TUFA" - MAGNET COVE INTRUSIVE ZONE - SW, NW, SEC. 20, 3-S, 17-W

TABLE 5.--Partial chemical analyses of selected samples from the Arkansas barite region

Sample number	1	14	15	25	47	49	89	95	98	136	145
loss	4.43	8.97	0.34	0.76	N	N	N	N	N	0.02	0.96
SiO_2	70.00	68.52	98.65	21.73	7.74	41.01	28.08	18.94	16.70	83.16	92.57
Fe_2O_3	3.20	8.00	...	tr	0.80	13.40	2.00	2.80	2.60	8.80	5.00
Al_2O_3	12.30	13.40	...	tr	1.25	24.10	2.95	1.00	0.55	7.00	1.80
CaO	...	...	...	tr	0.99	2.36	0.93	0.26	2.36	tr	tr
$BaSO_4$	1.21	1.20	...	77.56	86.91	4.14	64.29	76.59	78.44	0.20	0.16
$SrSO_4$	0.17	0.57	...	0.18	0.41	11.37	0.39	0.31	0.36	0.34	0.16
MgO	0.26	0.37	...	tr	tr	tr	tr	tr	tr	tr	tr
Na_2O	N	N	N	N	N	0.26	N	N	N	0.11	0.10
K_2O	N	N	N	N	N	7.15	N	N	N	0.96	0.34
TiO_2	0.73	0.68	...	tr	tr	1.42	0.56	0.44	0.57	tr	tr

Analyst: T. W. Carney

N - not determined; ... - not detected
Total Fe reported as Fe_2O_3

TABLE 5.--Continued

Sample Description

1. Stanley shale--20' above novaculite south side Lucinda Creek syncline; NW1/4SW1/4 sec. 10, T. 3 S., R. 17 W.
14. Footwall black shale--east end Chamberlin Creek syncline; NW1/4NW1/4 sec. 14, T. 3 S., R. 17 W.
15. Massive Arkansas novaculite--6' below no. 14.
25. Stanley shale--34' above novaculite, north limb Reyburn Creek syncline; SE1/4SE1/4 sec. 13, T. 3 S., R. 17 W.
47. Massive barite ore--south rim Chamberlin Creek syncline; NE1/4NE1/4 sec. 15, T. 3 S., R. 17 W.
49. Altered dike--Baroid pit "A", Chamberlin Creek syncline; NE1/4NE1/4 sec. 15, T. 3 S., R. 17 W.
89. Massive barite ore--Gap Mountain deposit; SE1/4SE1/4 sec. 24, T. 4 S., R. 26 W.
95. Nodular ore--Henderson property, Fancy Hill district; NW1/4NW1/4 sec. 29, T. 4 S., R. 26 W.
98. Massive ore--10' below no. 95.
136. Siliceous shale zone below barite--Yount property, Gap Mountain deposit; SE1/4SE1/4 sec. 24, T. 4 S., R. 26 W.
145. Pebbly sandstone--Mazarn Ridge; NE1/4NW1/4 sec. 30, T. 4 S., R. 23 W.

inaccurate methods of quantitative analysis and the inclusion of too many rare rock types to obtain the average. Goldschmidt gives 0.046 percent titanium as the average present in terrestrial muds and marine shale and further suggests that this is more accurate for the lithosphere than the averages given by Clarke and others.

The ionic radius of quadrivalent positive titanium is 0.64A°, or half the size of barium (1.46A°). There can be no substitution between the ions of these elements. Titanium, trivalent or quadrivalent, has a strong electric potential and in open systems unites with oxygen to form highly insoluble titanium oxides. The presence of titanium on the order of several thousand parts per million in barite ore consisting of as much as 87 percent barium sulfate shows that the titanium has been introduced and is not part of the original sediment.

Summary of origin and age. The evidence that the replacement type barium sulfate deposits were derived from the igneous rocks of the Gulf Coastal province can be summarized in the following manner: (1) The barite deposits are almost identically located with respect to structure and stratigraphy, and contain the same types of ore. (2) In each of these metasomatic deposits the precipitation of barium sulfate was followed by the precipitation of ferrous sulfide in the form of pyrite. (3) The igneous rocks of the Gulf Coastal Plain Cretaceous province are essentially saturated with barium and titanium. (4) The crystalline barite in these replacement bodies is characterized by an excess of titanium. (5) The igneous rocks and the barite deposits have a similar restricted suite of trace elements. (6) The Magnet Cove intrusion truncates the southwest end of the syncline containing the largest known barite deposit in the region. (7) Igneous dikes representing the second phase of the Magnet Cove intrusives cut through the Stanley formation in the Chamberlin Creek syncline, and were highly altered and slightly mineralized by the barite, pyrite and rutile-bearing solutions. (8) Igneous rocks as plutonic masses occur in the area from Little Rock southwest to Murfreesboro. (9) Concentrations of volcanic ash in the lower Upper Cretaceous strata of Arkansas indicate contemporaneous igneous activity. (10) Calc-alkalic dikes are known from the northern edge of the Coastal Plain to the Arkansas River, showing that the period of igneous activity was widespread and could have been the source of all these replacement deposits.

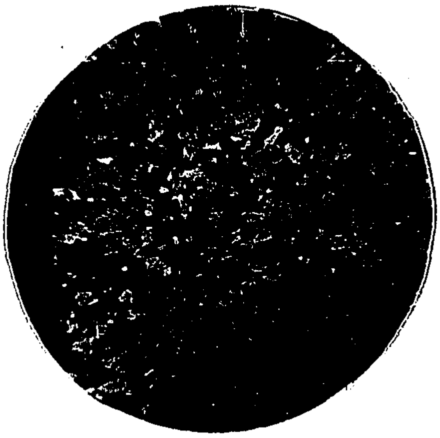
<u>Paragenesis</u>. The paragenetic sequence in these barite deposits is uncomplicated, but relating them to the stages of igneous activity entails considerable speculation. In the Chamberlin Creek syncline the barium-bearing solutions invaded the sequence of siltstones, silty shales, and clay shales, some members of which contained indigenous pyrite. In the later stages of the barite formation, pyrite was precipitated from solution and continued to form for some time

after the barium sulfate precipitation had ceased. After this period of sulfate and sulfide precipitation, the sequence of solutions rich in carbonates invaded the mineralized zone, replacing the barite in part. The carbonate is mostly calcite, but it contains a relatively high percentage of strontium. Apparently no witherite (barium carbonate) was formed during this period of replacement. The ore zones with the higher carbonate content, up to 11 percent, contain no more titanium than those in which the carbonate is very minor or absent. The titanium minerals in the Cove proper are associated with the carbonate veins. However, the titanium in the rim of the Cove is associated with quartz derived from the alteration of the novaculite. Brookite occurs on the southwest end of each of the anticlines bordering the Chamberlin Creek syncline. The titanium found with the barite may have been deposited during this period of mineralization. It is not possible to establish any sequence for the barite, brookite, and carbonate periods of deposition, but the above order appears to be the most reasonable. The fact that the dikes cutting the sediments in the Chamberlin Creek syncline are mineralized indicates that the barite, brookite (rutile), and carbonate mineralization were associated with the final stages of the Magnet Cove intrusive activity.

The barite bodies of the Pigeon Roost and Fancy Hill districts contain about the same percentage of titanium as do the barite zones in the Magnet Cove district, but the carbonate phase is not present in these western districts. The paragenetic sequence in these districts is barite succeeded and partly overlapped by pyrite with a later stage suggested for the titanium. Small veinlets and seams of crystalline barite may have formed during the period of introduction of titanium, or they may represent a much later stage of secondary concentration.

In all three of these replacement districts small irregular veins of quartz are present in the Stanley shale. A few of these veins cut the ore zone but most of them are stratigraphically above it. The relations of these quartz veins to the country rock are best seen in the cores made available from the diamond-drill coring programs of the companies operating in these districts (Plate XLII). Some of the shale adjoining and nearly all of that included in the quartz veins has been chloritized. Sulfides, particularly in vugs and fractures, are abundant in the quartz veins and the adjoining wall rock. Pyrite forms over 95 percent of the sulfides, but arsenopyrite, molybdenite, sphalerite, and galena were recognized. Most of the sulfides are later than, and were deposited on, the quartz, but some of the sulfide crystals are enclosed within the quartz veins. Some of these quartz veins cut the barite ore, showing that they are later than the barite, but other than that their age has not been determined. The thoroughly altered condition of much of the

PLATE XXXVII



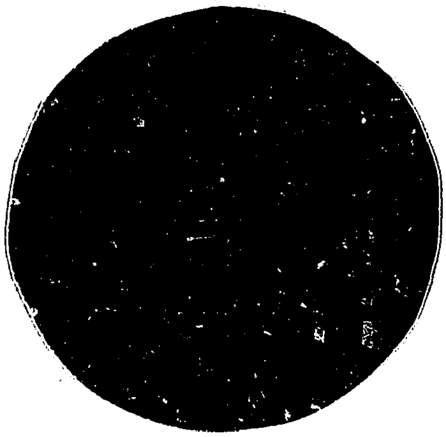
(A)

(B)

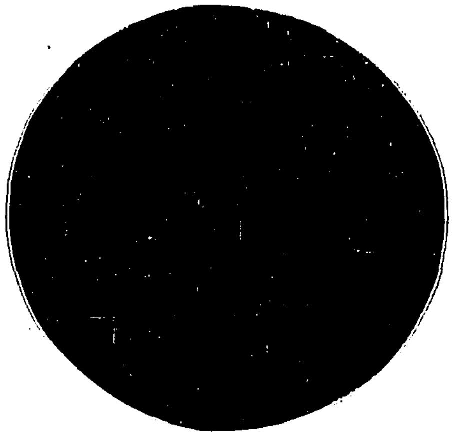
(A) Photomicrograph showing the quartzitic nature of the Upper Arkansas novaculite in the Chamberlin Creek syncline. Crossed nicols; X 13; section 8.

(B) Photomicrograph of the black shale at the base of the Stanley formation in the Chamberlin Creek syncline. Plane polarized light; X 13; section 14.

PLATE XXXVIII



(A)

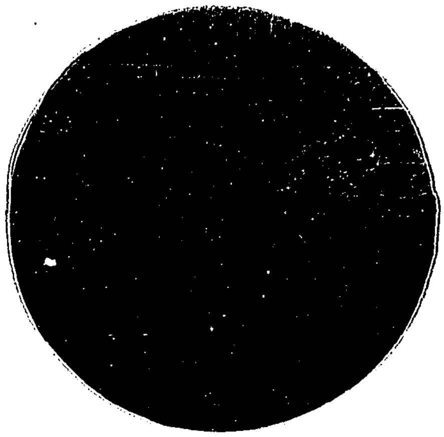


(B)

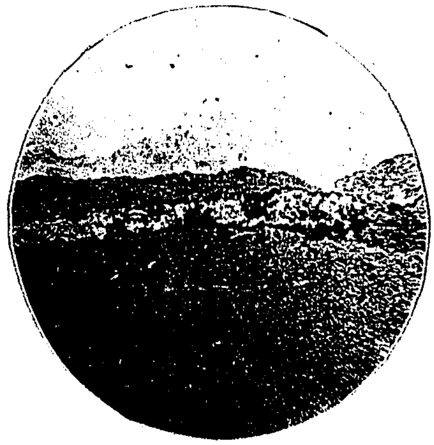
(A) Photomicrograph showing pyrite (black) partly replaced by fibrous barite, massive barite zone, underground workings, Magnet Cove district. Crossed nicols; X 46; section 56.

(B) Photomicrograph of a portion of the field of (A); crossed nicols; X 625.

PLATE XXXIX



(A)

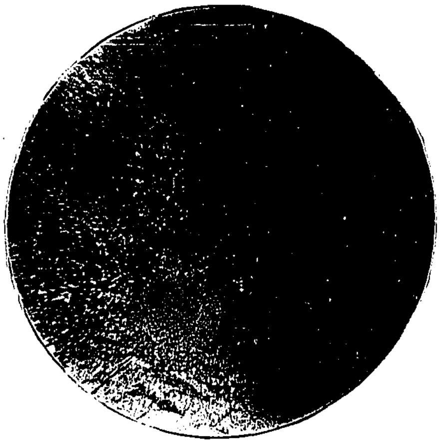


(B)

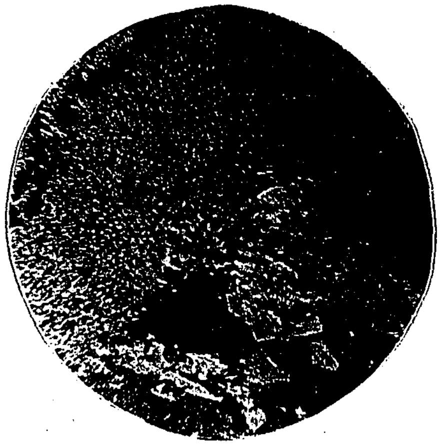
(A) Photomicrograph of rounded quartz (clear gray) partly replaced by barite (mottled gray) with pyrite (black) replacing the earlier minerals. Near top of mineralized zone in underground workings, Magnet Cove district. Plane polarized light; X 13; section 73.

(B) Photomicrograph of veinlet of barite (white) cutting shale (gray) and partly replaced by pyrite (black). Above massive ore zone, Baroid pit, south limb of Chamberlin Creek syncline. Plane polarized light; X 13; section 45.

PLATE XL



(A)

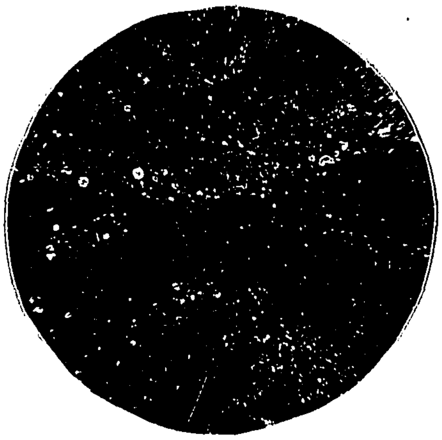


(B)

(A) Photomicrograph of barite (mottled gray) partly replaced by calcite (light gray), late stage vein cutting barite ore body. Baroid pit, Magnet Cove district. Plane polarized light; X 13; section 33.

(B) Same view with nicols crossed.

PLATE XLI



(A)

(B)

(A) Photomicrograph showing differential replacement of silty shale (black) by barite (gray); white specks are barite crystals and spherulites. North wall Baroid pit, Magnet Cove district. Crossed nicols; X 46; section 147.

(B) Photomicrograph of "clay" dike cutting ore zone, underground workings, Magnet Cove district. Crossed nicols; X 208; section 49.

Many of the dikes in the Chamberlin Creek deposit are thoroughly altered to submicroscopic particles. These "clay" masses flow plastically when penetrated by mine operations, causing difficult and sometimes hazardous working conditions.

PLATE XLII

Photograph showing vugular quartz veins transecting bedding planes of the Stanley shale. Bright specks in the vugs are metalliferous sulfides. Above barite zone, Magnet Cove district.

PLATE XLIII

Photograph of crystalline barite along fracture face in Stanley shale. West end, Baroid pit, Magnet Cove district.

PLATE XLIV

Photograph of Ba, Sr and Ca carbonate veins (white) cutting dense barite (black). Foot wall ramp, Baroid pit, Magnet Cove district.

igneous rock in Magnet Cove indicates that pneumatolytic and hydrothermal action continued for some period of time after the igneous magma had completely crystallized.

Cemented Deposits

General statement. The deposits in which barite is present as a cementing material in clastic rocks are restricted to the Dierks district where the barite occurs as cement in the Pike gravel, and the lower sandstones of the Trinity. In these deposits, the barite is present almost entirely as pore filling, except where it has made additional space through the force of crystallization. Metasomatism is so slight that it can be considered to be absent. Barite was precipitated at a rate slow enough to allow the development of large crystals which incorporate a number of quartz grains; optically continuous barite crystals, up to three inches in their largest dimension, are common.

Origin and emplacement. In most cases where barite occurs as a cement in sandstone or conglomerate the concentration of the barium sulfate has been attributed to the action of ground water or precipitation from marine water (Ham and Merritt, 1944). The available evidence indicates that the barite cement in the members of the Trinity was precipitated from hydrothermal or, perhaps, telemagmatic solutions, but that ground water controlled to some extent the sites of deposition. The zones of barite concentration in these deposits are lenticular and quite irregular vertically and horizontally. In the sandstones the zones of barite concentration are governed as far as can be determined by concentration of clays and iron oxides that control the porosity. However, this is not true in the gravels. Vertical veinlets of coarsely crystalline barite suggest that the barium sulfate-bearing solutions may have migrated from one zone to another vertically as well as horizontally.

The writer has carefully evaluated the data pertaining to the origin of the barite occurring in the Trinity beds. The possible origins considered were precipitation from marine waters, precipitation from ground waters, precipitation from surface waters, precipitation from hydrothermal solutions, and an emplacement involving two or more of the above processes. Precipitation from marine waters appears to be the weakest interpretation. The barite occurs in the lower units of the Trinity, which are essentially coarse clastics. An area of deposition of coarse clastics is not ordinarily also an area of deposition of chemical precipitate at rates and in amounts sufficient to produce large crystals. Precipitation from ground water is not the most satisfactory interpretation for the origin of the barite cement because there is no apparent source of barium in the rocks immediately adjacent to the Trinity beds. It cannot be presumed that the relatively insoluble barium sulfate could be transported any great distance in ground water with ordinary temperatures and chemical makeup. The irregular geographic and stratigraphic distribution of the barite cement almost precludes the possibility that barium chloride or other readily soluble barium salt-bearing ground water reacted with sulfide or sulfate-bearing interstitial fluids to precipitate barite.

The theory that the barite in the Trinity was derived from the barite in the older sediments is based on several suppositions. Such a theory presumes that barium carbonate or sulfate in the Ouachita Mountains was more subject to chemical than mechanical erosion, and that a drainage system similar to the present drainage pattern transported the barium in solution to the margin of the Gulf Coastal Plain, where the change in stream velocity enabled the barium-bearing waters to seep down into the porous zones of the lower Trinity beds, and deposit the barite. The major arguments against this theory are that there is little or no barium carbonate in the exposed barite deposits in the Ouachita Mountains, and as far as can be determined, the barite in the mountainous area is being removed by mechanical rather than chemical erosion. It is doubtful if appreciable amounts of barium would stay in solution in the well-aerated waters of mountainous streams for considerable distances.

The available data support to a large extent the theory that the barite in the Trinity sediments was derived from igneous sources. Cinnabar-bearing barite veins almost certainly of hydrothermal origin occur less than six miles east of and nearly along the strike of the Trinity units which contain the barite zones. The peridotite plugs in which barite veins occur are less than 20 miles east of south from the barite zones in the Trinity. Ross, Miser, and Stephenson (1929, p. 190), after an extensive study of the tuffaceous beds of the Cretaceous in southwestern and northeastern Texas concluded, on substantial evidence, that volcanic necks are present in the vicinity of Locksburg and Nashville. These postulated centers of igneous activity are 8 to 15 miles south of the barite areas. There are no known igneous masses nearer to the sites of barite deposition than these, although one or more could be present beneath the Cretaceous cover.

Not only are possible igneous parent rocks present in the vicinity of these barite deposits, but the trace element suite of this barite is similar to the suites in the replacement-type barite deposits and the igneous rocks of the Gulf Coastal Plain province (Table 4).

The erratic distribution of the barite in the Trinity beds forces the writer to prefer the alternative that the concentration of the barite was effected by more than one process. The writer believes that barium-bearing hydrothermal solutions derived from igneous masses associated in time and position with the nearby plugs, volcanic necks, and cinnabar-barite veins were the sources of the barium sulfate cementing the Trinity clastics. These solutions migrated up dip or along strike to sites where intermingling with ground water occurred. This intermingling was most pronounced in the more porous zones of the Trinity as these zones contained larger amounts of formational water. The hydrothermal solutions were cooled so that the barium sulfate was precipitated. The volume of hydrothermal solutions must have been much greater than that of the ground water because the cooling was not so rapid as to inhibit the growth of large barite crystals. The rate of precipitation was probably uniform, as the large barite crystals display no growth or zoning lines.

Associated sulfates. The Dierks limestone is in the zone which contains the barite bodies. Celestite beds or veins occur in the shale or sandstone unit overlying the Dierks limestone. This zone is considered by Miser and Purdue (1929, p. 83) to be in the lower part of the De Queen limestone member of the Trinity. Gypsum also occurs in this member. The gypsum horizon is above the celestite horizon and may represent a period of partial evaporation of the Trinity seaway. The gypsum beds are stratigraphically conformable with the adjoining strata, which suggests that they were deposited as part of the sedimentary sequence. The granular nature of the gypsum has no significance as to source for the writer. The celestite bodies are lenticular and coarsely crystalline. The exposures examined were too poor to determine if the bodies were concordant or discordant with the containing strata. The observable discordance may be more apparent than real because the bodies are lenticular. However, the writer believes that the celestite bodies are veins, are slightly discordant and are associated spatially and in time with barite in the underlying Trinity clastics. The barite in the Dierks district, as did the barite in the other districts of the region, yielded 0.5 to 8.0 percent strontium sulfate in chemical and spectrographic analyses.

It could be argued that the sulfates in the Trinity formation, the barite, celestite, and gypsum, with their ascending distribution represent a discontinuous evaporative sequence. The writer does not accept this possible interpretation. The Dierks limestone and thick coarse clastic beds occur above the barite and below the celestite and gypsum horizons. Coarse sand and clay beds occur between the gypsum and the celestite. There is no evaporative sequence discernible in any of the sulfate zones. A common sedimentary origin and a progressive relationship for these sulfate zones seems highly improbable.

The geographic and stratigraphic proximity of the sulfate zones seems to indicate a genetic relationship for these sulfate zones. The presence of 0.1 to 2.0 percent of titanium in the barite, the relative abundance of barium and titanium in the igneous rocks of the region, and igneous rocks and metalliferous barite veins in the general vicinity of the cemented zones strongly suggest to the writer that the barite cement was derived from igneous sources. The high percentage of strontium in the barite in all of the districts within the region indicates that the celestite and barite of the Trinity are genetically related. Other than its proximity, the writer has no evidence to relate the gypsum to the other sulfates. If the gypsum is genetically related to the celestite and barite it probably was deposited as anhydrite and altered to gypsum by hydrolysis.

Vein Deposits

The vein deposits of barite in the Ouachita Mountains probably are not in commercial quantities. They are discussed chiefly because of their role in dating and establishing the mode of origin of the barite in the replacement and cementing deposits.

Discordant veins. Peridotite area. In the peridotite plugs at Murfreesboro, particularly in the Ozark mine, crystalline barite occurs as a cement in the volcanic breccias and as fracture filling. Chalcedonic to massive quartz surrounds the barite crystals in many places. Magnetite and serpentine are the only minerals associated with the barite and they are probably present as inclusions rather than vein minerals. The only paragenetic sequence that can be established is barite followed by quartz.

Cinnabar district. The barite veins in the Cinnabar district occur 12 miles northwest of the veins in the plugs. The cinnabar-bearing barite occurs as fracture filling and emplacements along a fault zone. Nearly all the mines in this district are full of water and interpretations must be based on material that is available on the mine dumps and from the collections of the local citizens. The paragenetic sequence was cinnabar, stibnite, cinnabar and stibnite, barite, barite and cinnabar, presumably extending over some period of time and accompanied locally by minor deformation.

Southeastern Oklahoma. Vein barite in all probability related to those veins under discussion has been reported by Honess (1923, p. 39) from a mine two miles southwest of Watson in sec. 33, T. 1 S., R. 26 E., in the Ouachita Mountains of Oklahoma. The barite here is associated with sphalerite, dolomite, and quartz, with a minor amount of pyrite being present. In this report Honess presents rather conclusive evidence that deformation accompanied at least parts of the mineralization.

Concordant veins in the Middle Arkansas novaculite. The barite veins in the Middle Arkansas novaculite were emplaced along slippage zones between shale and novaculite beds, in fractured and brecciated zones, and along relatively undisturbed bedding planes. All of these veins occur on the steeply folded flanks or the plunging noses of anticlinal structures. In all but one of these vein deposits, the barite is dark gray to black, fine to coarsely crystalline, and exhibits no unusual texture or structural features. The single exception occurs in southwestern Montgomery County where the barite is present in nodules with a feather-like radiating structure (Plate LXIII).

The veins are post-deformation (post-Paleozoic), as they occupy fissures created during the orogenic disturbances. Manganese, to some extent concentrated by ground water (Miser, 1917, pp. 59-122) is associated with some of the vein barite. The manganese occurs as fracture and fault plane filling but also occurs in concentration as pore filling. The manganese was indigenous to and disseminated in the lower and upper novaculite. It is probable that the barite-bearing hydrothermal solutions were more effective concentrating agencies than ground water, at least locally.

Regional Relations of the Barite Mineralization

General Statement

The data presented in the foregoing section are presumed to be sufficient to show that the barite and associated minerals in this region were deposited from hydrothermal solutions derived from igneous sources. In this region two periods of igneous activity can be clearly demonstrated. The earlier occurred in lower Mississippian time when volcanic activity gave rise to the Hatton tuff and the associated pyroclastics. The second period of igneous activity occurred in the lower Upper Cretaceous; namely, post-Trinity-pre-Brownstown. Many writers, including Honess (1923), Stearn (1936), Reed and Wells (1938), and Miser (1943), have postulated a period of igneous activity related to the final stages of the Ouachita orogeny which they place in middle Pennsylvanian time. These writers ascribe the metalliferous deposits in the Ouachita Mountains as well as the remarkable quartz crystals to this period of igneous activity.

The writer believes that the Ouachita orogeny continued into Permian time, that much but not all of the quartz crystal and vein formation took place during the later part of the Ouachita orogeny, and that the metalliferous deposits are not associated with this period of quartz vein formation but are associated with the Cretaceous igneous activity.

The writer's deduction as to the age and magnitude of the Ouachita orogeny are discussed in Chapter II. Miser (1943) and Engel (1946, pp. 598-618) have offered strong evidence to show that the quartz crystals and veins of the Ouachita Mountain region were formed during the later stages of the Ouachita orogeny. However, the quartz veins in the ultramafic rocks near Murfreesboro, those formed from reconstituted novaculite by thermal waters at Hot Springs, and the quartz veins associated with the brookite at Magnet Cove show that there was some post-Paleozoic quartz vein formation.

In previous sections evidence has been presented to show that a barium-rich igneous suite of Cretaceous age occurred in the Gulf Coastal province and the adjoining parts of the Ouachita Mountains. The available data were interpreted as indicating that these igneous rocks were the sources of the barite occurring in the region. As the cinnabar of the region is associated with barite veins, it was concluded that the cinnabar is also of Cretaceous age. Stibnite is associated with the cinnabar, suggesting a genetic relationship between the quicksilver belt and the antimony deposits of northern Howard and southern Polk Counties to the north. Lead, zinc, and copper sulfides are associated with the stibnite in the antimony deposits, indicating that the sphalerite-galena-chalcopyrite deposits of central Polk County and lead-zinc deposits with barite gangue in southeastern Oklahoma are related to the barite-cinnabar deposits and are Cretaceous in age.

The foregoing suggested age and genetic relationships are supported by the nature of the sulfide minerals and their spatial occurrence. Stibnite and particularly cinnabar are epithermal minerals and are ordinarily deposited within a few hundred feet of the surface of the ground. Six to 12,000 feet of Atoka and Jackfork strata had to be removed by erosion before the mineralized zones were close enough to the surface to serve as loci for cinnabar-stibnite deposition. The writer does not believe that this amount of truncation could have occurred after the Atokan deposition and before middle Pennsylvanian or even lower Permian time without leaving some record of rapid denudation in the strata of the adjoining regions. Therefore the spatial relationships of the sulfide deposits are considered as further evidence that the metalliferous deposits of the Ouachita Mountains are genetically related to the barite and are Cretaceous in age.

CHAPTER IV

THE BARITE DEPOSITS - MINES AND PROSPECTS

Magnet Cove District

General Statement

The Magnet Cove district includes parts of Tps. 3 and 4 S., Rs. 16, 17 and 18 W., 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 of Cretaceous age, 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 Zig Zag Mountains, the northernmost part of the Trap Mountains, and the Magnet Cove intrusive masses. The major barite deposit, the only one presently being mined in Arkansas, is located in the Chamberlin Creek syncline, one of the southwestward plunging synclines of the Zig Zag Mountains. Minor amounts of barite are present in the Cove Creek syncline northwest of the Chamberlin

Creek syncline, in the Reyburn syncline on the southeast, and in the Trap Mountains to the south. Most of the barite in the Cove Creek structure is of the nodular type; that in the Reyburn syncline and the Trap Mountains is mostly massive.

Chamberlin Creek Syncline

<u>History of Development</u>. The discovery and earlier investigations of barite in the Chamberlin Creek syncline have been discussed by Parks (1932, pp. 8-9):

> Barite was first discovered in Arkansas in Hot Spring County about 1900 when a water well was dug on the Casey homestead two miles east of Magnet Cove. Because of its heavy weight, the mineral was thought to be a lead mineral and some search for lead minerals was made in this vicinity. Then in 1911 when the well was cleaned out, some of the barite was seen by John Inglis, Hot Spring County Surveyor, of Magnet, Arkansas, who recognized that it was not a lead mineral but who was unable to make a correct identification. Mr. Inglis later took samples to Joe Kimzey, of Magnet, and to A. E. Perkins, a mining engineer, both of whom identified the mineral as barite. In 1915 Mr. Kimzey, in examining the locality, found small fragments of barite mixed with clay and gravel which had been brought to the surface by uprooted trees near the Casey well. By examining the pits made by the uprooting of these trees, Mr. Kimzey was able to trace the barite in a narrow zone for approximately three-fourths of a mile, and by digging in the bottom of the pits encountered solid barite in a few places.
>
> Samples of the barite were first brought to the Arkansas Geological Survey in September, 1928, by E. E. Bonewits, of Little Rock. A specimen was analyzed and found to contain 82.60 percent barium sulfate and 12.98 percent silica, the samples being identified as pure barite. The locality in which the mineral occurred was reccommended for testing to several persons including Moritz Norden, of the Wil-Nor Development Company, who was referred to Joe Kimzey by the Survey in the late summer of 1930 in regard to the location of the deposit. Mr. Norden became interested and, through the Wil-Nor Development Company, acquired leases and began prospecting.

Parks mapped the barite and the related rocks in intermittent periods from November, 1930, to June, 1931. The only exposures of barite available to Parks for study were those in the trenches and shafts dug by the Wil-Nor Company. However, in May, 1931, the Southern Acid and Sulphur Company of St. Louis, Missouri, entered into an agreement with the Wil-Nor Company and drilled 34 holes on the north side of the deposit. Parks was permitted to study the analyses of the cuttings from these drill holes, but was not allowed to publish the results. This period of prospecting terminated in June, 1931.

Parks' (1932, pp. 46-52) report contains metallurgical reports from the U. S. Bureau of Mines and the Denver Equipment Company showing that the barite ore from the Chamberlin Creek area could readily be concentrated to about 90 percent barium sulfate and by reflotation even higher concentrates could be obtained. In spite of these favorable reports, no sustained effort was made to mine and mill barite in this area until 1939 when the Magnet Cove Barium Corporation started operations. In 1941 the National Lead Company began mining a portion of the same deposit.

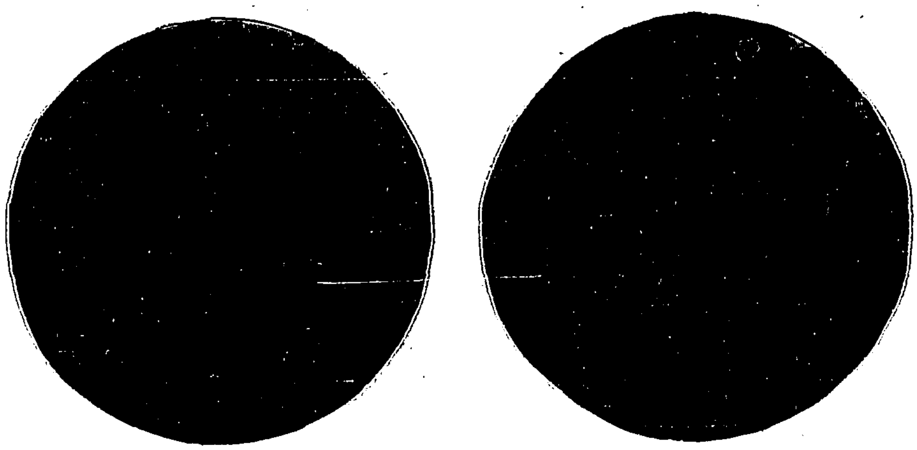
The annual production of barite from this district from 1935 to 1955 is shown in Table 1. Nearly all of the barite produced by these companies is sold for use as weighting material in drilling mud. Magcobar is the trade name of the Magnet Cove Barium Corporation, and Baroid is the trade name for the National Lead Division.

Local structure. The Chamberlin Creek syncline is truncated on the southwestern end by the Magnet Cove intrusives in the eastern part of sec. 17, T. 3 S., R. 17 W. From this locality, the syncline extends northeastward with a sub-symmetrical outline for about two miles. From near the northwest corner of sec. 14 to near the center of the southeast quarter of sec. 11, the axial trend is a few degrees north of east. Although the surface trace of the stratigraphic units within this syncline is roughly symmetrical, structurally the syncline is decidedly asymmetrical, with the southeast limb being steeper and locally overturned. The bounding limbs of the adjacent overturned anticlines in some cross sections (Plate IV) give the syncline an amphoral shape.

There are a great number of faults cutting the sediments in this syncline with displacements ranging from a fraction of an inch to two feet. Both pre- and post-mineralization occur. Nearly all of the post-mineralization faults, both underground and surface, seem to be the result of rock adjustments to the mining operations.

In the rock exposures made available by the underground mining operations, many more local structures can be seen than anywhere in the district. In the open pit workings the blasting operations have destroyed much of the continuity of the rock surface, making it difficult to

PLATE XLV



(A) (B)

(A) Photomicrograph of rounded coarse sand grains in silty shale above mineralized zone in Kimzey drift of the underground workings of the Magnet Cove Barium Corporation. Plane polarized light; X 13; section 72.

(B) Same view with nicols crossed.

PLATE XLVI

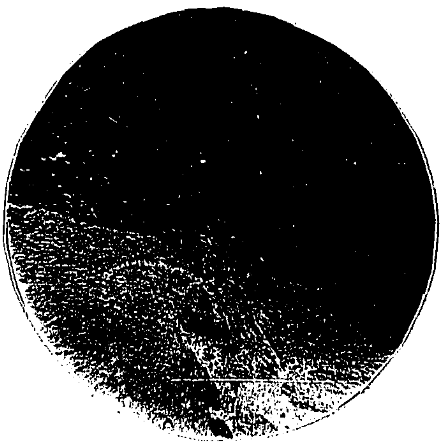
(A)

(B)

(A) Highly altered dike of Ouachitite (?) with the biotite (black) later than the analcite (?) (light gray to gray). Barite (whitish gray) cuts both igneous minerals. South rim of Baroid pit, Magnet Cove. Plane polarized light; X 46; section 37.

(B) Same view with nicols crossed. Barite at extinction.

PLATE XLVII

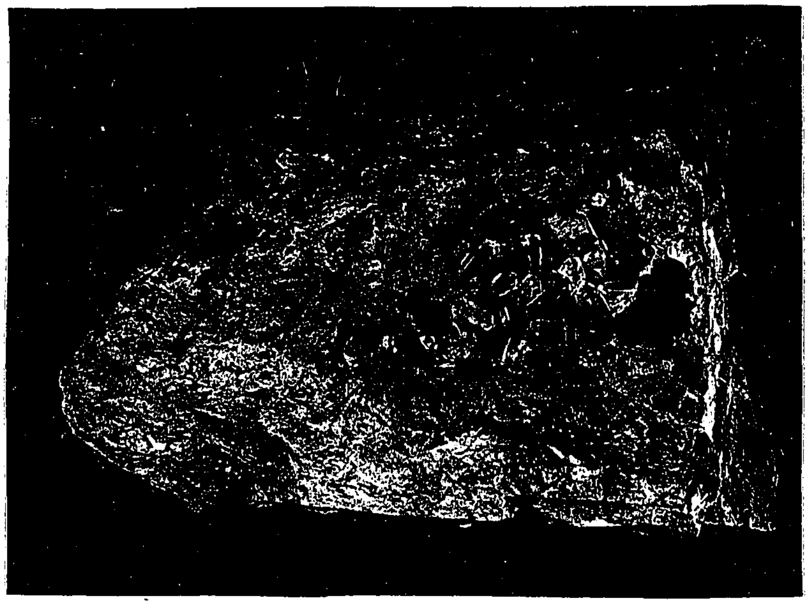


(A) (B)

(A) Photomicrograph of crumpled shales at apex of V-fold, underground workings, Magnet Cove district. Plane polarized light; X 13; section 79.

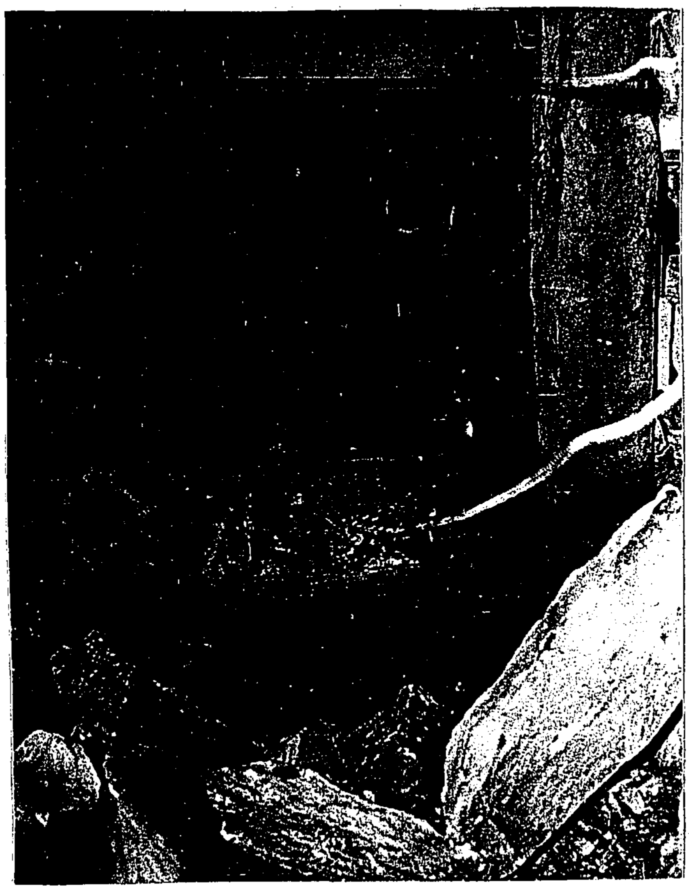
(B) Photomicrograph of pebble conglomerate in basal part of Stanley formation, novaculite pebbles (black) and siliceous cement. Yount property, Gap Mountain, Fancy Hill district. Crossed nicols; X 13; section 137.

PLATE XLVIII



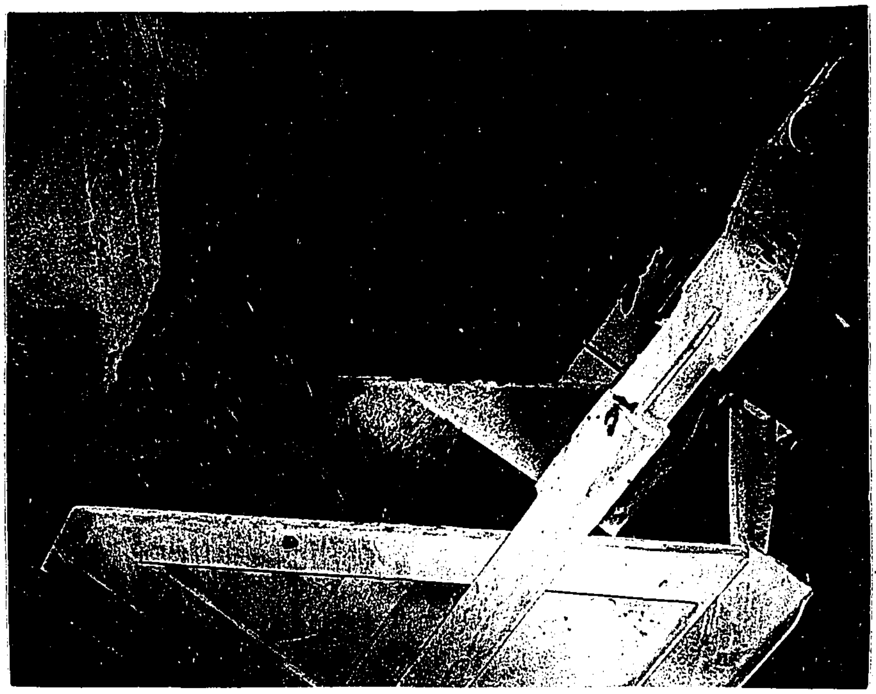
Photograph of transparent barite crystals in a vug in the Stanley shale 60 feet above the replacement zone in the Baroid Strip Mine, Magnet Cove district. (Photographer, Harry Smith, Jr.)

PLATE XLIX



Photograph showing operations in a scraper drift, Magcobar underground mine, Magnet Cove district. (Photographer, Fred A. Burnett)

PLATE L

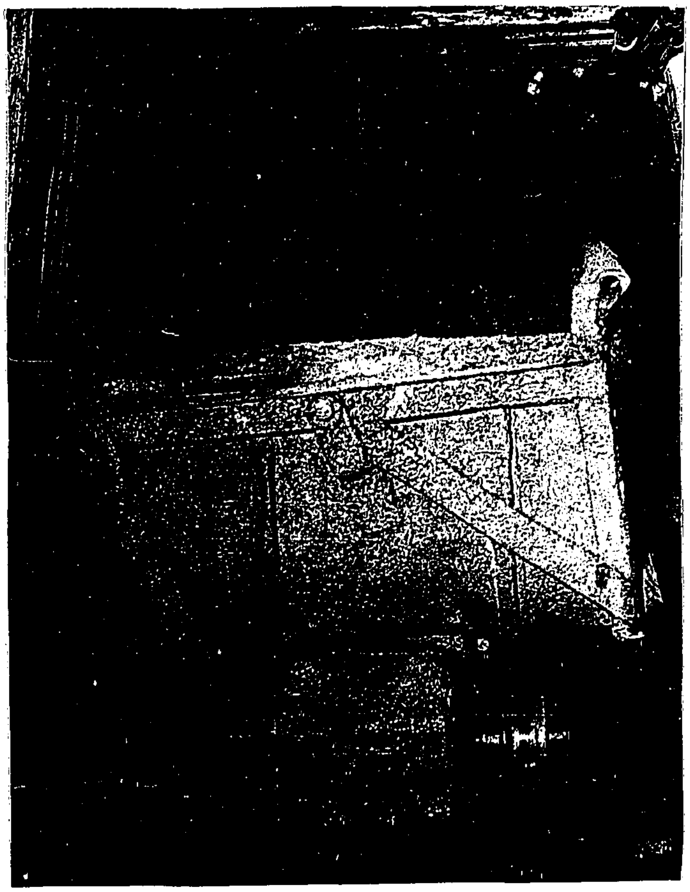


Photograph of skip loading at ore pocket, Magcobar mine. The ore is pulled up the inclined shaft and dumped into railroad cars at the surface. (Photographer, Fred A. Burnett)

PLATE LI

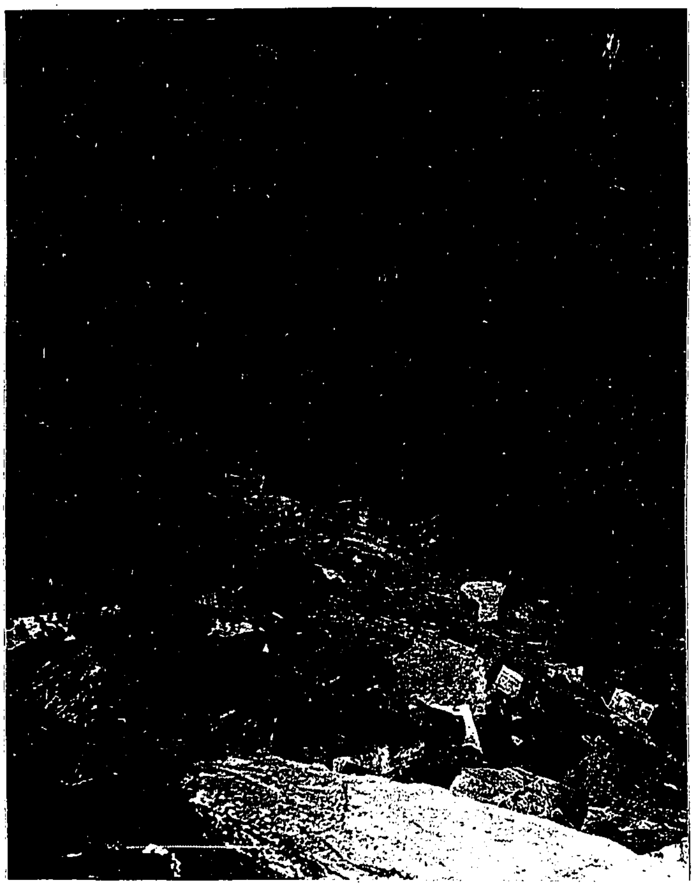
Photograph showing "mucking machine" loading ore cars in haulage drift, Magcobar mine. (Photographer, Fred A. Burnett)

PLATE LII



Photograph of ore cars being loaded at ore shoot from "raise," Magcobar mine. Water removal is an almost constant problem in the mine. (Photographer, Fred A. Burnett)

PLATE LIII



Photograph of dark gray massive barite, "top slice," Magcobar mine, Magnet Cove district. (Photographer, Fred A. Burnett.)

distinguish between structures formed by tectonic forces and those formed by the blasting operations. Underground, minor structures in the form of V and chevron folds, roll-overs, and normal and reverse faults are common (Plate XLVII A). 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 tenor of the ore along the axes of some of the folds.

Stratigraphic relations. In this deposit the Arkansas novaculite forms the floor of the mineralization. In the anticlines flanking the Chamberlin Creek syncline the lower and middle divisions are typical, the lower division is massive, and the middle division is thin bedded. The character of the upper division which is not everywhere present is somewhat different in this area than in other parts of the Ouachita Mountains. The upper division consists of alternating layers of dense, cryptocrystalline novaculite, mostly white or pink, and light gray, medium-grained quartzite. These two lithologies are present in beds ranging in thickness from 2 to 8 feet.

Everywhere in the Chamberlin Creek syncline where mining operations or core drilling enable the stratigraphic sequence to be studied, the novaculite is overlain by a black shale, ranging in thickness from 2 to 22 feet (Plate XXXVII B). This black shale is considered part of the mineralized zone. At the base of the black shale is a zone containing small pebbles which is ordinarily a fraction of an inch thick but does range up to a thickness of four inches. The pebbles are chiefly novaculite, but iron-stained clay pebbles are present.

At other places in the district, the novaculite is overlain by a quartzitic sandstone at the base of the Stanley. This quartzitic sandstone cannot readily, microscopically or megascopically, be separated from the quartzites of the novaculite. Exposures in a cut along the Chicago-Rock Island and Pacific Railroad near the east end of the center line in sec. 27, T. 3 S., R. 17 W., were the only ones seen by the writer in which the basal quartzitic sandstone of the Stanley was separated by an interval of Stanley shale from the quartzites of the novaculite, which indicates that all the quartzite does not belong to the novaculite formation. This quartzitic sandstone unit and some of the quartzite of the novaculite were mapped as the Hot Springs sandstone by Parks (1932). As discussed under regional stratigraphy, the writer does not believe the term Hot Springs is applicable to this area.

In the area of the mine workings there is a maximum of 600 feet of Stanley shale, sandstone, and siltstone overlying the black shale unit. This formation is probably about 2000 feet thick near the contact with the Magnet Cove intrusion. Elsewhere in the district, the thickness of the formation could not be determined because of the intricate crumpling of the beds and the deep weathering, which obscured any marker beds if such were present.

The ore bodies. The barite deposit in the Chamberlin Creek syncline is located in the northeastern part of the structure (Plate X). It has a maximum length of 3200 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 (1800 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 (Plate XII). 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 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. There is considerable variation of tenor in the ore of the commercial zone, as well as considerable variation in the hardness or resistance to grinding which affects the desirability of the ore with respect to mining costs and adjustments in the milling program.

Character of the ore. The barite ore in this deposit is discussed, in a general way, in the section on types of ore. All four of the varieties discussed under Replacement Type Deposits are to be found in this zone. The nodular type ore makes up from 3 to 30 percent of the ore body, depending on the section measured. It appears to be more prevalent on the flanks of the syncline, perhaps because of the effects of weathering. Coarsely crystalline barite is rare in this deposit. Most of the ore is of the gray or dark gray dense variety. Much of it has, superficially, a close resemblance to a dense limestone, which has led some observers to postulate that the barite replaced a limestone. The petrographic evidence will not support this interpretation.

Reyburn Creek Syncline

The barite deposit in the Reyburn Creek syncline occurs on the north limb of the structure. This limb is overturned and the dip at the contact of the Stanley shale with the Arkansas novaculite is 45° to the north, with the amount of overturning diminishing to the vertical near the axis of the fan-folded anticline bounding the syncline on the north.

Lenses of barite occur stratigraphically above and topographically below the Arkansas novaculite in the

NE1/4SW1/4 sec. 18, T. 3 S., R. 16 W., and the SE1/4SE1/4 sec. 13, T. 3 S., R. 17 W. The thickest mineralized zone determined was 25 feet, of which a maximum of 12 feet would be commercial ore. The various lenses range in length from 40 to 900 feet. In the spring of 1955 the Magnet Cove Barium Corporation stripped the overburden from the topographic face of this deposit without finding much evidence to indicate appreciable amounts of reserves.

Cove Creek Syncline

The Cove Creek syncline is the downfolded structure immediately northwest of the Chamberlin Creek syncline. The Lucinda Creek syncline is a prong of the Cove Creek syncline along its southeastern margin (Plate III). The Lucinda Creek prong is separated from the main part of the structure by a narrow elongate anticline projecting southwestward into the Cove Creek structure.

A zone of barite extends along the southeast limb of the Lucinda Creek syncline. Abundant novaculite float and the deeply weathered condition of the Stanley shale prevented any extensive tracing of this barite zone. From a road cut in the NW1/4SW1/4 sec. 10, T. 3 S., R. 17 W., discontinuous exposures of this horizon, which is approximately 35 feet above the novaculite-Stanley contact, were traced about one-fourth of a mile to the southwest and about 2 1/4 miles to the northeast.

The barite as seen was mostly of the nodular type, although some massive and crystalline material was observed. The maximum thickness noted was about 15 feet. The poor quality of the exposures prohibits making any estimates as to maximum or average thickness of the mineralized zone.

Assays of samples from this zone made in the chemical laboratories of the Arkansas Geological Survey show a barite content of 2 to 84 percent in various samples. A well-planned trenching program would be necessary to evaluate this mineralized zone.

In the NW1/4 sec. 2 and the SE1/4 sec. 3, T. 3 S., R. 17 W., on the north limb of the anticline projecting into the Cove Creek syncline, massive crystalline and nodular barite was observed in the float from 20 to 150 feet above the Stanley-novaculite contact. In this case, and in all others where a reference is made to the Stanley-novaculite contact, unless specifically stated otherwise, "above the contact" means stratigraphically above and topographically below.

A drill hole of the U. S. Bureau of Mines drilled near the closure of the Cove Creek syncline in the SE1/4SE1/4 sec. 35, T. 2 S., R. 17 W., in Garland County, drilled through 360 feet of the Stanley shale and bottomed in the Arkansas novaculite without encountering any barite. Calcite seams and pyrite were reported from the shale just above the novaculite contact (McElwaine, 1946 A, p. 20).

Trap Mountains

In the northern part of the Trap Mountains in the southern part of the district, small lenses and pods of barite were noted in numerous places. The mineralization, as seen, lacks the continuity to be called a zone or horizon. A sample of Stanley shale collected from a cut on the Chicago-Rock Island-Pacific Railroad in the northern part of sec. 33, T. 3 S., R. 17 W., was submitted to the laboratory for an analysis which was to represent the chemical makeup of unaltered, unmineralized Stanley shale. Analysis shows that this shale contained 5.5 percent barium sulfate.

The greatest concentration of observed barite mineralization in the Trap Mountains was noted near the center of sec. 31, T. 3 S., R. 17 W. Several pods of barite a few inches thick and only a few feet long and assaying as much as 87 percent barium sulfate were observed in this area. A rather dense vegetation cover and the weathered condition of the rocks made it impossible to determine the amount of barite that could possibly be present in this area. The veinlets and pods are mostly earthy or shaly-appearing in the weathered state. Where fresh samples could be obtained the barite resembled closely the massive barite in the Chamberlin Creek syncline in that it had an appearance similar to that of a dense crystalline limestone.

Mazarn Basin

West of the Magnet Cove intrusions in the Mazarn Basin, the Stanley is for the most part deeply weathered. All of the roads, stream valleys, and utility line rights of way were worked rather closely in order to find fresh samples of the Stanley formation. Fifteen such samples from scattered localities were analyzed and each contained less than one percent barium sulfate, from one-half to two percent pyrite, and from a trace to five percent carbonate, substantiating, to some degree, the idea that the mineralization of the replacement deposits is restricted to that part of the formation immediately overlying the Arkansas novaculite.

Mining Operations

The Baroid Division of the National Lead Company is mining the eastern half of the deposit, and the Magnet Cove Barium Corporation is mining the western half. In the portion of the deposit controlled by the National Lead Company, the ore is recovered entirely by stripping operations. The engineers of this company (Chaney, 1954) anticipate initiating underground operations where the overburden is too thick to make the stripping economical.

The Magnet Cove Barium Corporation in their initial operation strip-mined along the limbs of the syncline. After a few years of operation the excessive overburden in this deeper part of the syncline necessitated opening underground operations. The company sank an inclined shaft on the north limb of the syncline and to date has opened two levels of operation (Plate XIII). The company has driven one drift completely across the syncline, the geology of which is shown by the cross section on Plate IX.

The open pit mining operations of the National Lead Company are governed by the requirements of the mill, the structure of the ore body, and the character of the ore. The general procedure is to mine along the flanks and east end of the structure toward the center of the syncline in order to minimize the amount of waste removal and to utilize the existing haulage ramps without making major alterations. The waste is dumped in areas adjoining the mine and the ore is hauled to a mill located on the property.

The Magnet Cove Barium Corporation, in the underground workings, has used a great variety of mining methods, with scraper drifts and stopes being the most common (Plates XLIX-LII). Local areas of bad ground require some deviation from standard mining methods. The ore recovered from this mine is shipped by rail to Malvern, where the company's mill is located.

Pigeon Roost District

Discovery and Description

The Pigeon Roost barite district is located at the western end of Pigeon Roost Mountain, in the southern part of Montgomery County. The barite occurs as lenticular bodies in sec. 25, T. 4 S., R. 24 W., and sec. 30, T. 4 S., R. 23 W. According to Jones (1948, p. 5) the barite of this district was first discovered in November, 1946, when a bulldozer used in constructing logging roads uncovered several barite boulders. Under the direction of Jones, trenches were dug to determine the extent of the deposits. The trenches were shallow, and caving of the walls and vegetation have destroyed the exposures available to Jones' studies. However, the Baroid Division of the National Lead Company stripped the zones adjacent to the trenches dug by Jones and found that the mineralization did not extend beyond the lenses mapped by him (Schoenike, 1955). Jones' descriptions are given below:

> In each of the barite bodies in the Pigeon Roost Mountain area, barite has apparently replaced beds of shale and sandstone in the Stanley shale formation. The nearest observed outcrop of novaculite in the vicinity of the deposits is 250 feet south of trench I in the southwestern deposit. It is probably part of one of the many synclinal structures of the Mazarn synclinorium that are mostly hidden by the overlying Stanley shale.
>
> The southwestern deposit is lenticular, measuring 800 feet along the strike, with a maximum thickness of 29 feet near the center of the lens. The general strike is N. 60° E., but on the northeastern and southwestern extremities of the lens, the strike is N. 70° E. and N. 80° E., respectively. The dip varies from 66° in the center of the body to 60° and 50° on the northeastern and southwestern ends of the body. At each of the places where measurements were taken, the dip was to the northwest. Approximately 200 feet from the northeastern end of the lens, the ore has apparently been faulted along a plane bearing N. 12° W., with a resultant displacement of 30 feet to the southeast.
>
> On either end of the body, the barite-bearing beds grade rapidly into shales having practically no barium sulfate content.

Four types of ore are in the southwestern deposit. One type is white crystalline barite disseminated in a porous, greenish-gray sandstone member of the Stanley formation. The barium sulfate content is directly proportional to the porosity of the sandstone which varies considerably within the lens. In trench G (fig. 3), the sandstone has a barium sulfate content of 62.1 percent, whereas in trenches E and H, 200 and 300 feet on either side of trench G, the barium sulfate content of the sandstone is 74.0 percent.

A second type of ore is that in which barium sulfate has permeated the bluish-black Stanley shale. Within the lens, the shale member has an average barium sulfate content of 75 percent. This type of ore occurs in thin beds, usually not more than 3 inches thick, interbedded with the greenish-gray sandstone member. Some of the shale beds have a barium sulfate content as low as 30 percent, and it is difficult to differentiate in the field between the beds of high and low barium sulfate content.

Barite also occurs in dark-gray rocks of dense, fine-grained texture, similar in appearance to weathered novaculite. Some of these beds have a cellular honeycomb structure that is commonly filled with iron-stained clay and silica grains. Because of the cellular structure, the material is locally termed "rotten rock." This third type of ore has an average barium sulfate content of 73 percent.

A fourth type of ore is in a whitish-gray shale, stained with limonite and containing veinlets of white crystalline barite. Although this shale often averages 69 percent barium sulfate, some parts have a content of only 38 percent and it is difficult to differentiate in the field between the beds having a high or low barium sulfate content.

Each of the four types of ore is of the fetid variety, in that a strong odor of hydrogen sulfide is released when the rocks are struck with a hammer.

The central deposit of the Pigeon Roost Mountain barite deposits consists of a small lens that appears to be on the nose of a small anticline. That part of the lense striking N. 80° and dipping 75° to the southeast has a strike length of 100 feet and is revealed in trenches F and S (fig. 3). The other part of the lens strikes N. 5° W., and dips 60° to the southwest; it has a strike length of 100 feet and is revealed in trenches D, T, and U. The ore in the lens is of the whitish-gray shale variety and has a maximum thickness of 7 feet, with an average barium sulfate content of 56 percent.

On the northeastern end of the Pigeon Roost Mountain barite area is a lenticular body of barite measuring

500 feet along the strike. The general strike of the lens is N. 55° E. with a dip of 75° to the southeast. The four types of barite found in the southwestern deposits are also in this body; but the beds are few in number and are interbedded with shale beds of equal thickness that have practically no barium sulfate content. The maximum thickness of the zone in which mineralization occurs is 16 feet, as revealed in trench C (fig. 3), but the total thickness of ore beds is only 3 feet.

Samples were collected from each trench that could readily be cleaned enough to determine the contact of the wall rock and the barite. Petrographic studies of these samples show that they are almost identical with those occurring in the Magnet Cove and Fancy Hill districts. The barite cemented sandstone, however, is rare in these other districts.

Geologic Setting

In order to ascertain the stratigraphic and structural picture in the vicinity of the barite bodies the area was traversed as systematically as possible using aerial photographs with a scale of 1' - 500" for orientation. The dense undergrowth and thick humus soil made it impossible to determine the exact stratigraphic and structural relationships of the barite zones. Although the exact corrugations of the Stanley formation were not determined, the general structural and stratigraphic features were established.

An intermittent zone of novaculite scree a mile to two miles south of, and roughly paralleling Pigeon Roost Mountain, may mark the southern flank of the syncline

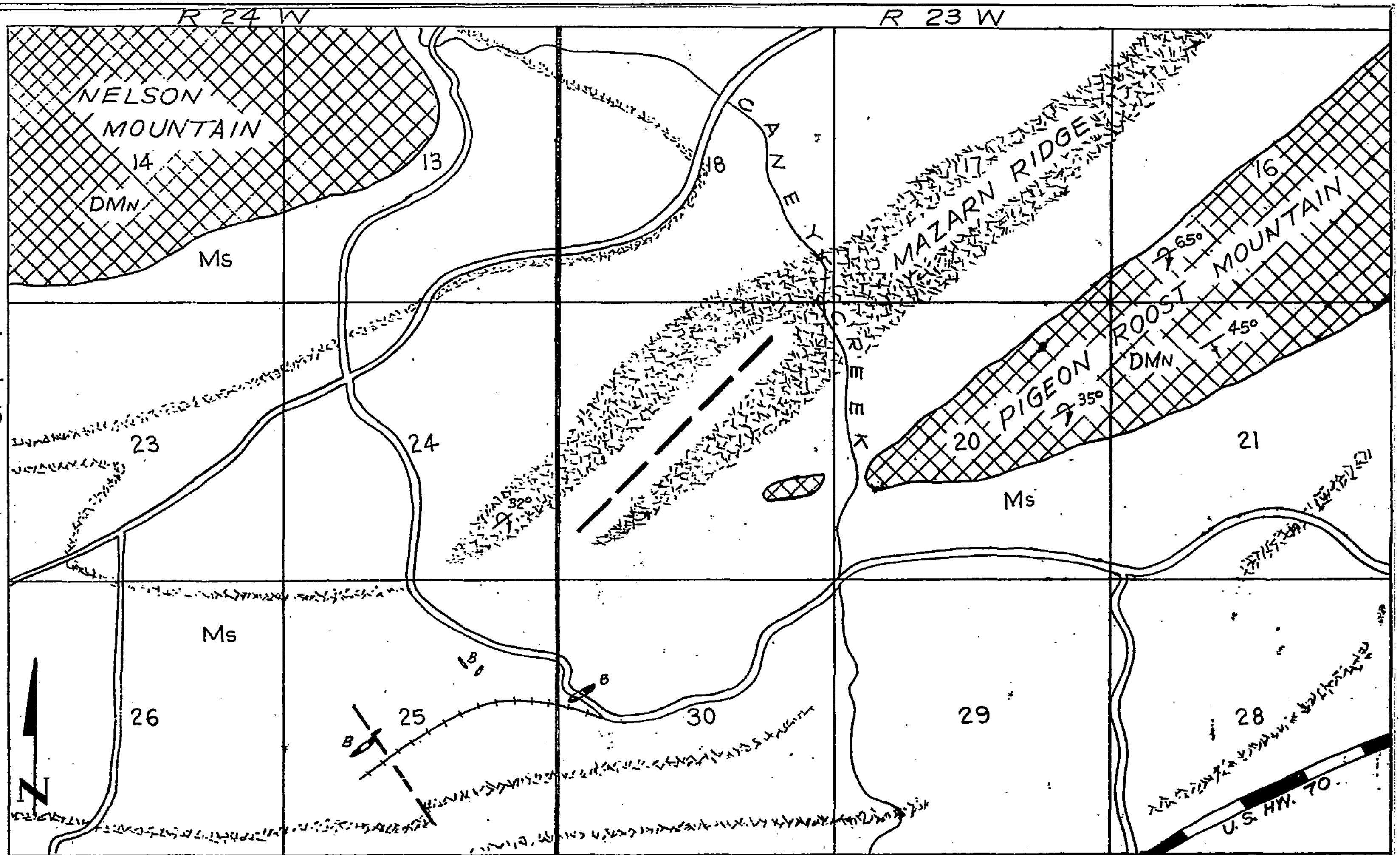


FIGURE 3
SKETCH MAP SHOWING GEOLOGY
OF PIGEON ROOST BARITE DISTRICT
MONTGOMERY CO., ARKANSAS

- Ms Stanley Fmtn.
- Mappable Stanley SS
- Ark. Novaculite
- Fault
- B Barite Deposit
- U.S. Highway
- Abandoned R.R.
- County Road

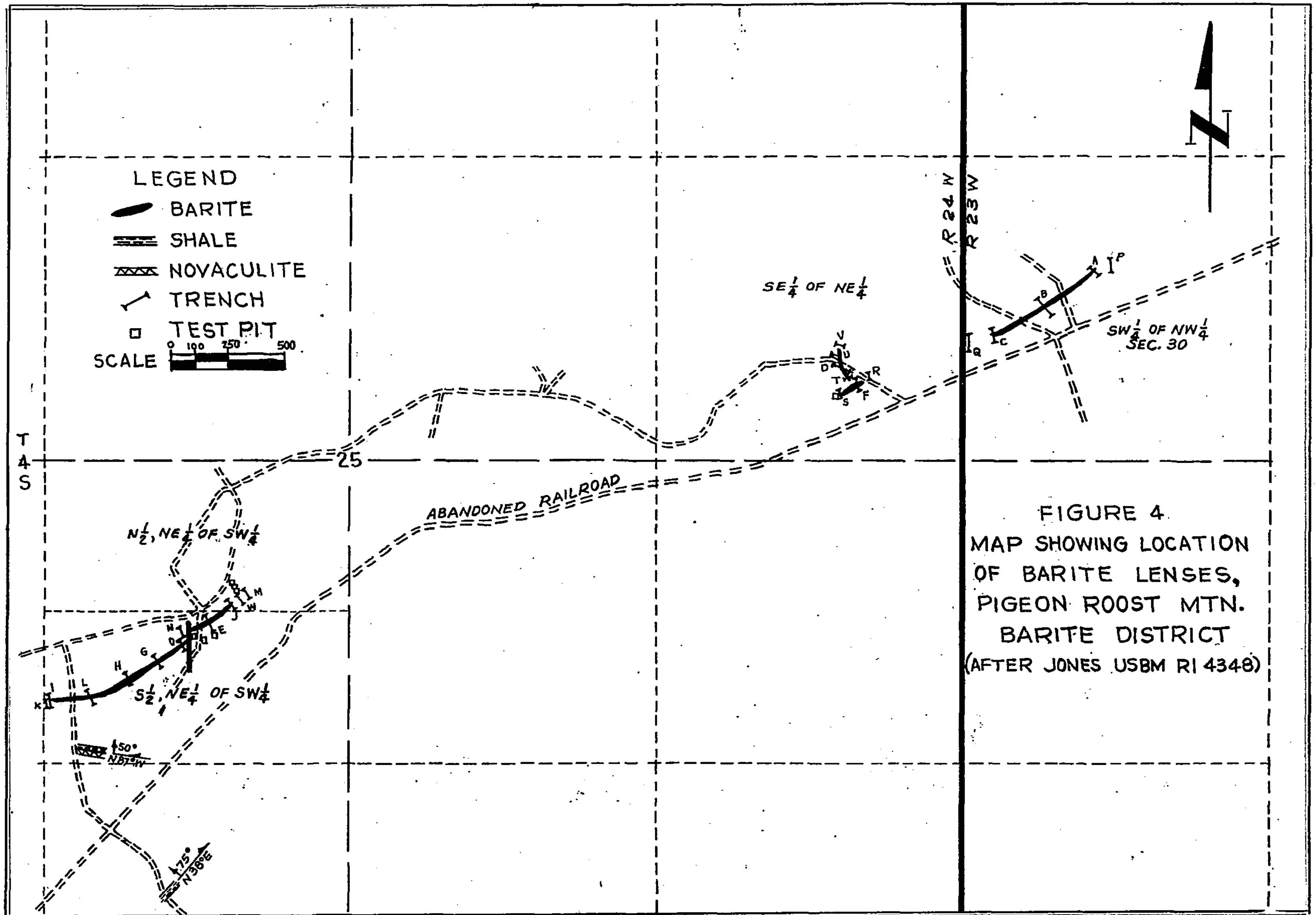
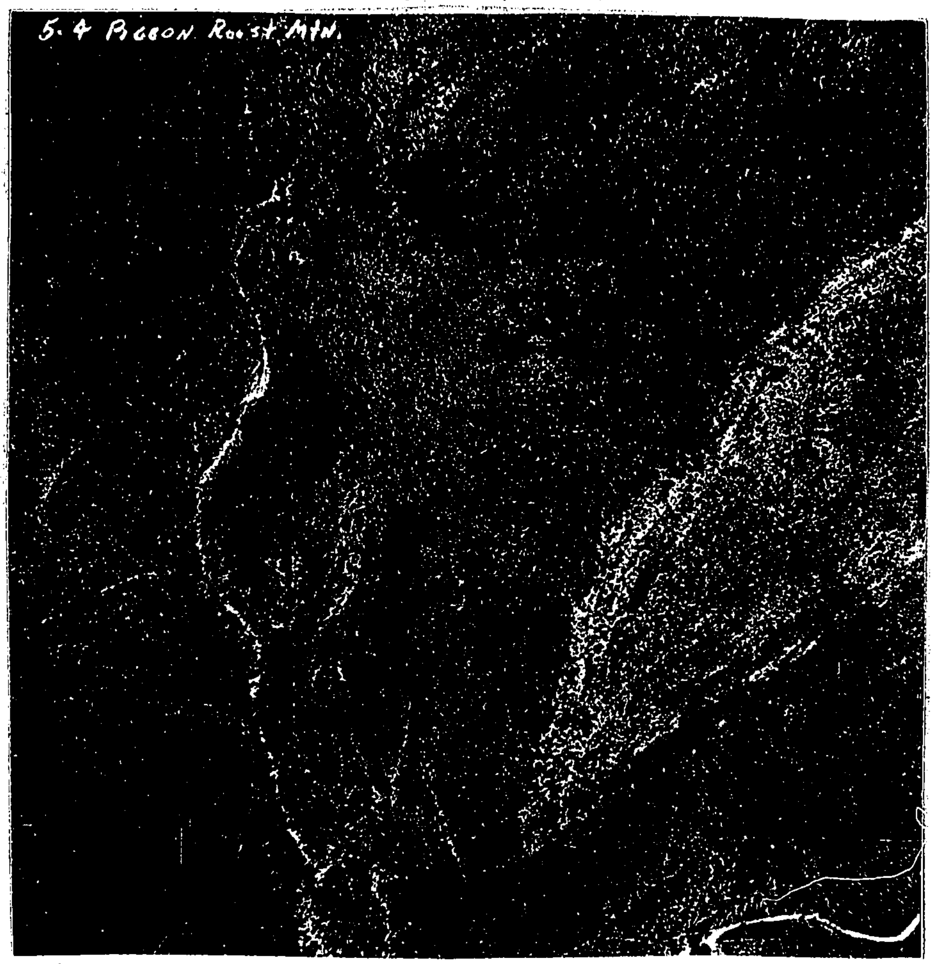


FIGURE 4
MAP SHOWING LOCATION OF BARITE LENSES, PIGEON ROOST MTN. BARITE DISTRICT
(AFTER JONES USBM RI 4348)

PLATE LIV



Aerial photograph showing westward plunging core of novaculite of Pigeon Roost Mountain. Caney Creek transverses left part of photograph. Scale about 1" = 1000'. (Original photographer, D. F. Holbrook; reduction, Jay Simmons) containing the Pigeon Roost barite deposits. Exposures along Caney Creek in the southwest part of T. 4 S., R. 23 W., were the only ones with any continuity south of Pigeon Roost Mountain. Although these beds are highly corrugated, their attitudes tend to substantiate the idea that there is a larger syncline about two miles wide in this area. The dip patterns indicate that the barite deposits occur at the southwest end of this syncline, although the mineralization was governed by local stratigraphy and structure.

The geologic setting of the barite deposits of the Pigeon Roost district is poorly known considering the amount of information available. The size of the deposit did not seem to warrant the time that would be required to map in detail the geology of the adjoining area; however, the older reports are in such conflict that reconnaissance traverses were made, using aerial photographs for orientation over a considerable part of the surrounding area. The conflict in the older literature centers around the structure of Pigeon Roost Mountain and the stratigraphy and structure of the Mazarn Ridge.

Pigeon Roost Mountain is an arcuate ridge of novaculite that extends about five miles northeast from the barite deposits. The Mazarn Ridge is held up by sandstones and extends from north of the barite deposits and north of Pigeon Roost Mountain some 14 miles to the northeast. Griswold (1892, pp. 364-66) considered these two ridges to be part of the same overturned anticline, with Pigeon Roost Mountain at the core of the anticline and the south flank, including the sandstones, mostly removed by erosion. In both ridges the north flank is overturned to the south. Miser and Purdue (1929, Plate 3) show only the southwestern tip of the Mazarn Ridge, which they mapped as Jackfork sandstone overturned to the south. The state geologic map of Arkansas shows the Mazarn Ridge as being Jackfork sandstone and having a thrust fault to the north bounding its south side. Croneis (1930, pp. 347-50) considers each ridge to belong to a separate overturned anticline and deems the sandstone in the Mazarn Ridge to be Stanley. Of all these interpretations, the writer believes that of Griswold to be the most accurate. Southwest and northeast of Pigeon Roost Mountain, the Mazarn Ridge shows anticlinal closure which is to be expected along a double plunging anticline.

None of these reports points out that the resistant sandstone in the Mazarn Ridge is actually a series of lenticular pebbly sandstones (Plate XXII). Placing the sandstones of the Mazarn Ridge in the Jackfork formation creates numerous problems with no apparent answers. First and foremost of these is that the Stanley in this area between the "Jackfork" and the Arkansas novaculite in Nelson Mountain in the W1/2 sec. 13, T. 4 S., R. 24 E., would be less than 2000 feet thick. Second, placing a thrust fault on the south side of the Mazarn Ridge creates a very improbable structural configuration. Evidence of faulting was noted in several places along this ridge, but no more than would be expected in a tightly folded overturned structure in brittle beds. If the faulting is major it is similar to and perhaps is an eastward extension of the thrust faulting in the eastern part of the Cossatot Mountains, or possibly the thrusting of the Caddo Gap in the Caddo Mountains.

Fancy Hill District

General Discussion

Within the Fancy Hill district there are four barite deposits that occur in replacement zones in the basal parts of the Stanley shale: the Gap Mountain deposit (Yount) extending along the south side of Gap Mountain from the southeast part of sec. 19, T. 4 S., R. 25 W., to the northeastern part of sec. 23, T. 4 S., R. 26 W.; the Fancy Hill (Henderson) deposit extending along the south side of Fancy Hill from the northeastern part of sec. 29 to the southwestern part of sec. 19, T. 4 S., R. 26 W.; the Sulphur Mountain (McKnight) deposit extending along the north side of Sulphur Mountain in sec. 29, T. 4 S., R. 26 W.; and the Dempsey Cogburn deposit on the southeast side of Sulphur Mountain extending from the center of sec. 33 to the northeastern part of sec. 32, T. 4 S., R. 26 W. Assigned to this district are two barite deposits in which the mineral occurs as veins in the middle member of the Arkansas novaculite. The Boone Springs

Creek deposit is in the SE1/4 sec. 24, T. 4 S., R. 27 W., and the Polk Creek Mountain deposit occurs in the SW1/4 sec. 12, T. 4 S., R. 27 W. McElwaine (1946 B) has described the replacement deposits, with the exception of the Dempsey Cogburn, and Jones (1948) described the veins in the Middle Arkansas novaculite.

Gap Mountain Deposit (Yount)

History and description. The Gap Mountain barite deposit was discovered by Mr. Leo Yount in December, 1944 (1946 B, p. 4). Six mining claims were filed on public domain and leases totaling 140 acres on private land were obtained. The claims at the eastern end of the property have since been patented. After studying the general geology of the deposit and making detailed examinations of U. S. Bureau of Mines trenches and drill holes, McElwaine (*Idem*., p. 6) reports:

> The barite occurrences consist of intermittent lenticular bodies occurring as replacement deposits in sedimentary beds near the stratigraphic base of the steeply dipping Stanley shale formation. The dip of the beds in which the barite occurs changes and travels westward along the strike from a steep north dip at the east end of the deposits to vertical near the center and then to a steep south dip at the west end. At depth, all of the beds must assume a south dip, but on the eastern part of the property drill holes indicate the dip to be still 86° to the north at a depth of 200 feet. The areas between the ends of the intermittent ore bodies contain considerable barite-bearing shale, but only thin lenses and scattered concretionary nodules of good barite are present. The latter type of material has been traced westward along the south side of Gap Mountain for a distance of 5 or 6 miles to the east side of R. 27 W. The important known deposits are four lenticular bodies of

barite ranging from 300 to 1200 feet in length. The zone in which the barite is found is 20 to 30 feet thick and occurs near the base of the Stanley formation, about 70 to 90 feet from the massive novaculite. The actual point of the contact between the two formations can be observed only in a few places where the thin-bedded chalcedonic novaculite is exposed in ravines on the mountain side. At one point near trench L-1-D, west of claim 2, the contact is 30 feet from the barite zone. However, it is known to be considerably more than this on claims 1 and 2. The material occurring between the barite and the novaculite is a dense, light-gray shale and is of a very different appearance than normal Stanley shale. It is composed chiefly of illite with some quartz. The beds to the south of the barite are typical of the Stanley shale formation and contain considerable sandstone and sandy shale. At many places the ore beds show a flat dip to the north, but trenching revealed this to be a result of surface slump on the hillsides, and within a few feet of depth the dip becomes nearly vertical.

Local structure. Structurally, Gap Mountain is the common flank between the Caddo Mountains and the Mazarn Basin. Throughout its length the south flank of Gap Mountain is essentially vertical or slightly overturned to the south, but locally high south dips were noted. Readjustments of the Arkansas novaculite in response to deforming pressures produced a large number of north to north-northeast trending faults with displacements ranging from a few inches to a few feet. Only a few of these faults were of sufficient magnitude to affect the overlying Stanley shale. In each case where these faults could be demonstrated to be associated with an ore body, they marked the westward extremity of a mineralized zone. No evidence indicating major faulting could be found associated with these deposits. A major fault probably is present 1500 to 2000 feet south of the barite zone, but this could not be proven because of poor exposures. This leads to the tentative conclusion that the barite occurs on the north flank of an extremely steep-sided syncline having a length of about 12 miles and a width not exceeding one-half mile. The novaculite at the center of this syncline would have a cover of Stanley of not less than 1000 nor more than 4000 feet.

Stratigraphic relations. The shale overlying the novaculite is 10 to 30 feet thick. In texture and composition it closely resembles the black shale in the Chamberlin Creek deposit. It is not as dark, possibly because of weathering, and does not contain as much pyrite. It also contains lentils of conglomerate composed of novaculite pebbles and a siliceous matrix. Unlike its counterpart in the Magnet Cove district, the basal shale in the Gap Mountain deposit has not been mineralized. It forms the foot wall of the mineralized zone.

Because suitable exposures were not available it is not possible to determine accurately the thickness of the mineralized zone. It is between 100 and 150 feet thick. Unlike the Magnet Cove and Fancy Hill deposits, the commercial grade barite zones in the Gap Mountain deposit are not confined to a definite horizon. Lenticular bodies from 3 to 30 feet thick occur from 30 to 50 feet above the base of the mineralized zone.

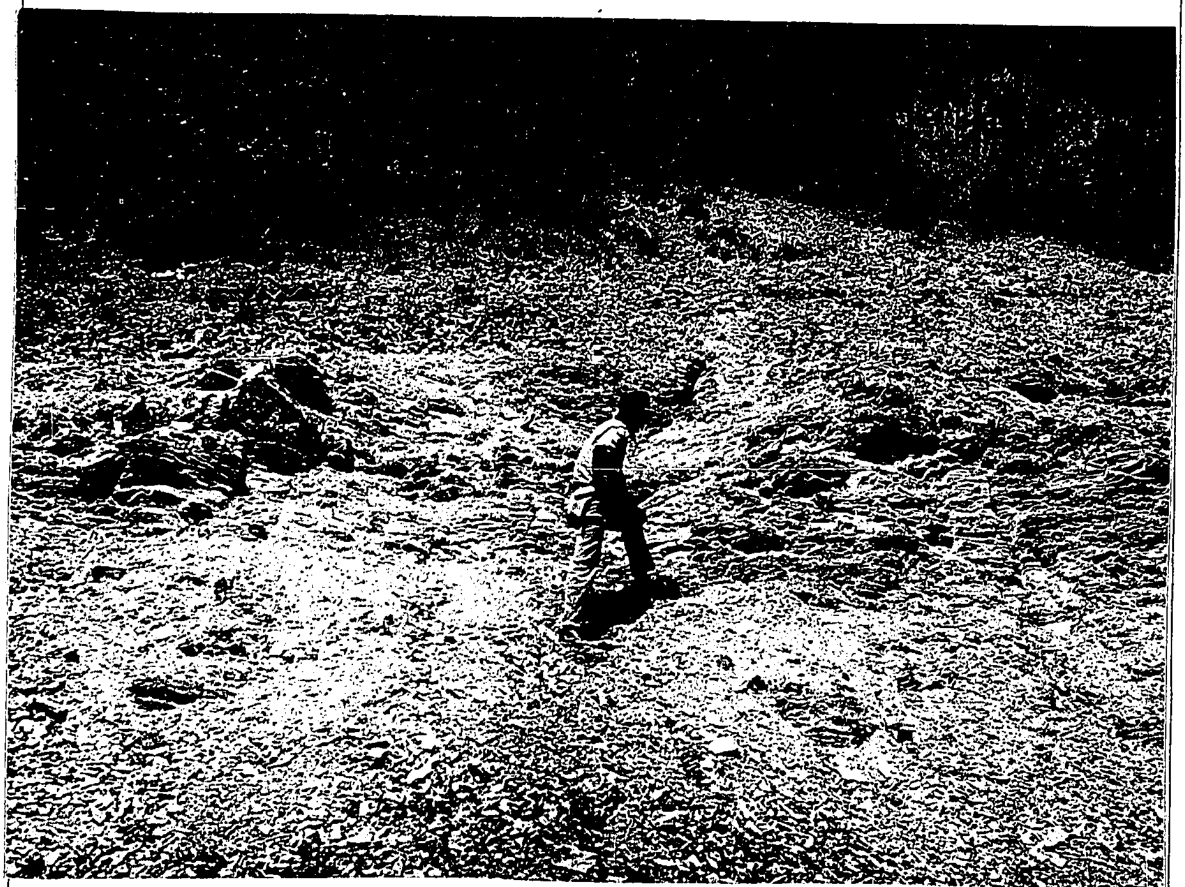
PLATE LV

Aerial photograph showing location of Patented Claim on south flank of Gap Mountain. The Arkansas novaculite crops out north of the strip pit, and the Stanley formation crops out south of it. Scale about 1" = 1000'. (Original photograph, D. F. Holbrook; reduction, Jay Simmons.)

PLATE LVI

Photograph of strip pit on Gap Mountain shown on Plate LV. Novaculite-Stanley contact is at upper edge of pit. Figures in right middle distance indicate scale. (Photographer, N. F. Williams.)

PLATE LVII



Photograph of east end of pit shown in Plate LVI showing mineralized Stanley dipping northward under novaculite. (Photographer, N. F. Williams.)

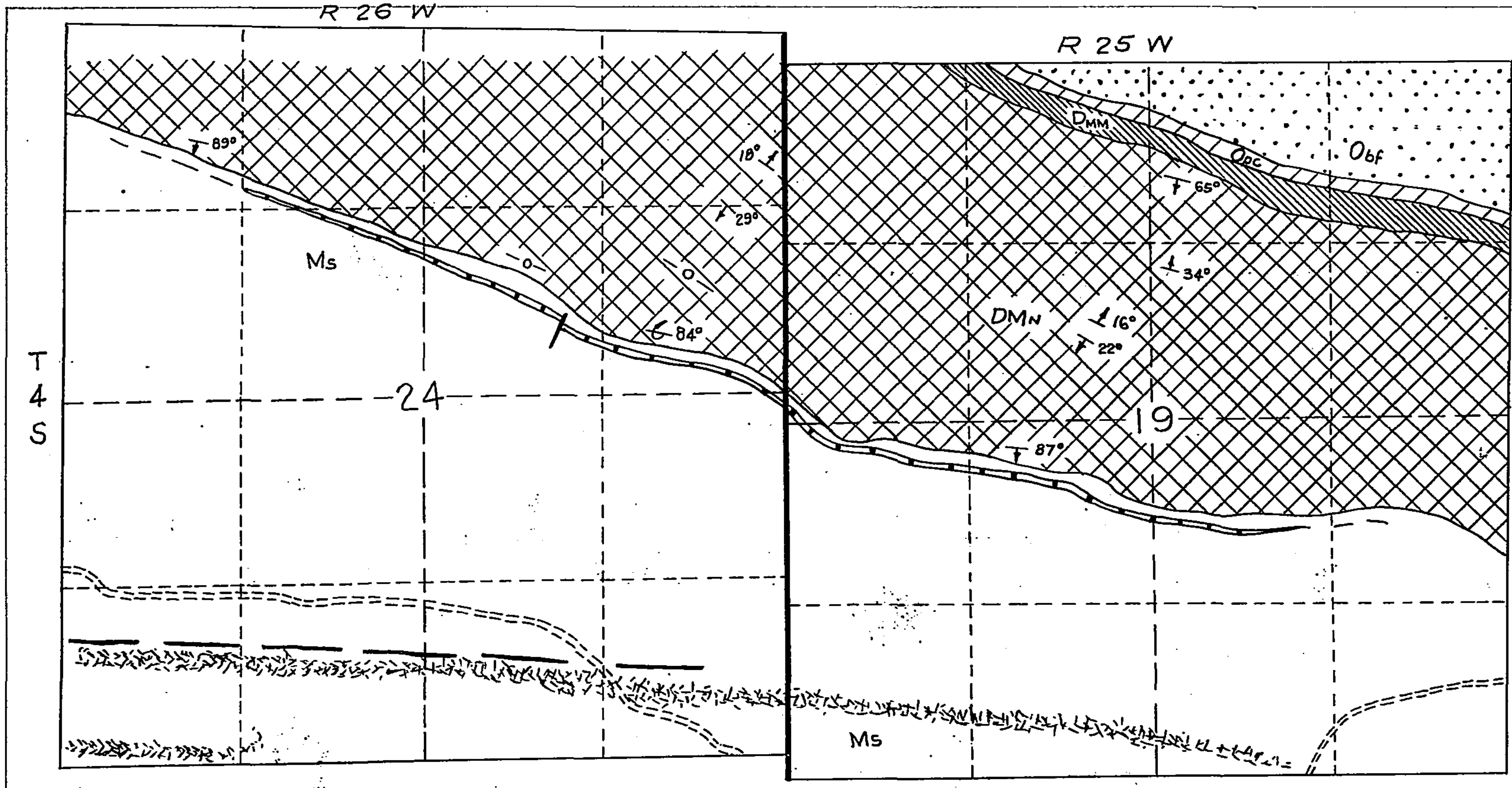
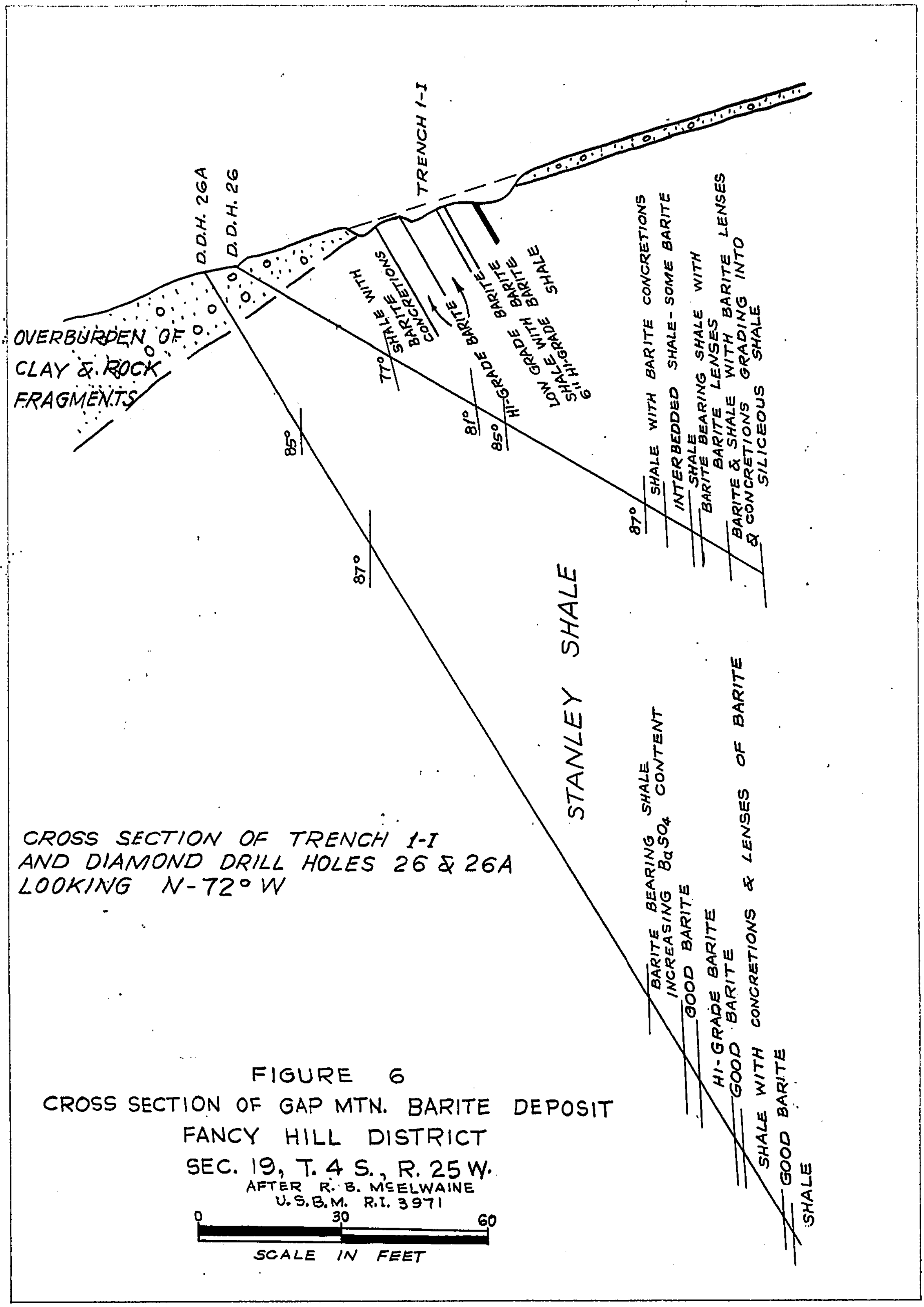


FIGURE 5

SKETCH MAP SHOWING THE GEOLOGY OF THE GAP MTN. BARITE DEPOSIT FANCY HILL DISTRICT, ARKANSAS

- Ms — Stanley Fmtn.
- Mappable Stanley SS
- DMN — Arkansas Novaculite
- DMM — Missouri Mtn. Sh.
- Opc — Polk Creek Sh.
- Obf — Bigfork Chert
- Probable fault
- Mineralized zone
- Road



CROSS SECTION OF TRENCH 1-I AND DIAMOND DRILL HOLES 26 & 26A LOOKING N-72° W

FIGURE 6
CROSS SECTION OF GAP MTN. BARITE DEPOSIT
FANCY HILL DISTRICT
SEC. 19, T. 4 S., R. 25 W.
AFTER R. B. McELWAINE
U.S.B.M. R.I. 3971

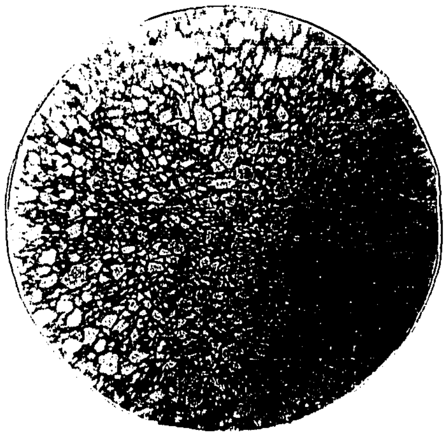
Character of the ore. The individual bodies of barite contain at least two types of ore and ordinarily contain all four types, with the exception of those bodies made up of interbedded nodular ore and baritic shale. In these bodies, branching tubular barite concretions are associated with the nodular zones. These concretions have a maximum dimension of 3 1/2 inches.

The barite bodies considered to be commercial (containing 65 percent or more barium sulfate) have a fairly uniform thickness and tenor except for the pinchout at the ends. The lower grade bodies are much more irregular. There is a distinct diminishing of amount of barium sulfate in the mineralized zone east to west. It could not be determined whether the thickness of the mineralized zone also diminished westward.

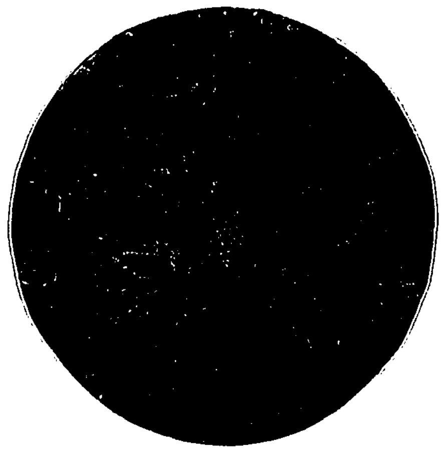
Fancy Hill Deposit (Henderson)

History. The presence of barite on the south flank of Fancy Hill has been known since the early 1900's. A formal claim was not filed until 1944 when Mr. Allen Cogburn, a resident of the area, staked claims to properties which lie within the confines of the Ouachita National Forest. Mr. Cogburn deeded his claims to Mr. J. E. Henderson, who, with his partners, leased the properties to the Baroid Division of the National Lead Company. The Company meets the annual assesment requirement by doing exploration, evaluation and maintenance work.

PLATE LVIII



(A)

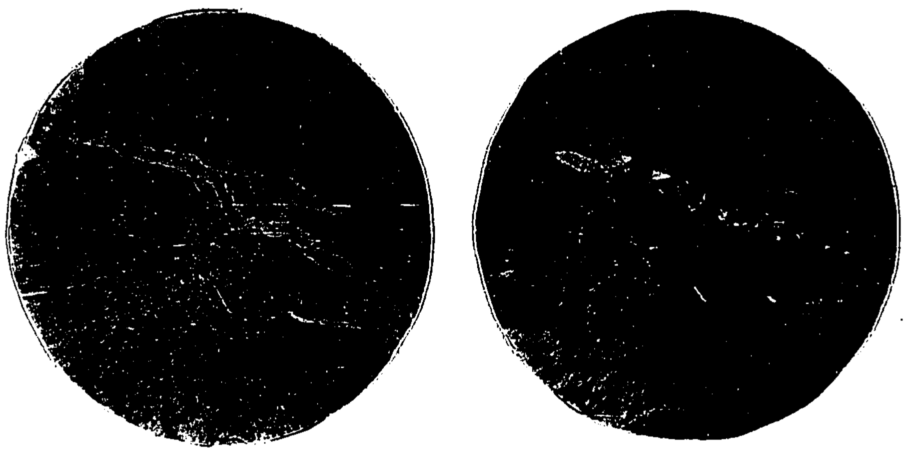


(B)

(A) Photomicrograph of sandy shale forming the hanging wall of the mineralized zone in the Fancy Hill district. Plane polarized light; X 13; section 90.

(B) Photomicrograph of radial barite nodules from a high-grade ore zone, Henderson property, Fancy Hill district. Crossed nicols; X 13; section 91.

PLATE LIX

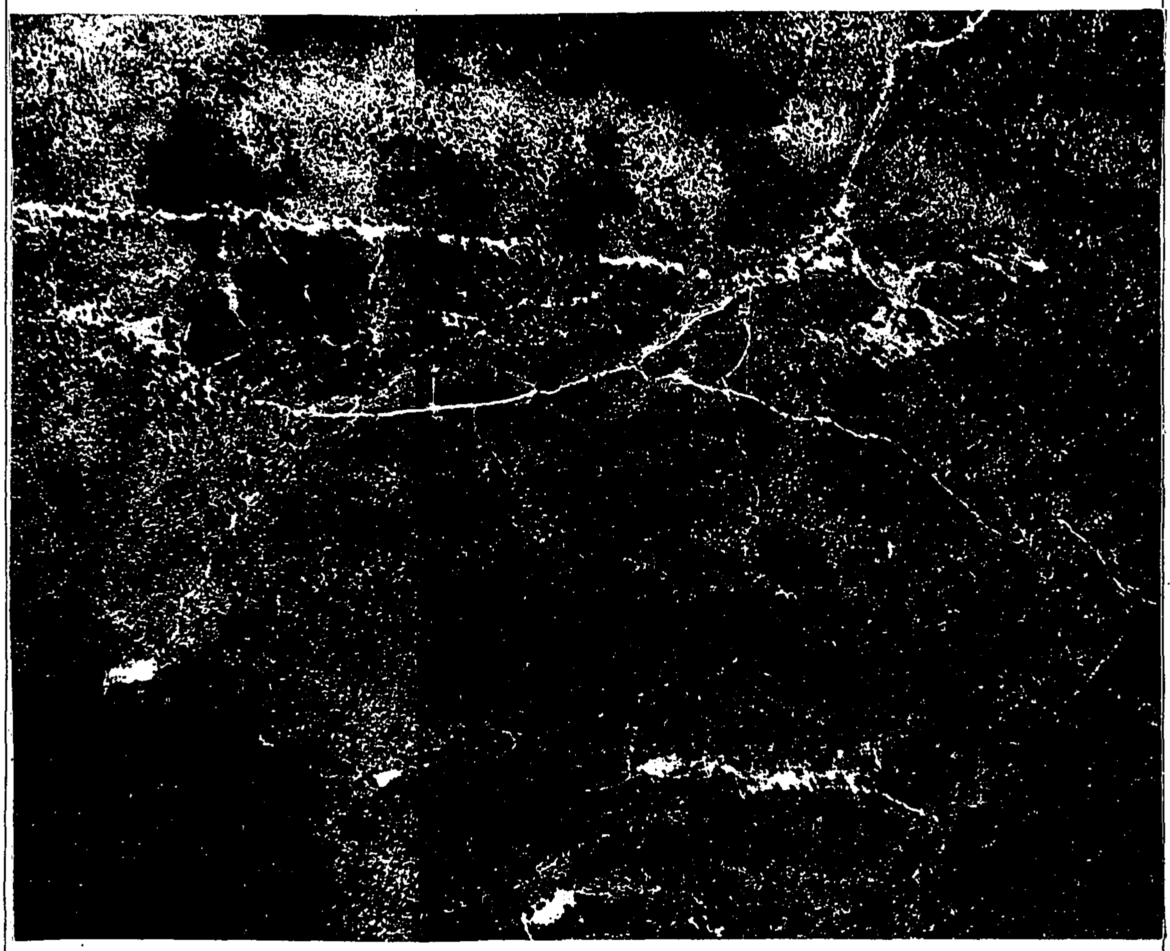


(A) (B)

(A) Photomicrograph of quartz veins (light gray) cutting fractured barite (gray), Henderson property, Fancy Hill district. Plane polarized light; X 13; section 89.

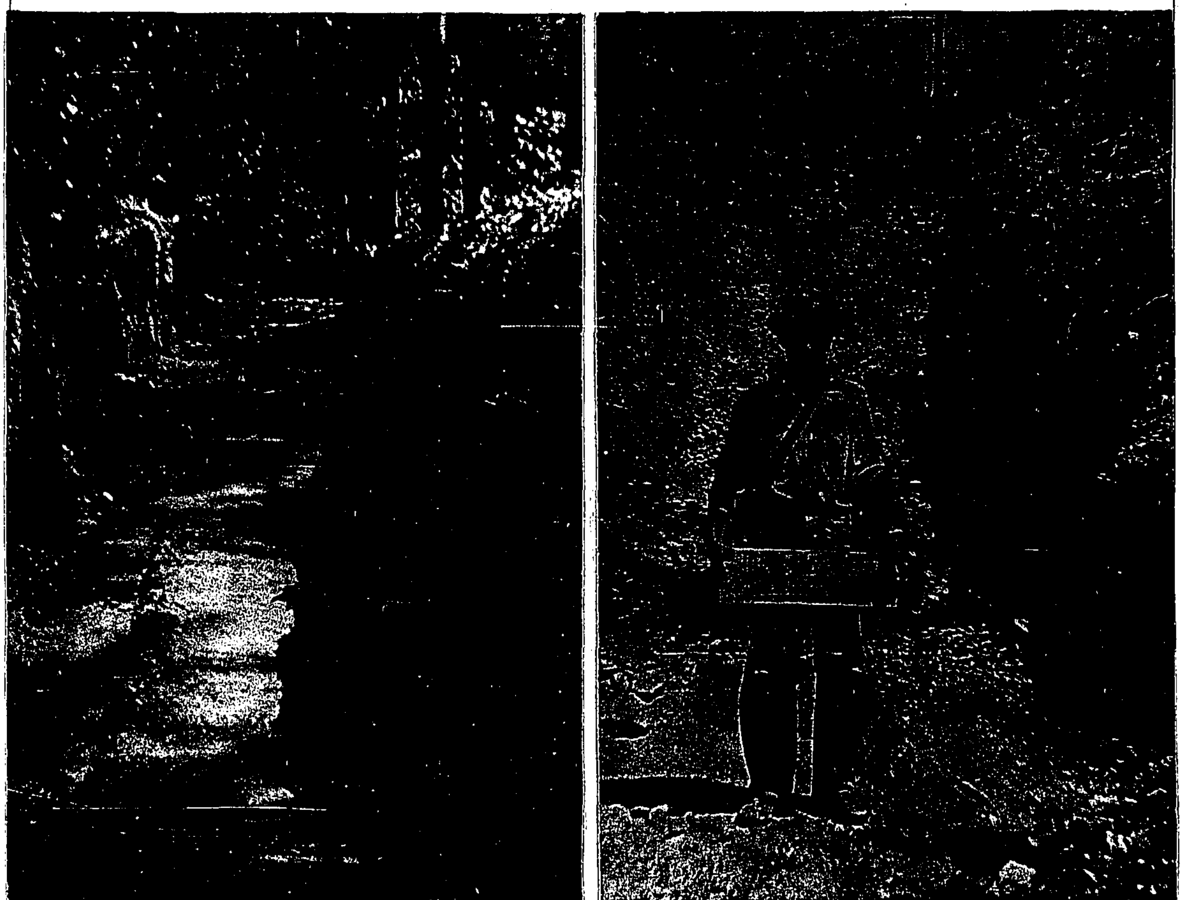
(B) Same view with nicols crossed.

PLATE LX



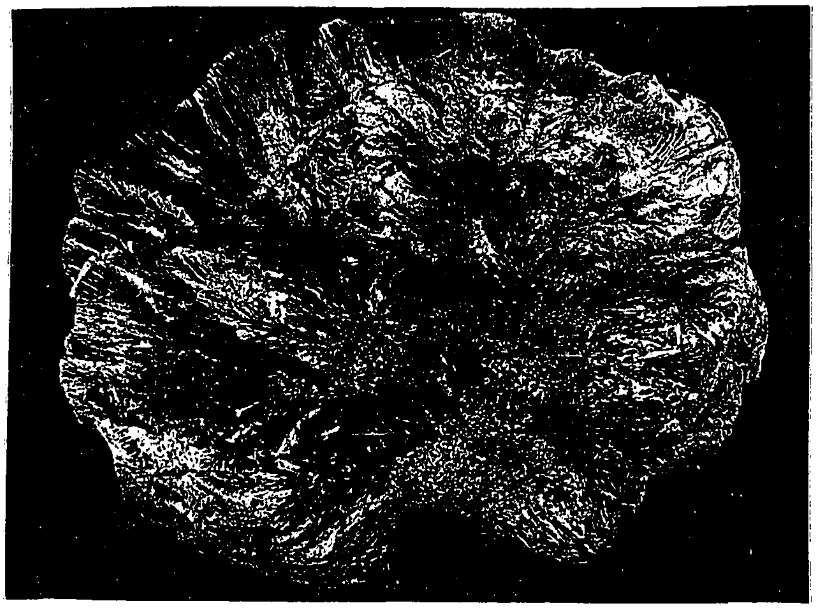
Overlapping aerial photographs to show position of exploration trenches, Henderson and McKnight properties, Fancy Hill district. Scale about 1" = 1000'. (Original photograph, D. F. Holbrook; reduction, Jay Simmons.)

PLATE LXI



Photographs showing the types of exploration trenches in the Fancy Hill district. (Photographer, H. G. Schoenike.)

PLATE LXII



(A)

(B)

(A) Photograph of radial barite nodule from Polk Creek Mountain deposit, Fancy Hill district. X 13. (Photographer, Harry Smith, Jr.)

(B) Photomicrograph of section of nodule above. Plane polarized light; X 13; section 142.

Local structure. Fancy Hill is an anticlinal mountain rising from the floor of the Mazarn Basin. The anticline is asymmetrical, the north flank having an average dip of about 50° to the north and the south flank having an average dip of 85° to the south; locally the beds are vertical or overturned. At places, erosional sapping has undermined the Arkansas novaculite resulting in slumpage and creep to give the beds an apparent northward dip of 45° or less. As in the Gap Mountain deposit the brittle novaculite has been shattered by deformational stresses so that joints, fractures, and small faults are extremely numerous in the formation. Only a small number of the faults were of sufficient magnitude to affect the overlying Stanley formation. These faults preceeded and affected the course of mineralization. The available drill hole data show that the steep south dip continues at depth.

The Back Valley syncline is bordered on the north by the Fancy Hill anticline and on the south by the Sulphur Mountain anticline. The projection of the dips observable on the flanks and on the floor of this syncline indicates, unless unknown faulting is present, that the barite-bearing zone can have a depth no greater than 2000 feet at the center of this syncline.

Stratigraphic relations. As in the previously discussed deposits, the barite mineralization occurs near the base of the Stanley formation. A black shale, 10 to 30 feet thick, forms the foot wall of the mineralized zone.

The black shale overlies 40 to 70 feet of chalcedonic to punky upper Arkansas novaculite. Unlike the deposits previously discussed, the mineralized zone in Fancy Hill appears to have a definite hanging wall. A yellow to brown highly oxidized sandy shale or shaly sandstone, apparently impervious to the mineralizing solutions, forms the hanging wall. This unit ranges in thickness from a few inches to 10 feet.

The mineralized zone ranges in thickness from 30 to 80 feet. In all of the assays of samples from this zone some barium sulfate was found to be present. The bodies of barite of potential commercial grade are lenticular and are not evenly distributed throughout the mineralized zone.

Character of the ore. There are six lenticular high-grade barite bodies in the mineralized zone ranging from 300 to 1800 feet in length. These bodies of high-grade barite are 15 to 40 feet thick, with the individual barite beds ranging from 1 to 18 inches in thickness. The ore occurs as the various types noted in all the other replacement deposits of the region. The chief type of ore is the dense gray material which superficially resembles the novaculite. Many such beds in this deposit can be recognized as barite only by scratching or hefting the material. The nodular type ore is much less conspicuous here than at Gap Mountain. Locally the limestone-resembling barite is the most abundant. In this deposit as in all other replacement deposits in the region, the chief impurity in the ore is the silica of the

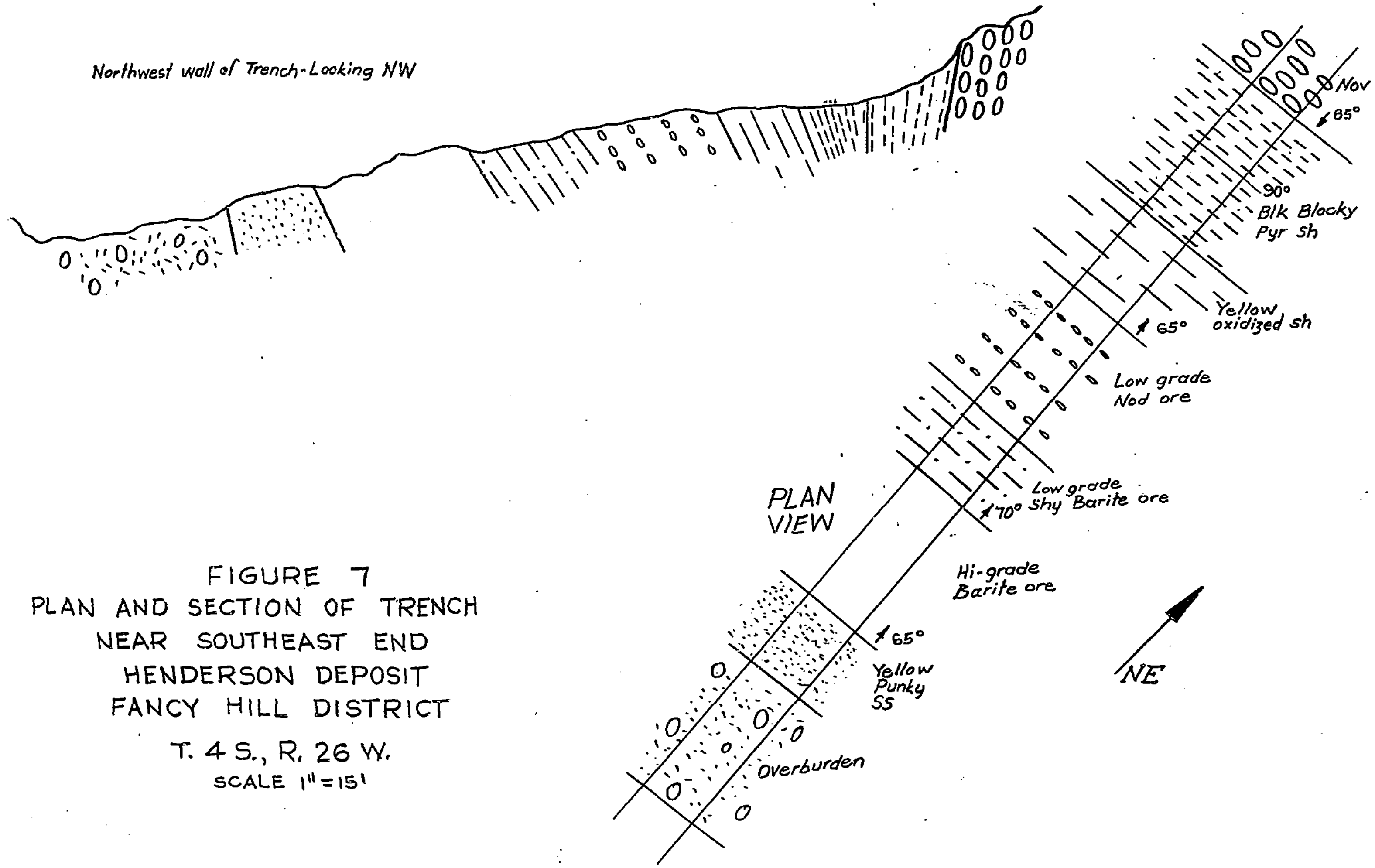


FIGURE 7
PLAN AND SECTION OF TRENCH
NEAR SOUTHEAST END
HENDERSON DEPOSIT
FANCY HILL DISTRICT
T. 4 S., R. 26 W.
SCALE 1" = 15'

clay minerals. The clay minerals as studied in thin section can be classified as illite or montmorillonite. Probably members of both groups are present, as reconstituted chemical analyses for the most part require the presence of two types of clay minerals.

Sulphur Mountain Deposit (McKnight)

History. McElwaine (1946 B, p. 5) reported that his attention was called to the Sulphur Spring Mountain barite deposit by Jerry Cogburn, a native of the district, and that H. R. McKnight, of Hot Springs, controlled the property. Since then the National Lead Company has acquired a lease on the property and holds it by doing annual assessment work. This deposit occurs on the opposite flank of the Back Valley syncline from the Fancy Hill deposit.

Description. The Sulphur Mountain barite deposit occurs in a highly deformed zone along the common limb of the Back Valley syncline and the Sulphur Mountain anticline. A major thrust fault with a strike slightly north of west and having a strike length of some 15 miles has its eastern terminus in the area of the Sulphur Mountain deposit. Associated with this major thrust are numerous cross folds and cross faults, the structural details of which could not be determined because of the lack of suitable exposures.

The apparent structural setting of the barite deposit is a small graben with the bounding faults striking slightly north of west. The local structural features that could be recognized in trenches and bulldozer cuts are shown on the district geologic map (Plate XV). The ore body and the Stanley host rock dip to the south between novaculite beds. If the structure were simple the ore beds would dip to the north and the novaculite would occur only on the southern part. The stratigraphic relations show that the beds bearing the barite are not overturned where they are exposed. The foot wall shale and the hanging wall sandstone of the Fancy Hill deposit are readily recognized in this area. The writer's interpretation of the structural conditions existing in this deposit are shown in the cross sections on Plates XVI and XVII.

As in the Fancy Hill deposit, the chief type of ore is the novaculite-appearing barite, although the limestone-appearing and the nodular barite are quite abundant.

Dempsey Cogburn Deposit

History. Mr. Dempsey Cogburn, a native of the district, staked claims on the deposit after the activity at Fancy Hill. The Mil-White Company obtained the leases and later turned them to the National Lead Company.

The barite zone can be studied only in the trenches and cuts made by the National Lead Company. The mineralized zone has an apparent thickness of about 50 feet and the high-grade lenses as seen in the trenches and cuts have a thickness ranging from 12 to 25 feet. The ore types are the same as in the other deposits of the district. It should be noted that this is the only deposit within the district where a major fault forms a boundary of the mineralized zone. As shown on the geologic map, the cross fault near the east line of section 32 apparently forms the western margin of the mineralized zone. The exposures as observed in the cuts and trenches show that the mineralized zone has a stratigraphic foot wall and hanging wall, probably identical to those of the Henderson and McKnight properties.

Boone Spring Creek Prospect

The Boone Spring Creek barite deposit occurs as a vein in the Middle Arkansas novaculite on the overturned south limb of the Fancy Hill anticline. The vein as exposed in prospect pits has a maximum thickness of one foot and a maximum length of 24 feet. Thick vegetation and overburden prevented tracing the barite away from the pits. Numerous other prospect pits in the vicinity did not expose any barite. The beds containing the barite strike north 45° west and dip 40° to the northeast. This anomalous attitude of the beds is the result of drag along the cross fault cutting across the Fancy Hill anticline.

Polk Creek Mountain Prospect

A comprehensive description of this deposit is given by Jones (1948, p. 6):

A mineral claim, designated as the Polk Creek Mountain Claim No. 4, North Group, was owned by Mrs. Mabel G. Stenger of Norman, Arkansas. In 1945 the Mil-White Company of Houston, Texas, obtained an option to lease the property and dug the trenches described below.

The work done on the prospect consisted of two cuts, made by a bulldozer, in the south side of Polk Creek Mountain, about 200 feet above the base of the mountain and at an elevation of 1300 feet above sea level. The largest cut, in which mineralization was exposed, paralleled the strike of the strata, bearing N. 70° W., and measured 25 feet wide, 16 feet deep, and 100 feet long. The other cut was barren. It was normal to the strike of the strata, was at the east end of the first cut, bore N. 20° E., and measured 25 feet wide, 16 feet deep, and 75 feet long.

Examination shows the barite mineralization as sparsely disseminated nodular concretions of barite enclosed in shale beds of the middle division of the Arkansas novaculite formation. The concretions average 0.3 feet in diameter, and ranged in size from 0.1 to 1 foot in diameter.

The nodules were found in the north wall and floor of the large cut in the zone 30 feet long in an east-west direction. The thickness normal to the dip was computed to be 24 feet. The depth to which mineralization extends is unknown. No concretions were found in the south wall of the cut, or in any part of the other cut.

The shale beds containing the barite concretions have been metamorphosed to such an extent that they approach the hardness and texture of slate. The beds range in thickness from one inch to one foot, and are colored red, buff, brown, gray-green, and black. The shales above and below the ore zone were interbedded with thin beds of reddish-brown novaculite ranging from 1 to 3 inches in thickness. In the vicinity of the prospect, the strata strike N. 70° W. and dip 52° to the southwest.

Channels were cut across the beds, normal to their strike, 2 feet wide and 6 inches deep, spaced at 10 foot intervals along the strike. All nodules encountered in each channel were collected and submitted for analyses. The barium sulfate content of the nodules averaged 81.9 percent. It is estimated that the concretions occur in the ratio of one per cubic foot of host rock.

No ore had been shipped from this deposit at the time of the investigation.

This deposit lies on the south flank of one of the anticlines forming the southern border of the Caddo Mountain anticlinorium. The barite-bearing horizon was traced laterally from the east side of sec. 12 to the central part of sec. 11, T. 4 S., R. 27 W., and the adjoining ridges were checked in a general way. Crystalline barite, probably of the vein variety, was noted in a few of the numerous prospect pits, in the debris brought up by uprooted trees, and in the banks of a few ravines. No continuous zone could be established as it would require and extensive trenching and drilling program to evaluate this mineralized belt.

Hatfield District

General Statement

The barite deposits of the Hatfield district occur as vein material in the middle member of the Arkansas novaculite on the flanks of the anticlines at the west end of the Cossatot anticlinorium. As far as could be determined, these veins filled available fractures with a minimum amount of replacement or displacement of the wall material. Most of these veins were emplaced in open fissures but some are present as fracture filling and cement in brecciated zones. About 60 pits or prospects were examined during the course of the work in the Hatfield district. In nearly all cases it was necessary to enlist the aid of the local residents in order to find a given pit or prospect. The larger prospects have been described by Jones (1948, pp. 11-13).

Bee Mountain Prospect

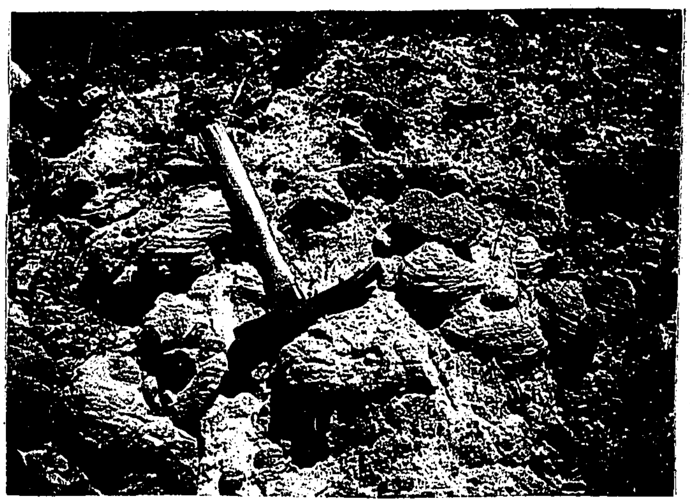
The Bee Mountain prospect occurs in the SE1/4NE1/4 sec. 15, T. 3 S., R. 31 W., along the south flanks and near the west end of this anticlinal mountain. According to Jones a pit measuring 20 feet long, 10 feet wide, and 7 feet deep was dug on the outcrop, and an estimated 18 tons of barite removed from it. This pit is badly caved so that only at the ends and part of the middle could the vein be studied. The barite is dark gray and megascopically crystalline. The vein was emplaced along an opening formed by differential slippage and perhaps weathering of the contact between novaculite and shale in the middle member of the Arkansas novaculite.

Boar Tusk Mountain Prospects

North flank. One Boar Tusk Mountain prospect is in the NW1/4NW1/4 sec. 23, T. 3 S., R. 31 W. The mineralization occurs on the north flank near the west end of this anticlinal mountain. The barite occurs as fracture filling and breccia cement, and is disseminated to small extent into the wall rock. On the dump there are boulders, ellipsoidal and discoidal, with a maximum dimension of 30 inches. They were not found in place.

South flank. On the south flank of the mountain in the NE1/4SW1/4NE1/4 sec. 22, T. 3 S., R. 31 W., a small vein of barite in the middle member of the Arkansas novaculite is

PLATE LXIII



Photographs of barite "rosettes" developed in the weathered residual zone, Trinity sandstone, Dierks district.

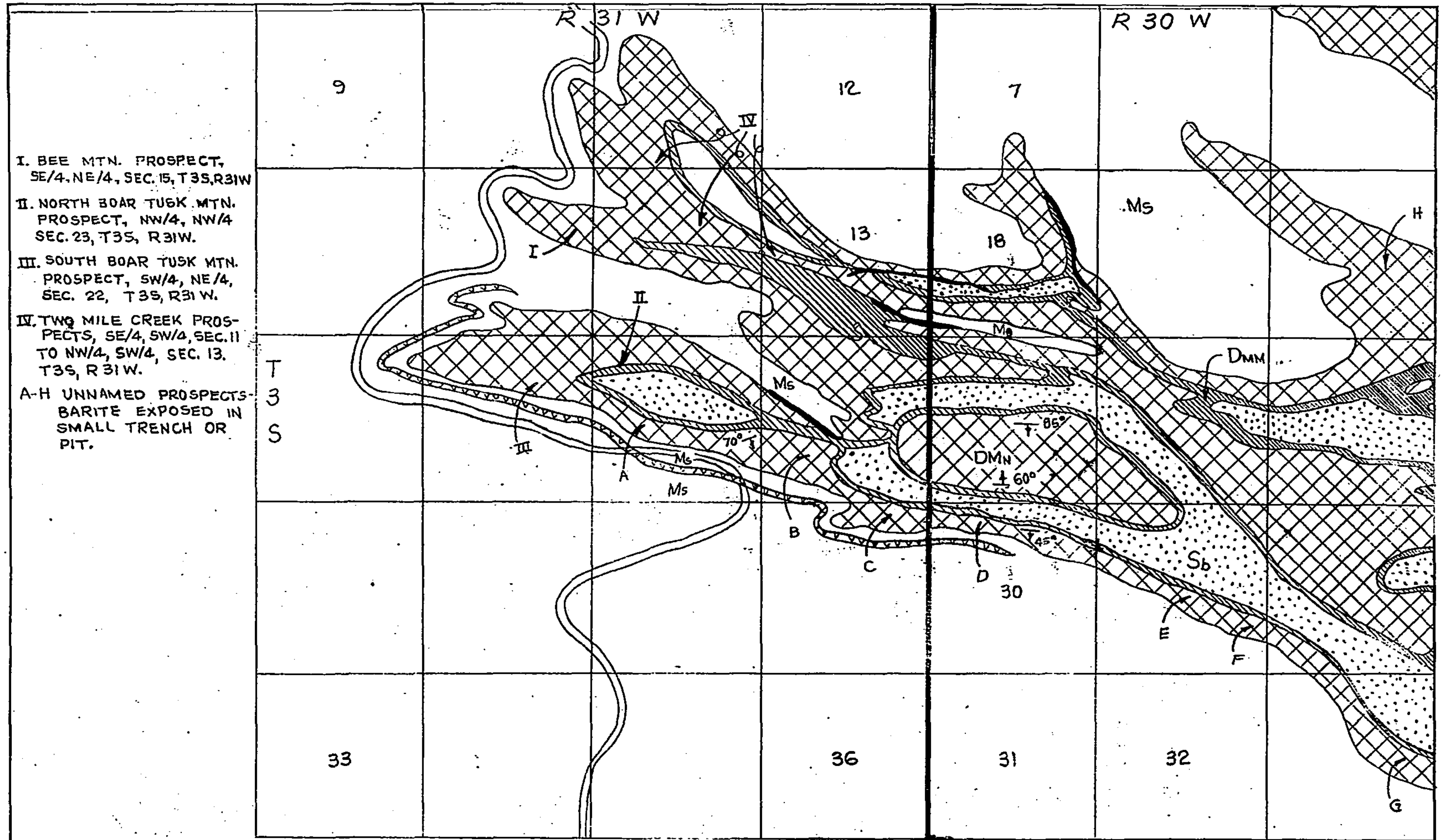


FIGURE 8
SKETCH MAP SHOWING GEOLOGY OF HATFIELD BARITE DISTRICT, ARKANSAS
(AFTER U.S.G.S. BULL. 808)

exposed in a road cut. This deposit is of particular interest because the barite occurs stratigraphically below a manganese deposit. The manganese was deposited in a porous section of faulted upper novaculite. In nearly all other places in the region where manganese and barite are present in the same vicinity the barite occurs stratigraphically above the manganese.

Southeastward from this deposit along the strike of the middle member of the Arkansas novaculite on the south side of Boar Tusk Mountain are numerous prospect pits. In about one-fourth of these pits small lentils of barite are exposed. No individual lentil has a strike length greater than 20 feet and all of them observed have a thickness of less than one foot. This mineralized zone extends southeastward at least to the east side of Brushy Creek in the NE1/4 sec. 33, T. 3 S., R. 30 W.

Two Mile Creek Prospects

Two other prospects of particular interest in the district were described briefly by Jones (1948, p. 12) as the Two Mile Creek prospects. The western prospect consists of several lenses of crystalline barite with a strike length ranging from 3 to 60 feet and the average thickness being less than one foot. These lenses occur in the middle member of the Arkansas novaculite on the westward plunging nose of the most northwestern anticline of the Cossatot anticlinorium. These lenses are best exposed in the SE1/4SW1/4 sec. 11,

T. 3 S., R. 31 W., where Two Mile Creek has cut across the nose of the anticline. The mineralized zone can be traced eastward to a northwest plunging anticlinal spur in the NW1/4SW1/4 sec. 13, T. 3 S., R. 31 W. There are several lenticular barite bodies ranging up to 50 feet in length and ordinarily less than a foot thick in the middle member of the Arkansas novaculite on the southwest flank of the anticlinal spur. The Two Mile Creek mineralized zone is about 40 feet thick, and the maximum aggregate thickness of barite would be on the order of 5 1/2 feet. This zone apparently contains more barite than any other deposit visited by the writer in the district.

Dierks District

General Statement

There are four known barite deposits in the Dierks district, the Northwest 16 and the Northeast 16, which occur in and adjacent to the NW1/4NW1/4 and the NE1/4NE1/4 respectively of sec. 16, T. 8 S., R. 29 W. A third deposit, the Cherry, occurs in the NW1/4 sec. 6, T. 8 S., R. 28 W. The largest deposit is the Lucky 13 which occurs in the western parts of secs. 13 and 24, T. 7 S., R. 28W. All these properties are on lands belonging to the Dierks Coal and Lumber Company, and are held by leases issued to Leo Yount and R. B. McElwaine. Each of these deposits occurs on a topographic high because the barite cemented sediments are more resistant to erosion.

Northwest 16

The Northwest 16 deposit trends diagonally across the NW1/4 of the section (Figure 10). It has a maximum length of 1500 feet and a maximum width of 400 feet with the average width being about 250 feet. A small barite-bearing sandstone-capped knob in the SE1/4 of section 8 is probably a continuation of this deposit. Here the barite cemented zone is about 175 feet long, and about 80 feet wide.

The Trinity sandstones in this area are for the most part uncemented and their true thickness could not be determined. The barite-bearing beds occur at least 50 feet above the Dierks limestone and at least 30 feet below the De Queen limestone. The barite was deposited in several lenticular sandstone units within a zone having a maximum thickness of 22 feet. The exact shape and size of these lenses could not be determined because they were exposed only in the exploratory trenches and pits on the property.

The cemented lenses have an average thickness of 8 to 10 inches with a thickness range from 1 to 16 inches. The maximum aggregate thickness observed in the trenches was 8 feet. The average is probably less than 5 feet. The assays of 16 samples collected at random from the trenches show the barite content to range from 0 to 45 percent, with an average barite content of slightly over 20 percent. The average content in selected samples of high-grade material was 32 percent.

At places along this deposit residual accumulations of rosettes form a mantle from 2 to 14 inches thick. These rosette accumulations are the highest grade of ore present in the deposit. The barium sulfate content is about 50 percent.

Northeast 16

The Northeast 16 barite deposit is dumbbell-shaped in plan (Figure 9). It trends northwest and has a length of about 1300 feet, with the width ranging from 200 to 500 feet. The northeast corner of section 16 is near the center of the deposit. The barite here, as is that in the Northwest 16, is present as a cement in sandstone lenses of the Trinity formation. It is highly probable that the mineralized zones in each of these deposits are stratigraphic equivalents, but this could not be proved. The maximum thickness of the mineralized zone is 30 feet, and the average is about 15 feet. The barite is present in units ranging from 1 to 14 inches in thickness, and the aggregate thickness of barite observed in any single trench is 6 feet. As in the companion deposit, the highest grade barite occurs in a residual zone of barite rosettes.

Cherry Deposit

The Cherry deposit consists of a roughly tadpole-shaped mineralized zone about 500 feet wide at the head or northeastern end, and tapering to a width of about 100 feet at the

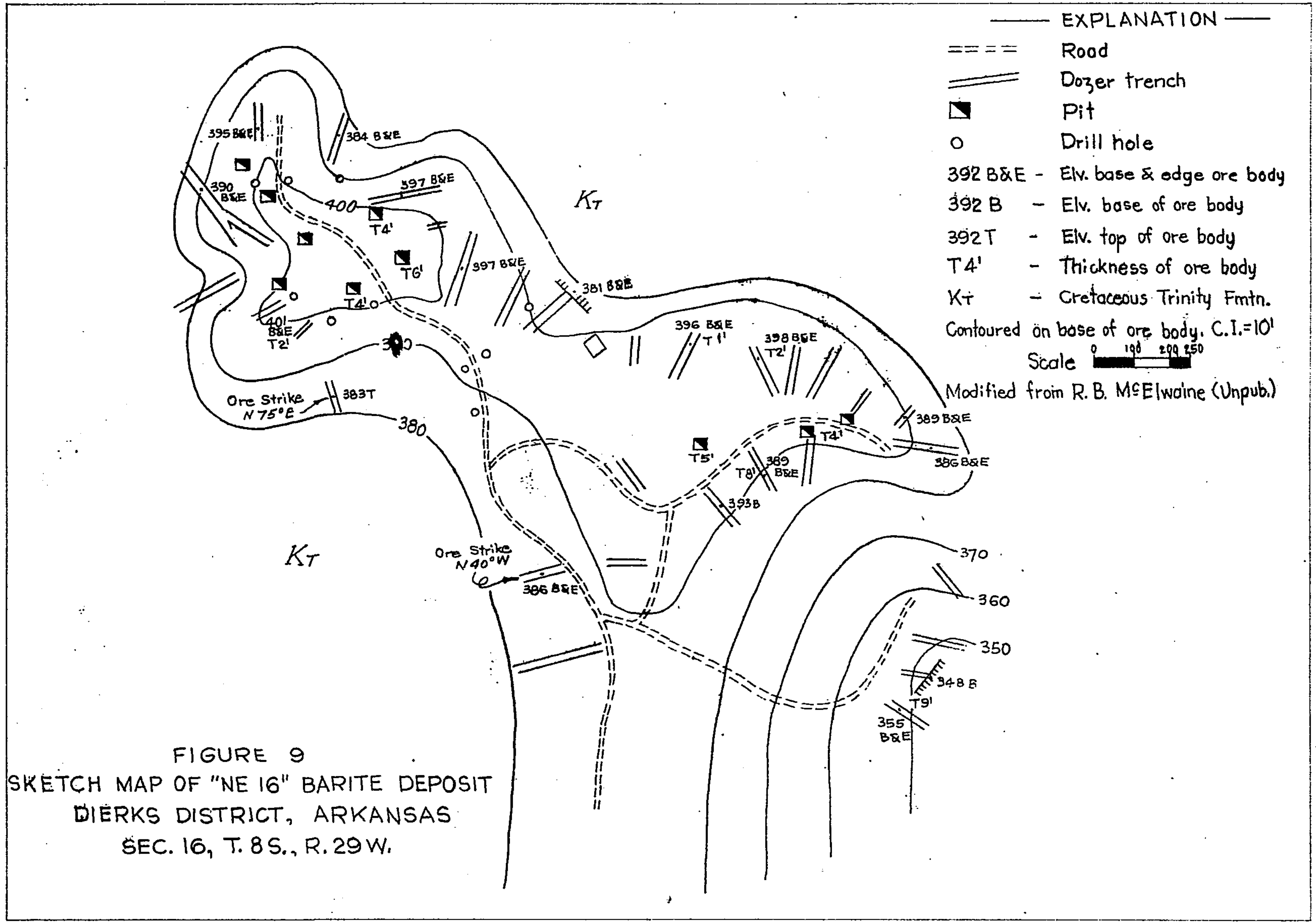
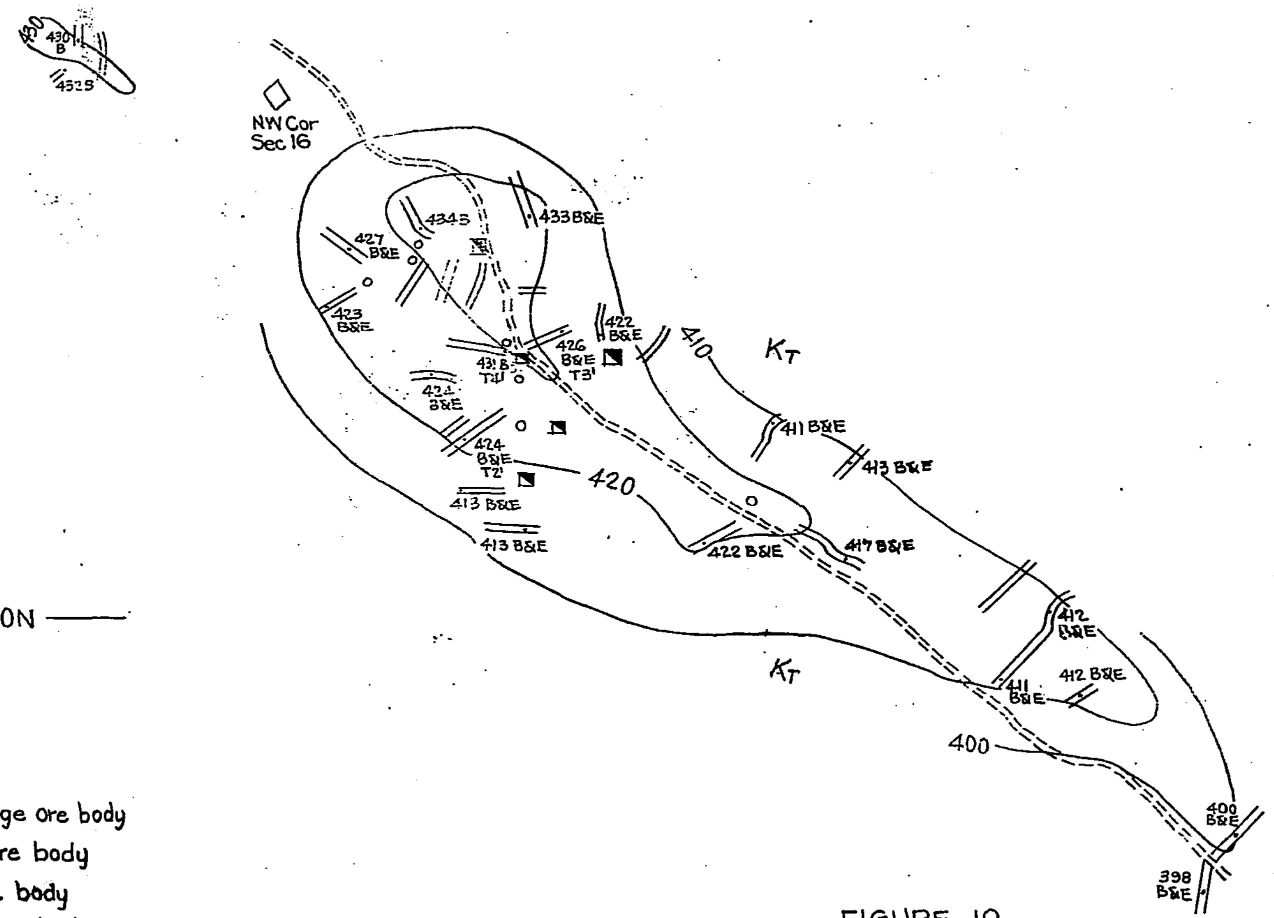


FIGURE 9
SKETCH MAP OF "NE 16" BARITE DEPOSIT
DIERKS DISTRICT, ARKANSAS
SEC. 16, T. 8 S., R. 29 W.



EXPLANATION

Road

Dozer trench

Pit

Drill hole -

392B&E - Elv. base & edge ore body

392B - Elv. base of ore body

392T - Elv. top of ore body

T4' - Thickness of ore body

K_T Cretaceous Trinity Fmtn.

Contoured on base of ore body. C.I.=10'

Scale 0 100 200 250

Modified from R. B. McElwaine (Unpub.)

FIGURE 10

SKETCH MAP OF "NW 16" BARITE DEPOSIT
DIERKS DISTRICT, ARKANSAS
SEC. 16, T. 8 S., R. 29W.

southwest end (Figure 11). The length of the deposit is about 1800 feet. About 700 feet south from this mineralized zone are two barite-capped hills, each with a maximum diameter of 200 feet. Undoubtedly these two mineralized areas were connected before erosion removed the intervening beds.

This deposit, like the two previously discussed, consists mostly of barite present as cement in sandstones; however, a few barite cemented gravels are present in the section. The mineralized zone has a maximum thickness of 25 feet and an average thickness of about 18 feet. The barite-bearing units have about the same thickness range, 1 to 15 or 16 inches, as do those in the deposits in section 16, but here the units have a greater average thickness, on the order of 10 inches. Residual rosettes are fairly abundant along the flanks, but are not present in any quantity toward the center of the deposit. This deposit is about 20 feet above the Dierks limestone and about 100 feet below the De Queen limestone.

Lucky 13 Deposit

The Lucky 13 barite deposit has an irregular shape (Figure 12). Most of it lies along the western part of section 13, but the tongues or projections extend into sections 14 and 24. The total area of the deposit is approximately one-half mile square.

The barite occurs as cementing material in the lower Trinity sand and in the underlying Pike gravel. If an average could be taken it would probably show that about 50 percent of the barite is in the Pike gravel and 50 percent in the sandstones. Downward pinching veins of crystalline barite indicate that the barium sulfate solutions percolated along the sandstone and down into the gravel along fractures. In all of the pits, trenches and drill holes that penetrated the barite-bearing gravel, the barite was confined to the upper zone of the gravel with the lower zone being barren. The total thickness of the mineralized zone could not be determined, but it is no less than 12 feet in the gravel and no less than 18 feet in the overlying sandstones. Residual accumulations are common in the area, but rosettes are lacking or are poorly developed.

Petrographic studies of the sandstones indicate that the large barite crystals tend to have a parallel rather than a radial development in this deposit. On fresh fractures or bedding planes in some of the sandstones sheen surfaces up to six inches in diameter can be observed. Thin section examinations show that these surfaces are formed by barite crystals parallel to the bedding, and not by single crystals. The maximum observed length of an optically continuous crystal was 3 1/2 inches.

The concentration of barite is greater in this deposit than in the others in the district. It is not known whether this is because of more favorable host characteristics in the beds or because these stratigraphically lower beds have

EXPLANATION

= = = =	Road
(double line)	Dozer trench
(symbol)	Pit
o	Drill hole
392B&E	- Elv. base & edge ore body
392B	- Elv. base of ore body
392T	- Elv. top of ore body
T4'	- Thickness of ore body
KT	- Cretaceous Trinity Fmtn.

Contoured on base of ore body. C.I.=10'

Scale 0 100 200 250

Modified from R. B. McElwaine (Unpub.)

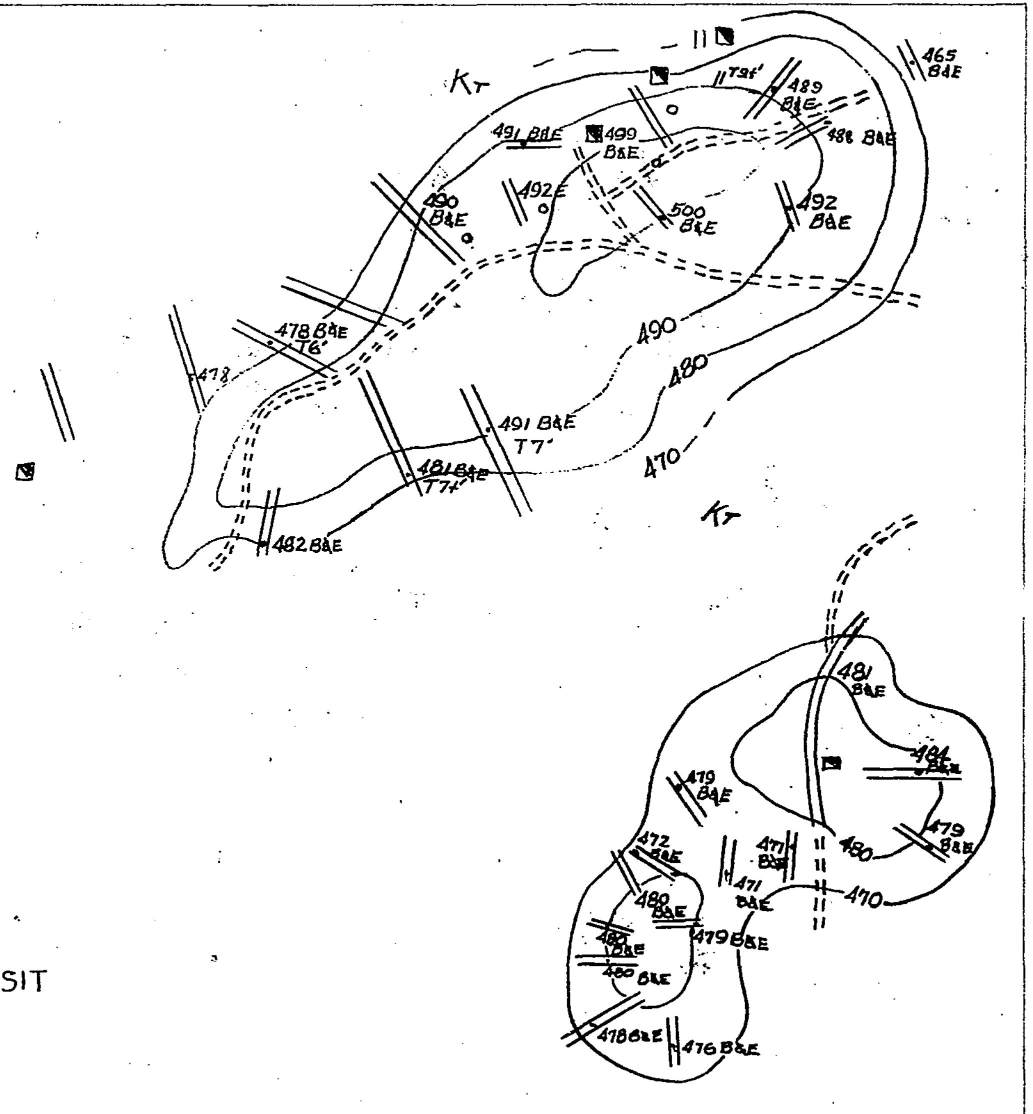


FIGURE 11
SKETCH MAP OF CHERRY BARITE DEPOSIT
DIERKS DISTRICT, ARKANSAS
NW/4 SEC. 6., T. 8 S., R. 28 W.

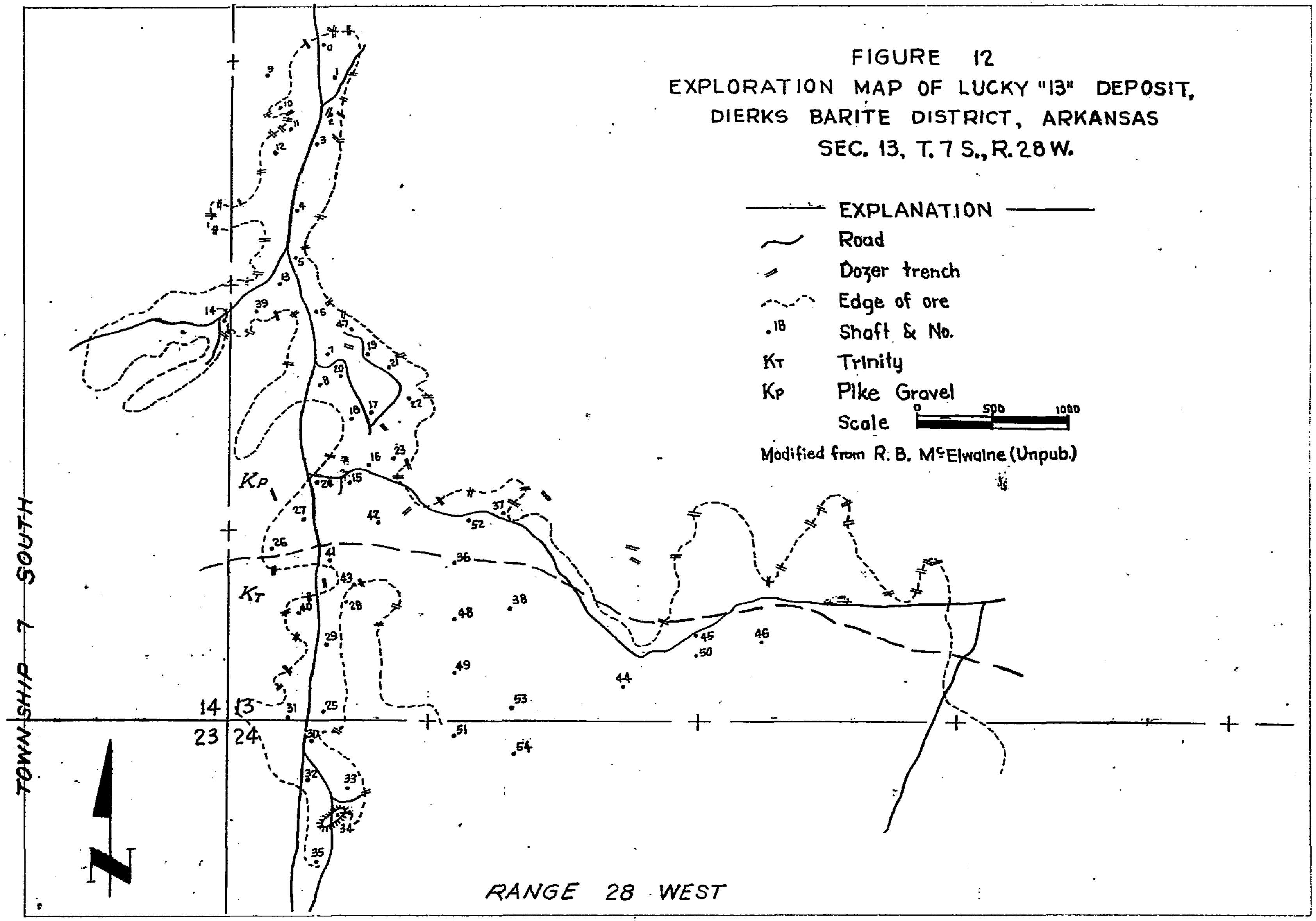


FIGURE 12
EXPLORATION MAP OF LUCKY "13" DEPOSIT,
DIERKS BARITE DISTRICT, ARKANSAS
SEC. 13, T. 7 S., R. 28 W.

been less weathered and eroded. Probably both factors are responsible to some degree.

The barite zone of the Lucky 13 deposit is about 50 feet below the Dierks limestone.

The barite in the deposits of this district is present as cementing material. The highest tenor of ore is over 50 percent (in the Pike gravel) and the average tenor (30 to 40 percent with selective mining) is considerably less than the tenor of the high-grade ore in the replacement deposits. The cementing barite can be freed from the enclosing rock much more readily than can the replacement-type barite. It is probable that the cost per ton of recovered barite, assuming suitable mining methods, would be about the same as that for the replacement deposits.

The economic value of the barite deposits in the Dierks district as well as those in the Pigeon Roost, Fancy Hill and Hatfield districts, is dependent upon (1) amount of reserves that can be established, (2) transportation costs, and (3) availability of a market.

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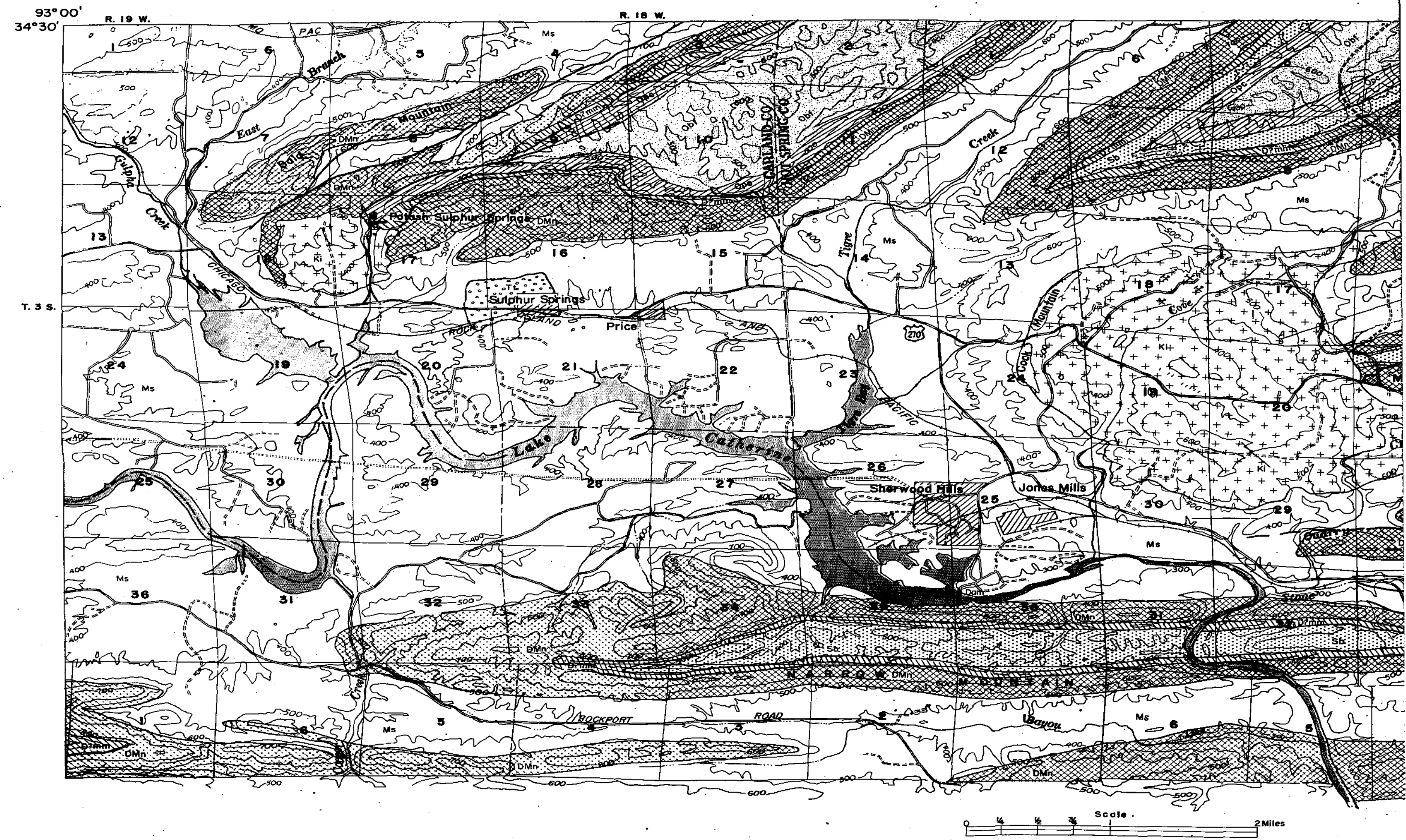
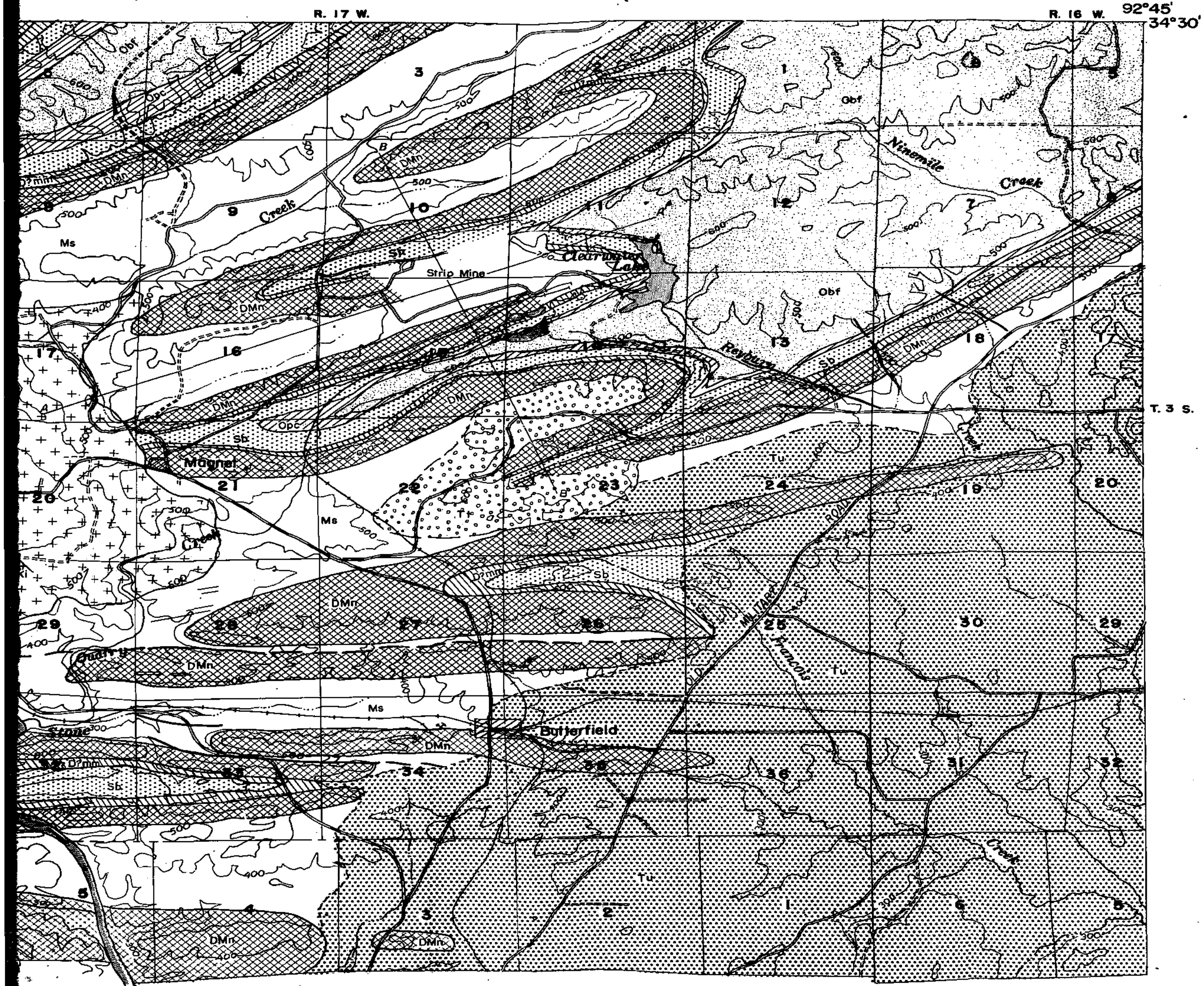
PLATE III



GENERALIZED GEOLOGIC MAP OF THE MAGNET COVE BARITE DISTRICT



Modifed from Culp 1948 and Parks 1932
Base from USGS topo. map of Malvern Quad

2 Miles

THE

EXPLANATION

CENEZOIC SEDIMENTS

- Tu — TERTIARY SEDIMENTS UNDIFFERENTIATED
- Tt — TERTIARY TERRACE GRAVELS

PALEOZOIC SEDIMENTS

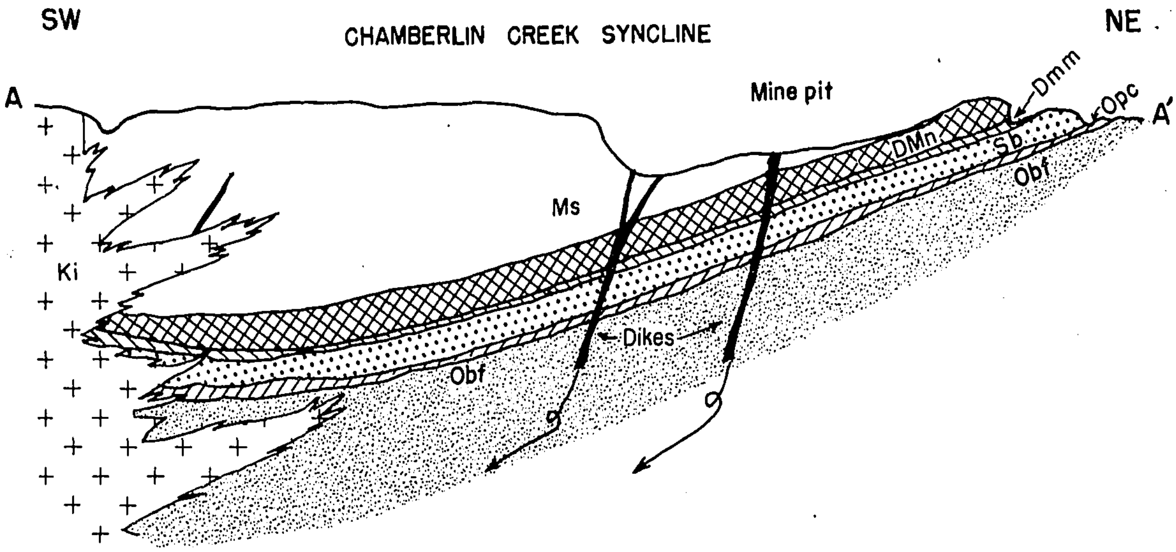
- Ms — STANLEY FORMATION
- DMn — ARKANSAS NOVACULITE
- D?mm — MISSOURI MOUNTAIN SHALE
- Sb — BLAYLOCK SANDSTONE
- Opc — POLK CREEK SHALE
- Obf — BIGFORK CHERT

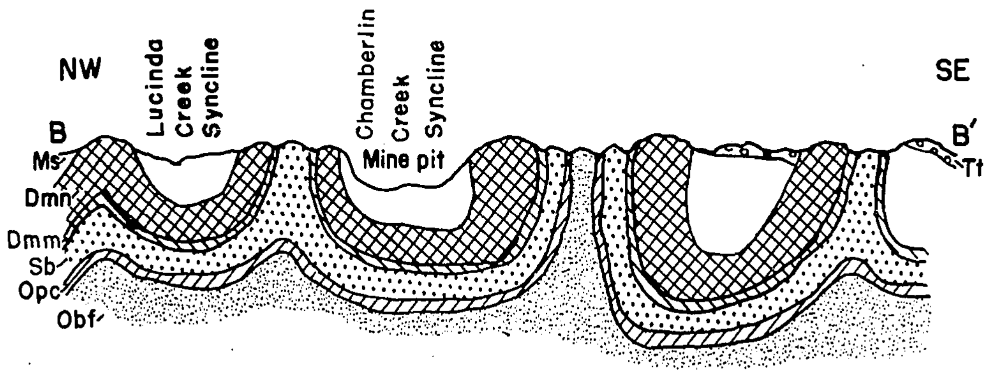
MESOZOIC IGNEOUS

- Ki — CRETACEOUS IGNEOUS WITH INCLUDED METAMORPHICS UNDIFFERENTIATED
- ALKALIC DIKES
- FAULT
- A—A' LINE OF CROSS SECTION

PLATE IV

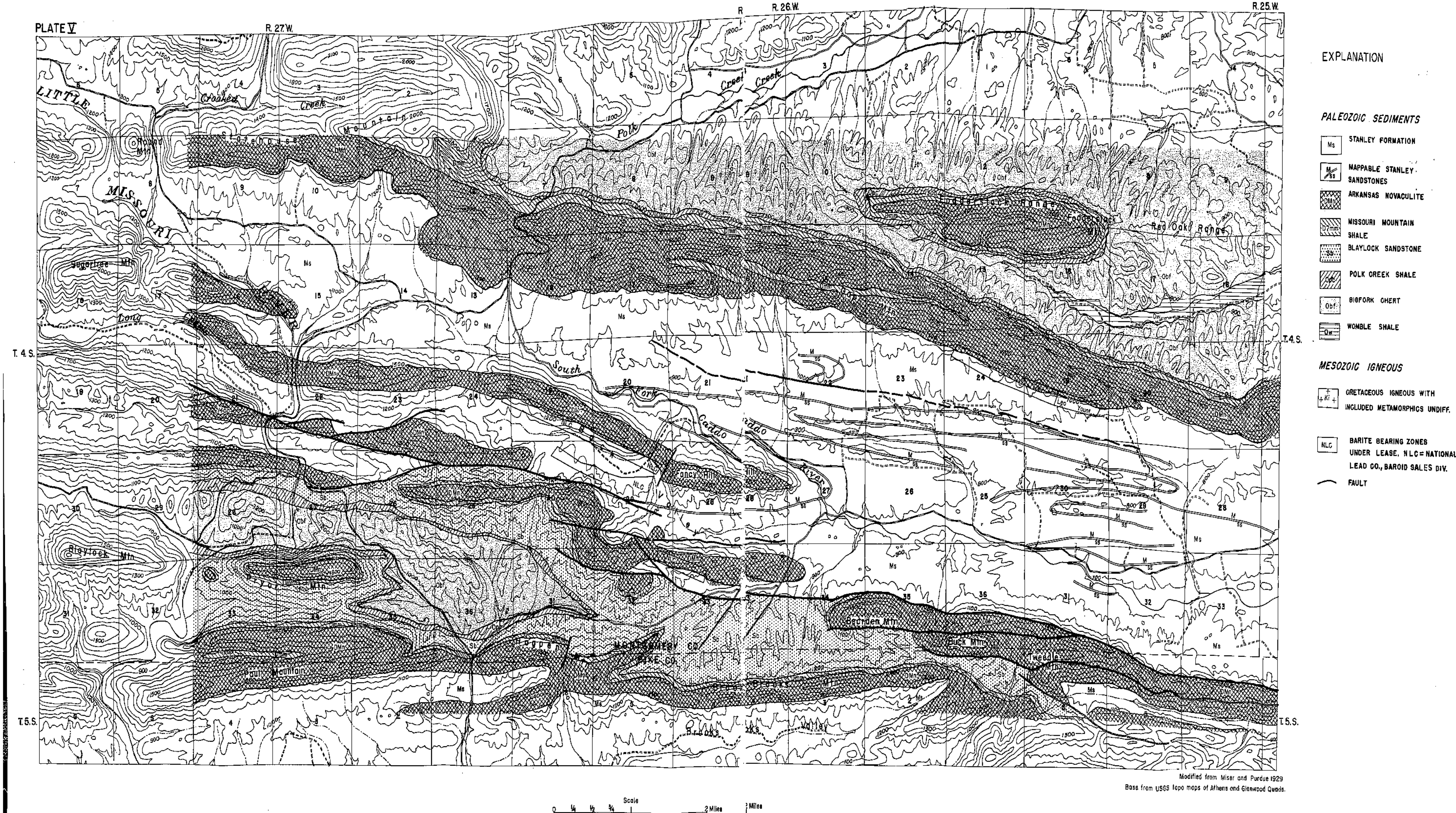
SCHEMATIC CROSS-SECTIONS TO SHOW GENERAL STRUCTURAL RELATIONSHIPS IN THE MAGNET COVE DISTRICT
(Symbols and lines of sections shown on PLATE III).



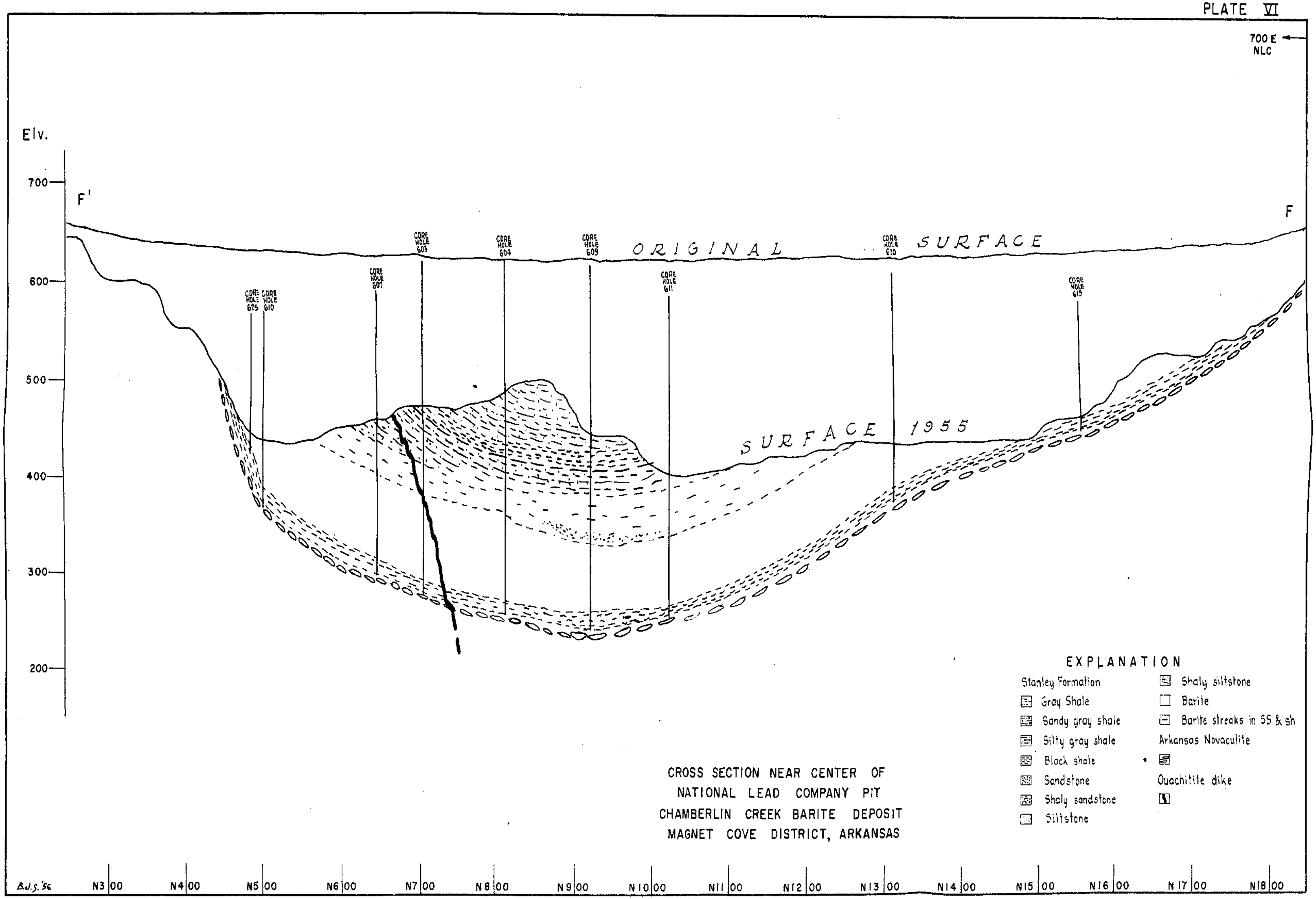


B. J. S. '56

PLATE V

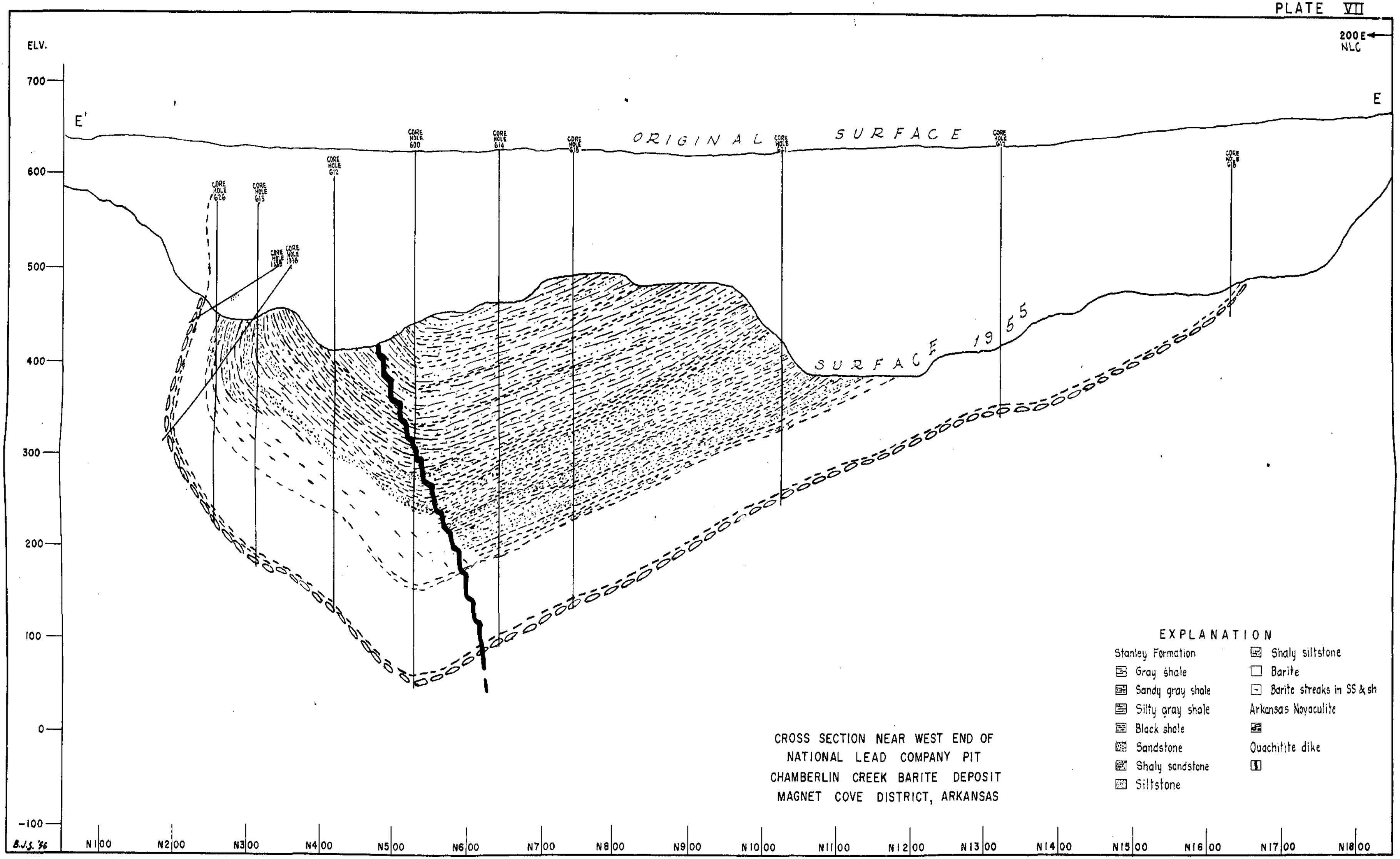


GENERALIZED GEOLOGIC MAP OF THE FANCY HILL BA[illegible]LL BARITE DISTRICT.



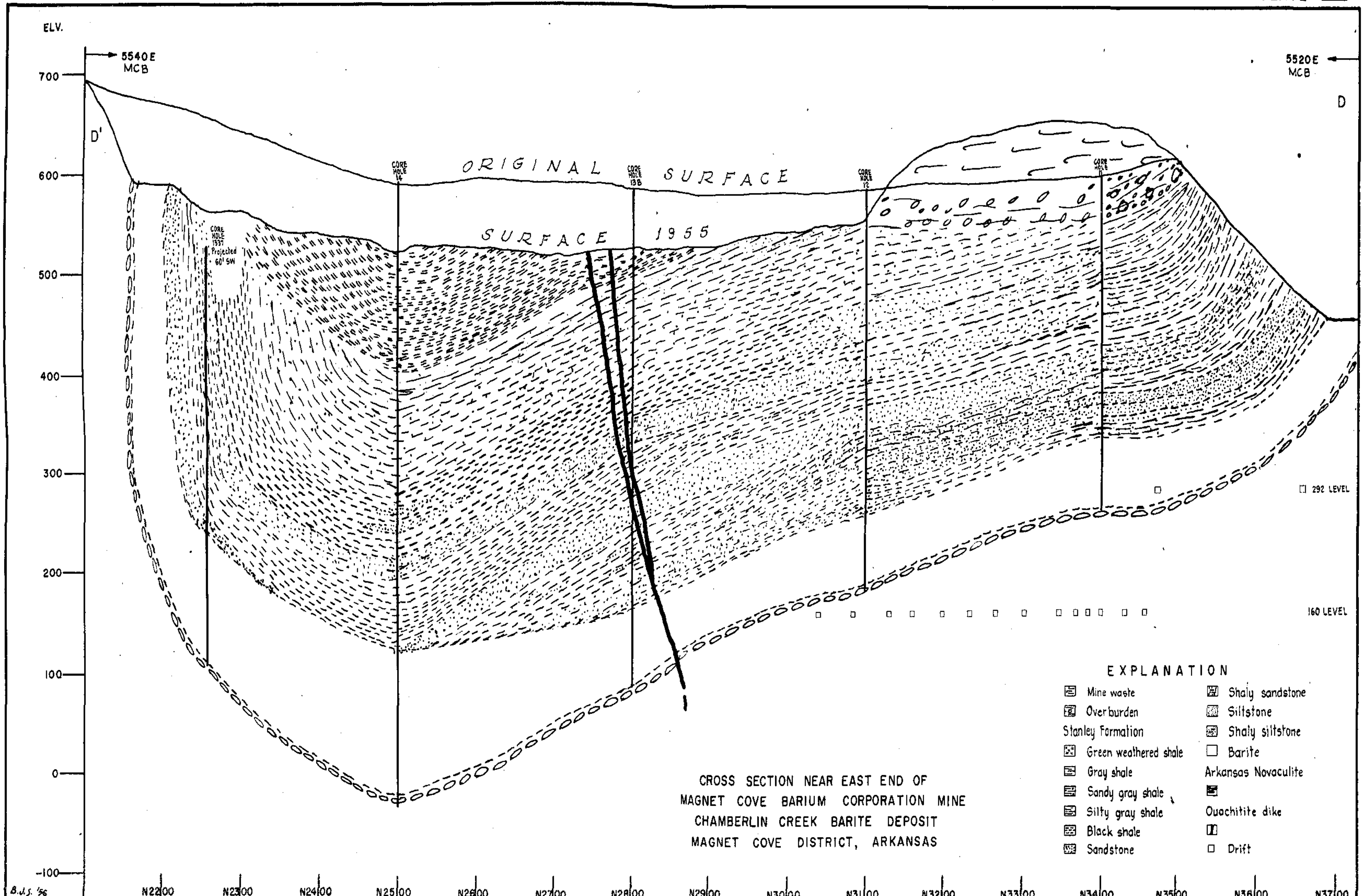
CROSS SECTION NEAR CENTER OF
NATIONAL LEAD COMPANY PIT
CHAMBERLIN CREEK BARITE DEPOSIT
MAGNET COVE DISTRICT, ARKANSAS

PLATE VII



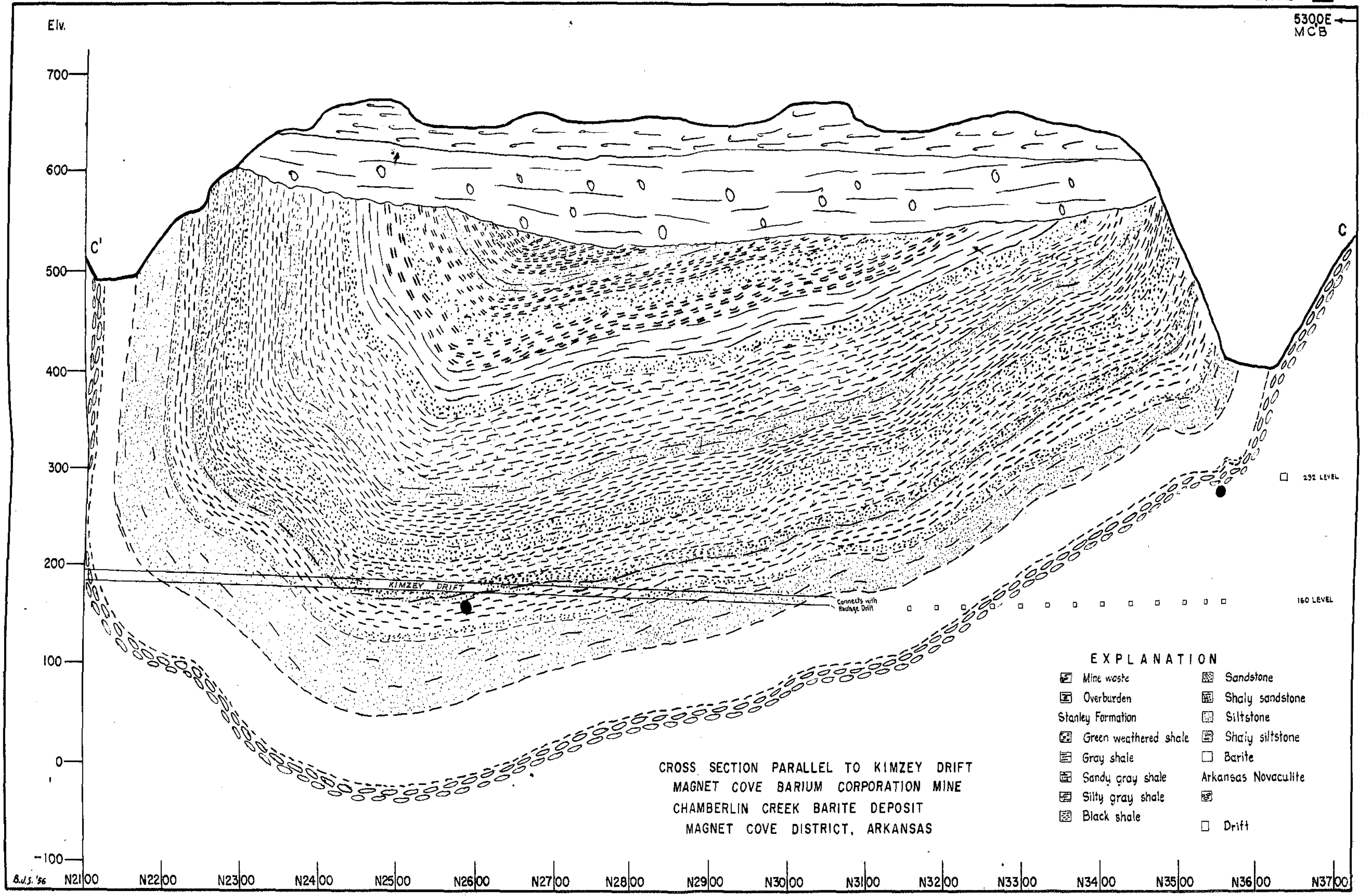
CROSS SECTION NEAR WEST END OF
NATIONAL LEAD COMPANY PIT
CHAMBERLIN CREEK BARITE DEPOSIT
MAGNET COVE DISTRICT, ARKANSAS

PLATE VIII



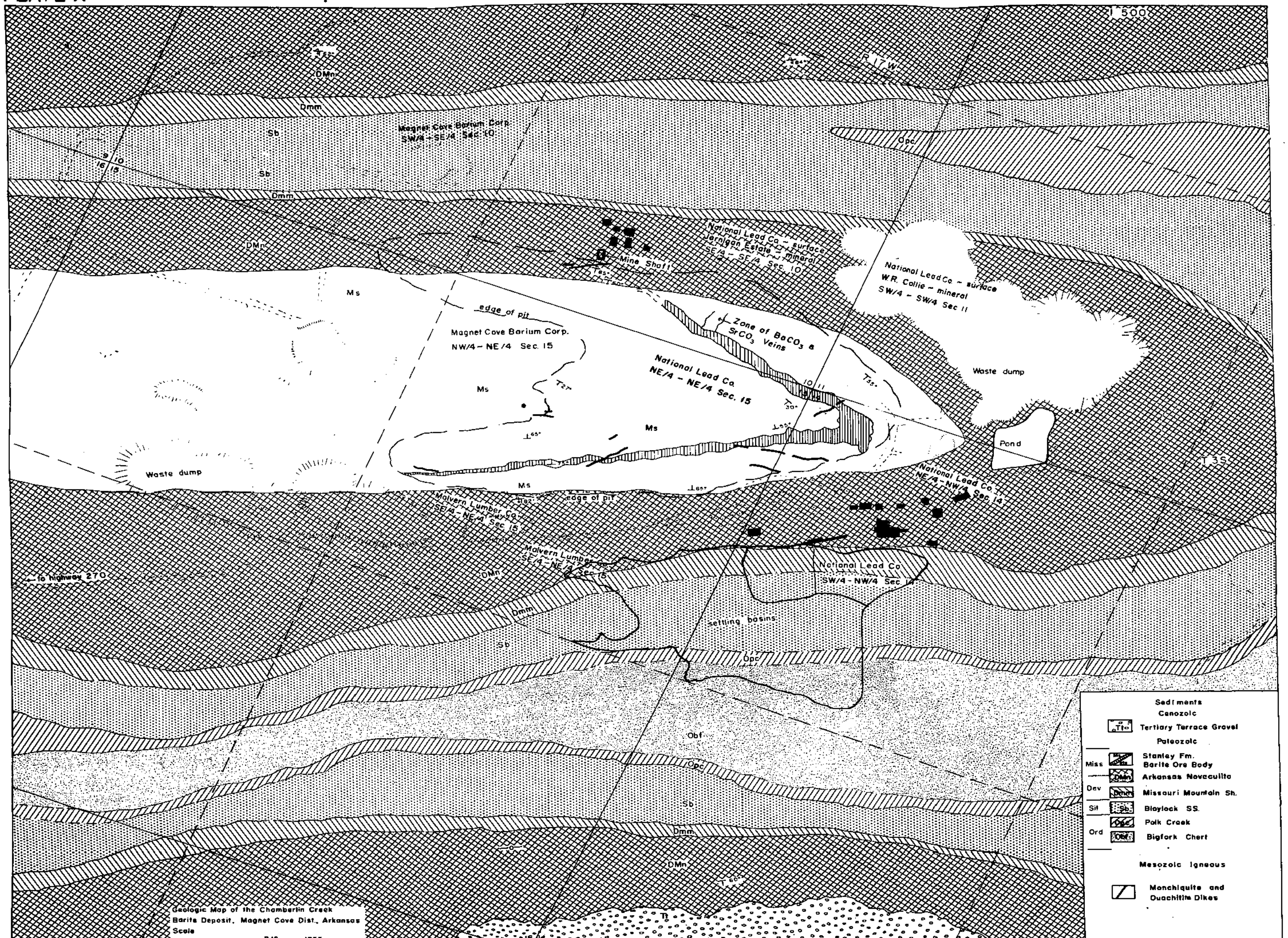
CROSS SECTION NEAR EAST END OF
MAGNET COVE BARIUM CORPORATION MINE
CHAMBERLIN CREEK BARITE DEPOSIT
MAGNET COVE DISTRICT, ARKANSAS

PLATE IX



CROSS SECTION PARALLEL TO KIMZEY DRIFT
MAGNET COVE BARIUM CORPORATION MINE
CHAMBERLIN CREEK BARITE DEPOSIT
MAGNET COVE DISTRICT, ARKANSAS

PLATE X


1 500
R 17 W
T 3 S
Dmm
DMn
Sb
Opc
Obf
Ms
Tt
Magnet Cove Barium Corp.
SW/4 - SE/4 Sec. 10
9 10
16 15
National Lead Co. - surface
Jernigan Estate - mineral
SE/4 - SE/4 Sec. 10
Mine Shaft
National Lead Co. - surface
W.R. Collie - mineral
SW/4 - SW/4 Sec 11
Zone of $BaCO_3$ &
$SrCO_3$ Veins
Waste dump
edge of pit
Magnet Cove Barium Corp.
NW/4 - NE/4 Sec. 15
National Lead Co.
NE/4 - NE/4 Sec. 15
10 11
Pond
National Lead Co.
NE/4 - NW/4 Sec. 14
Malvern Lumber Co.
SE/4 - NE/4 Sec. 15
← to highway 270
National Lead Co.
SW/4 - NW/4 Sec. 14
settling basins
Sediments
Cenozoic
Tertiary Terrace Gravel
Paleozoic
Miss
Stanley Fm.
Barite Ore Body
Arkansas Novaculite
Dev
Missouri Mountain Sh.
Sil
Blaylock SS.
Polk Creek
Ord
Bigfork Chert
Mesozoic Igneous
Monchiquite and
Ouachitite Dikes
Geologic Map of the Chamberlin Creek
Barite Deposit, Magnet Cove Dist., Arkansas
Scale
BJS 1955

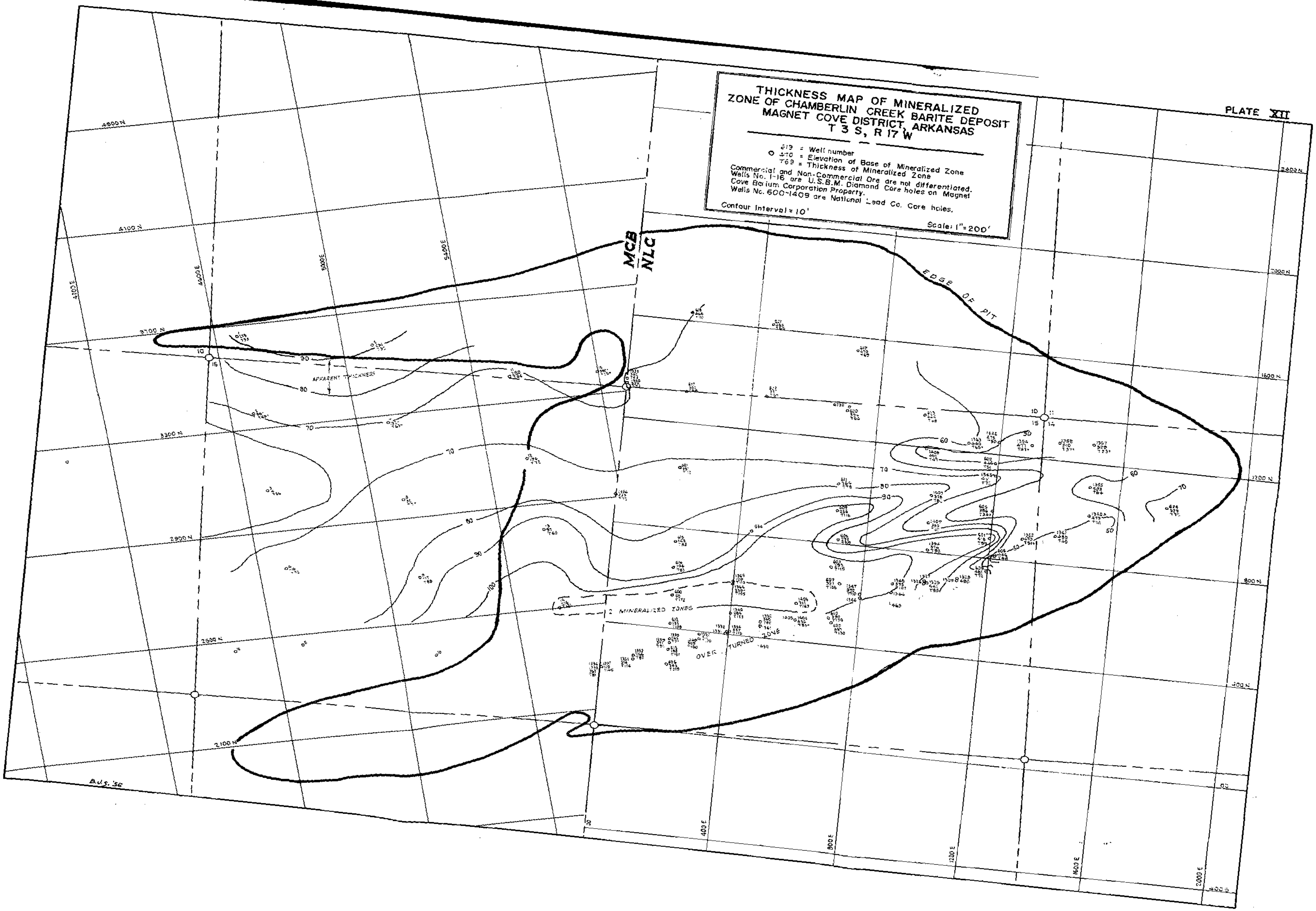
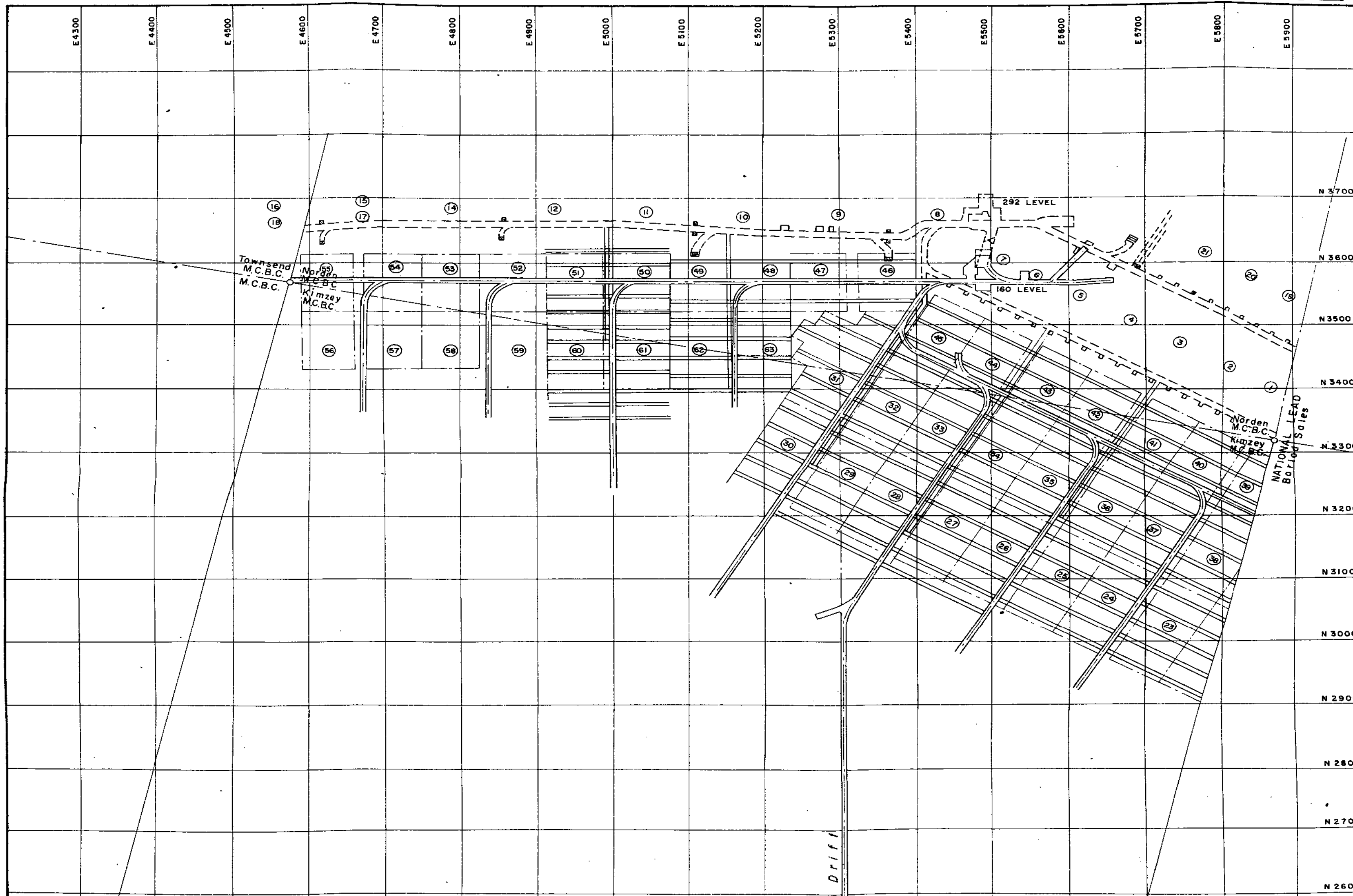
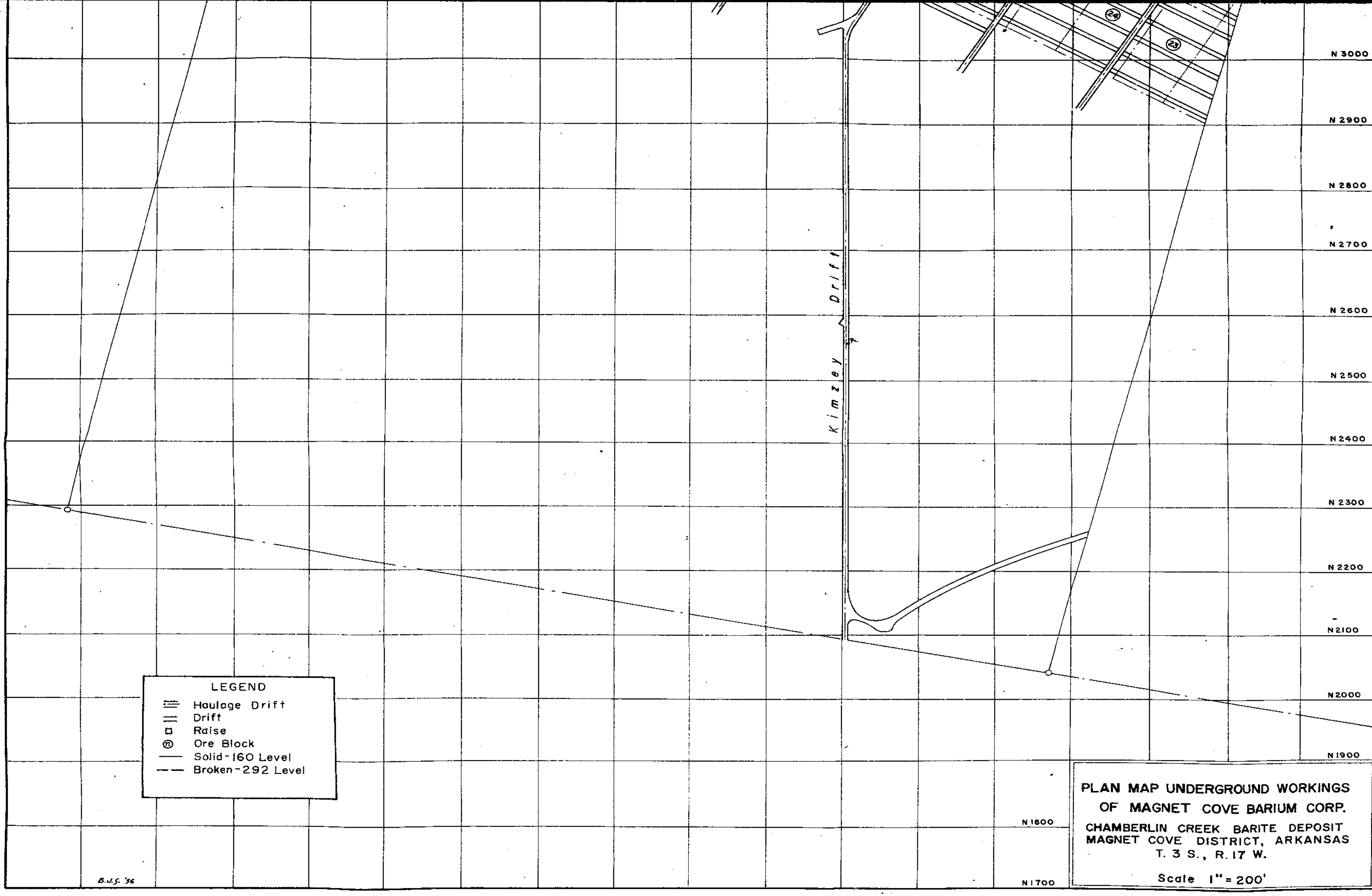


PLATE XII
THICKNESS MAP OF MINERALIZED ZONE OF CHAMBERLIN CREEK BARITE DEPOSIT MAGNET COVE DISTRICT, ARKANSAS
T 3 S, R 17 W
619 = Well number
470 = Elevation of Base of Mineralized Zone
T69 = Thickness of Mineralized Zone
Commercial and Non-Commercial Ore are not differentiated.
Wells No. 1-16 are U.S.B.M. Diamond Core holes on Magnet Cove Barium Corporation Property.
Wells No. 600-1409 are National Lead Co. Core holes.
Contour Interval = 10'
Scale: 1" = 200'
MCB
NLC
EDGE OF PIT
APPARENT THICKNESS
2 MINERALIZED ZONES
OVER - TURNED ZONE
B.J.S. '56

PLATE XIII



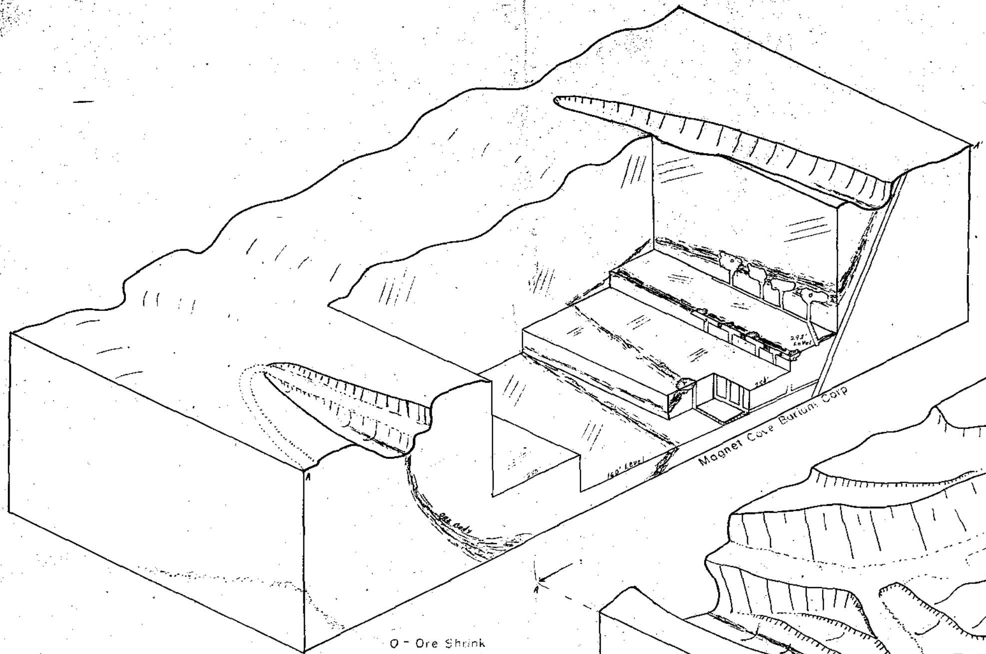
E 4300
E 4400
E 4500
E 4600
E 4700
E 4800
E 4900
E 5000
E 5100
E 5200
E 5300
E 5400
E 5500
E 5600
E 5700
E 5800
E 5900
N 3700
N 3600
N 3500
N 3400
N 3300
N 3200
N 3100
N 3000
N 2900
N 2800
N 2700
N 2600
292 LEVEL
160 LEVEL
Townsend M.C.B.C.
M.C.B.C.
Norden M.C.B.C.
Kimzey M.C.B.C.
Norden M.C.B.C.
Kimzey M.C.B.C.
NATIONAL LEAD Barlod Sales
Drift

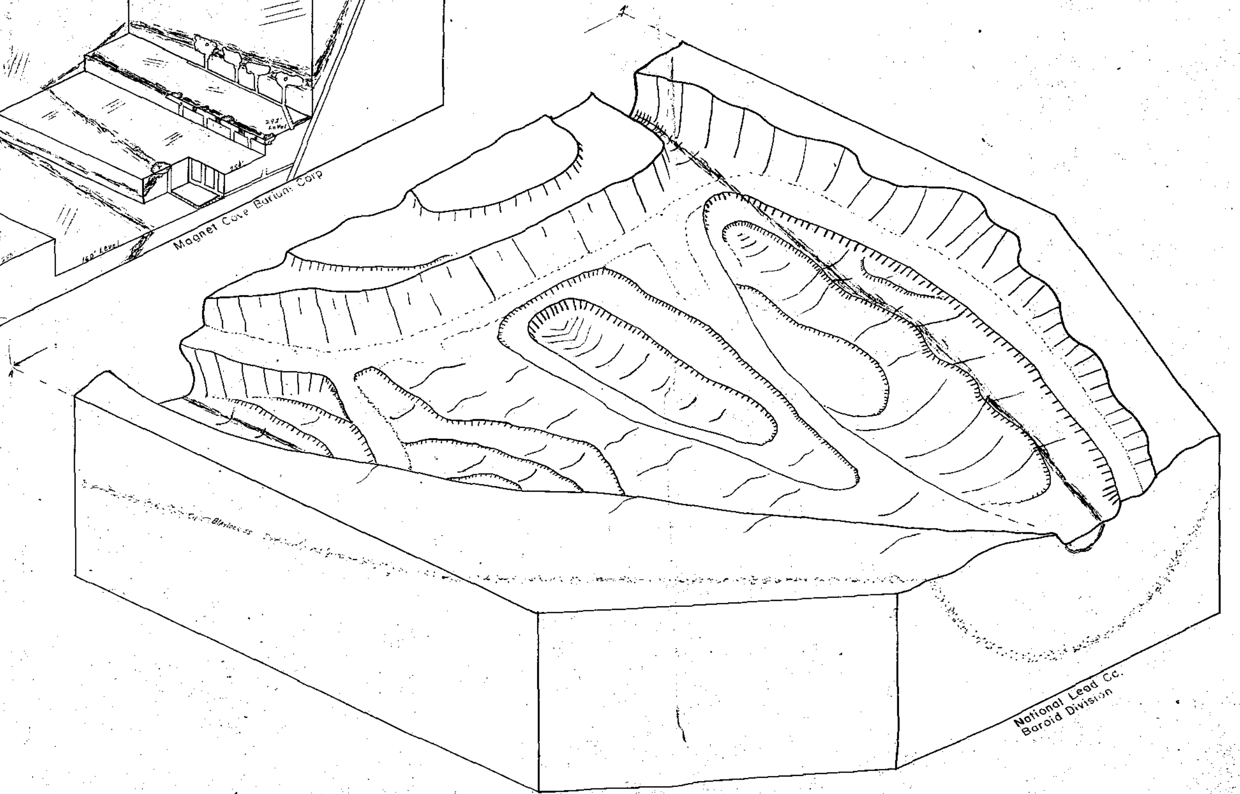


PLAN MAP UNDERGROUND WORKINGS
OF MAGNET COVE BARIUM CORP.
CHAMBERLIN CREEK BARITE DEPOSIT
MAGNET COVE DISTRICT, ARKANSAS
T. 3 S., R. 17 W.

Scale 1" = 200'

Plate XIV





O - Ore Shrink
S - Scraper Drift
T - Top Slice

Schematic isometric projection showing mining methods, Magnet Cove Barite District, Arkansas

Scale 1" = 200'

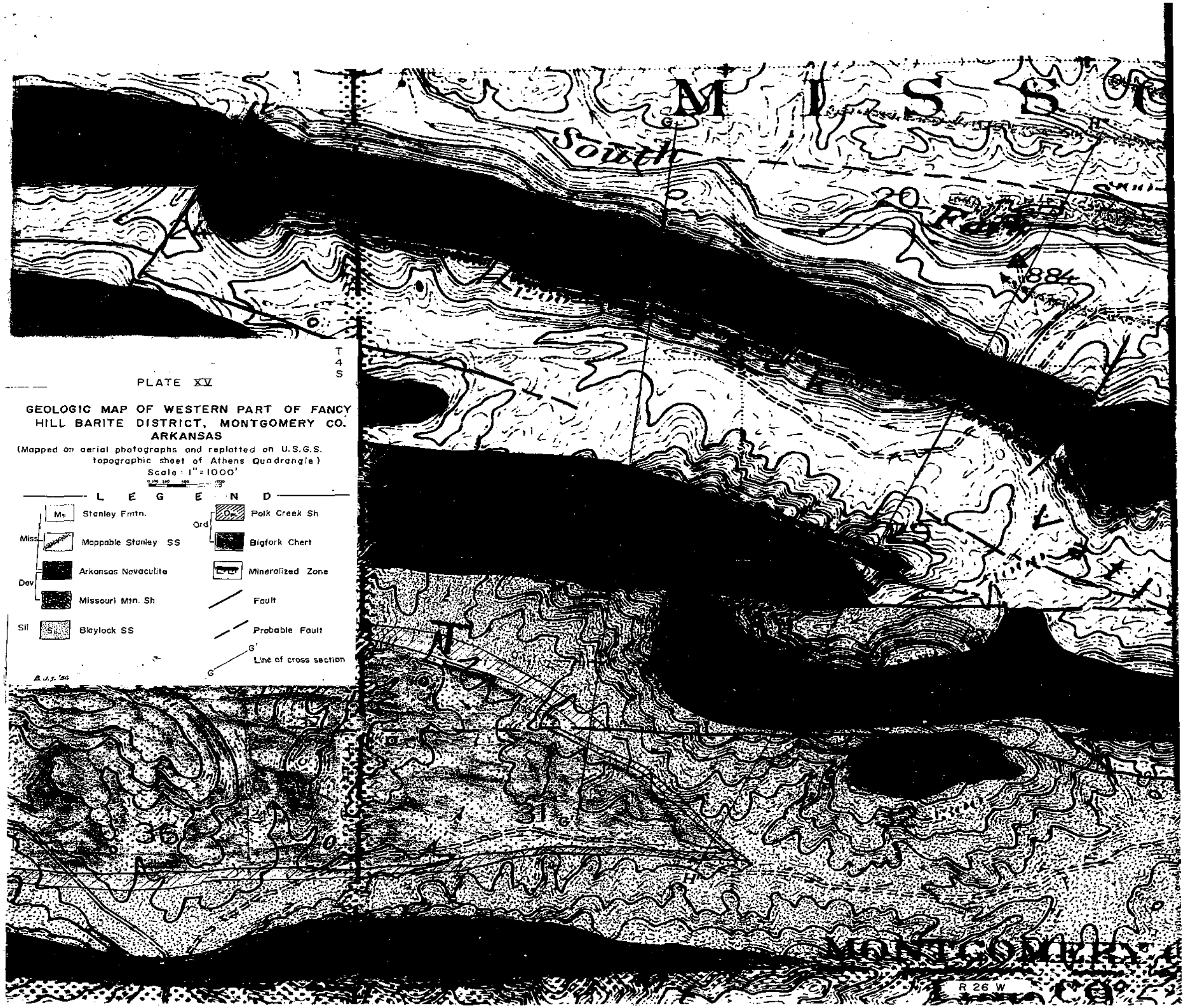
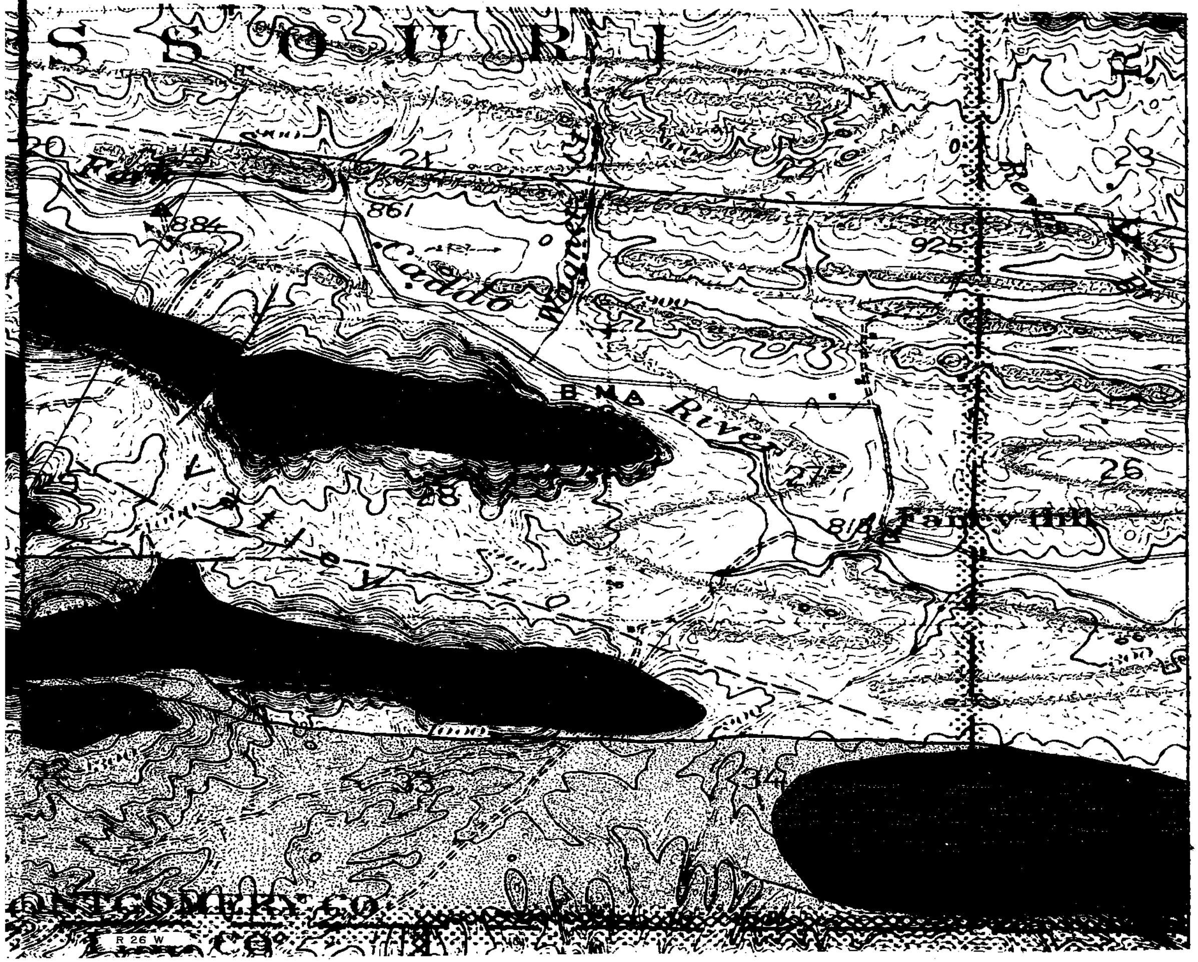
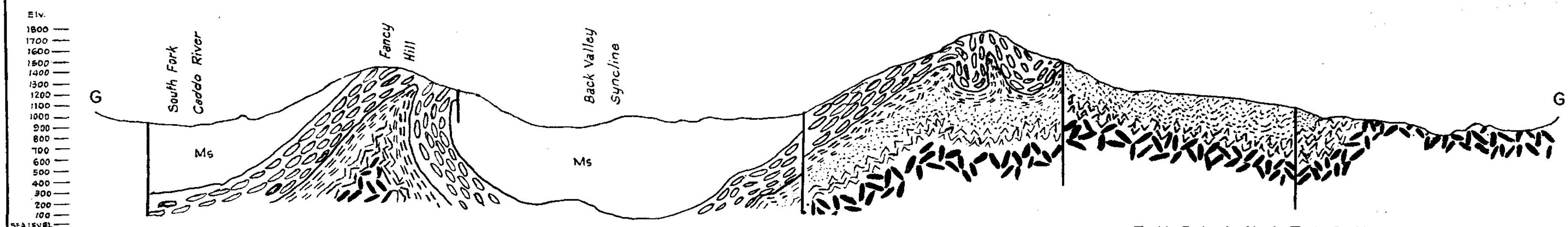


PLATE XV
GEOLOGIC MAP OF WESTERN PART OF FANCY HILL BARITE DISTRICT, MONTGOMERY CO. ARKANSAS
(Mapped on aerial photographs and replotted on U.S.G.S. topographic sheet of Athens Quadrangle)
Scale: 1" = 1000'
LEGEND
Miss
Ms Stanley Fmtn.
Mappable Stanley SS
Dev
Arkansas Novaculite
Missouri Mtn. Sh
Sil
Sb Blaylock SS
Ord
Opc Polk Creek Sh
Bigfork Chert
Mineralized Zone
Fault
Probable Fault
G G' Line of cross section
B.J.J. '36
T 4 S
MISSOURI
South Fork
MONTGOMERY CO
R 26 W



S S O U R I
Caddo
River
Fancy Hill
MONTGOMERY CO.
R 26 W
861
884
925

PLATE XVI



CROSS SECTION ACROSS BACK VALLEY SYNCLINE
FANCY HILL DISTRICT
MONTGOMERY CO., ARKANSAS

EXPLANATION

Miss
- Ms — Stanley Fmtn.
- Stanley SS
- DMN — Arkansas Novaculite

Dev
- DMM — Missouri Mtn. sh.

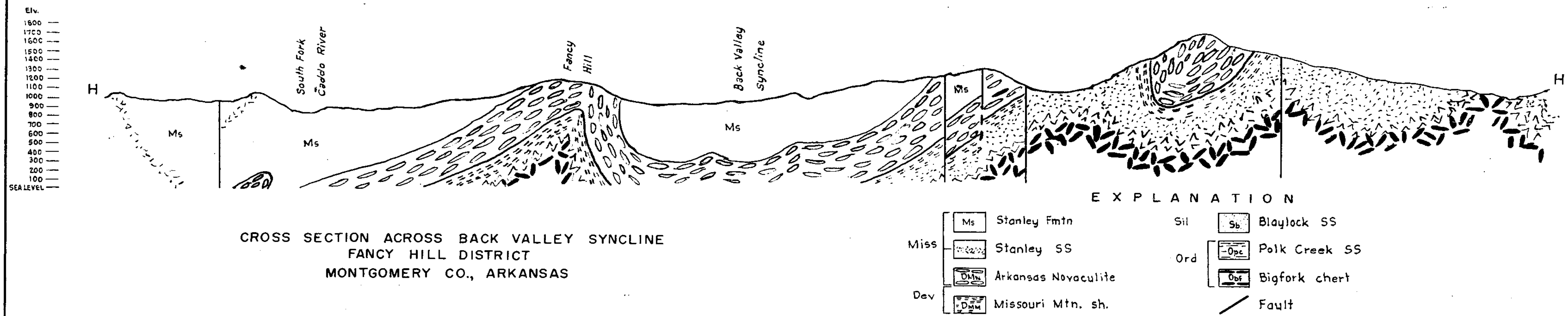
Sil
- Sb — Blaylock SS

Ord
- Ops — Polk Creek SS
- Obf — Bigfork chert

Fault

B.J.S. '56

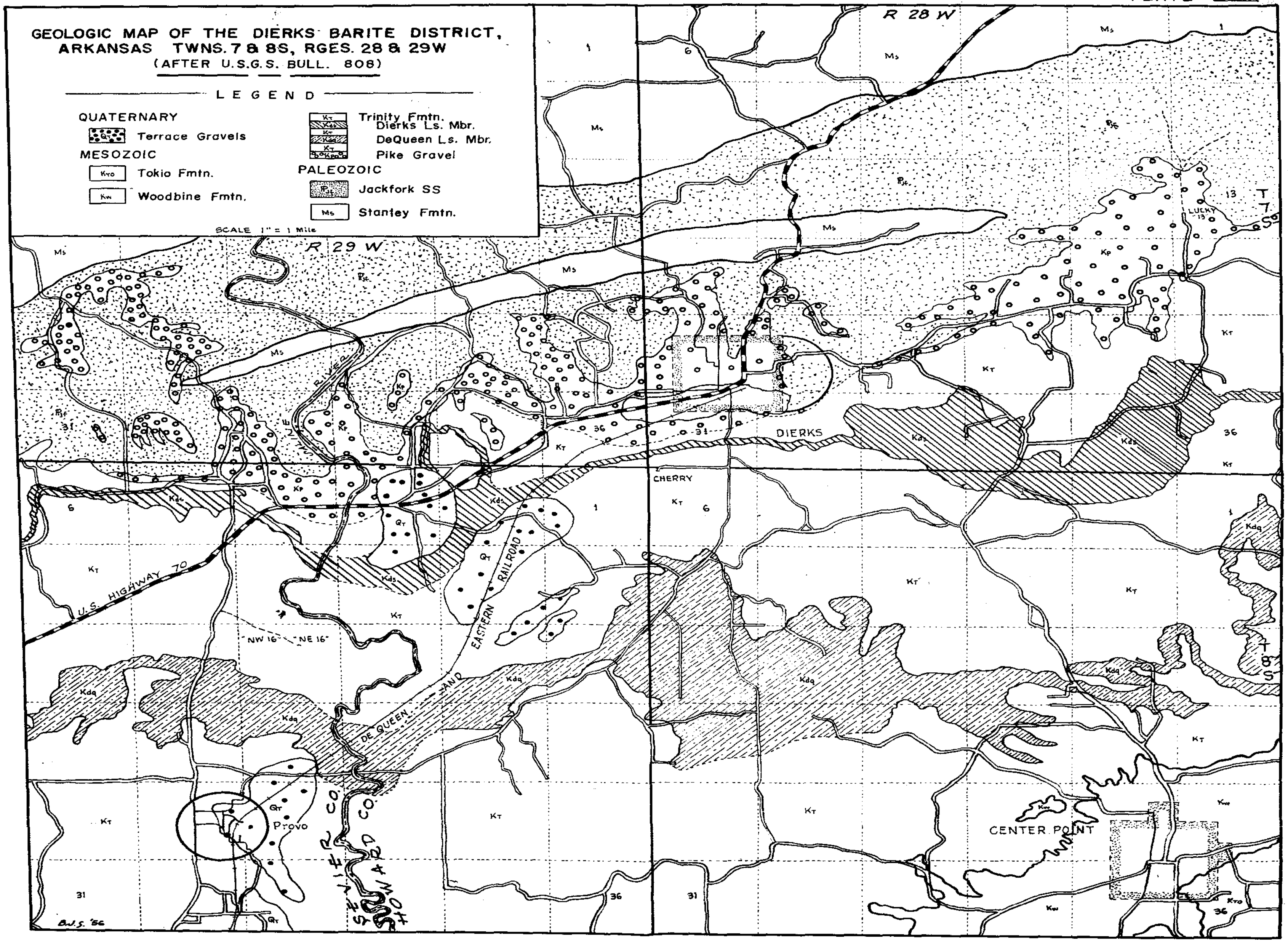
PLATE XVII



CROSS SECTION ACROSS BACK VALLEY SYNCLINE
FANCY HILL DISTRICT
MONTGOMERY CO., ARKANSAS

B.J.S. '56

PLATE XVIII


GEOLOGIC MAP OF THE DIERKS BARITE DISTRICT, ARKANSAS TWNS. 7 & 8S, RGES. 28 & 29W
(AFTER U.S.G.S. BULL. 808)
LEGEND
QUATERNARY
Terrace Gravels
MESOZOIC
Tokio Fmtn.
Woodbine Fmtn.
Trinity Fmtn.
Dierks Ls. Mbr.
DeQueen Ls. Mbr.
Pike Gravel
PALEOZOIC
Jackfork SS
Stanley Fmtn.
SCALE 1" = 1 Mile
R 28 W
R 29 W
T 7 S
T 8 S
LUCKY 13
DIERKS
CHERRY
U.S. HIGHWAY 70
DE QUEEN AND EASTERN RAILROAD
SEVIER CO.
HOWARD CO.
Provo
CENTER POINT
NW 16
NE 16
B.J.S. '56