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EXPLORATION

FOR

BARITE DEPOSITS

IN

COLE COUNTY, MISSOURI

BY

ARTHUR W. BRUNE

****

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

Degree of

MASTER OF SCIENCE

IN

MINING ENGINEERING

Rolla, Missouri

August, 1946

****

Approved by_____
Professor of Mining Engineering

ACKNOWLEDGMENTS

The writer wishes to acknowledge his indebtedness to: Dr. J. D. Forrester, Chairman, Department of Mining Engineering, School of Mines and Metallurgy for suggesting the problem and for advice and criticism offered in the preparation of the paper; Dr. William B. Mather, formerly Principal Geologist, Missouri Geological Survey and Water Resources, for indicating known barite deposits in Cole County, Missouri; Mr. Lloyd Sestak, operator of the Sestak pit, for the information he gave about his own and neighboring pits; Mr. Walter R. Hale, owner of the Hale prospect, for information he gave about his prospect; the various personnel of the United States Geological Survey, Topographic Branch, Rolla Division, for the generous aid offered in the compilation of the map; and to the inhabitants of southwestern Cole County for historical information about the pits.

PREFACE

This thesis is submitted to the Faculty of the School of Mines and Metallurgy of the University of Missouri in partial fulfillment of the work required for the degree of Master of Science in Mining Engineering.

The paper contains the results of investigation of structural control in regard to the occurrence and localization of the barite deposits in the southwestern part of Cole County, Missouri.

The field work was performed in June 1946.

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Plate

1. Map of Barite Bearing Area, Cole County, Missouri - Supplement

INTRODUCTION

Barite is mined in the Southeastern and Central districts of Missouri. The counties of Franklin, St. Francois, and Washington comprise the Southeastern district, and the counties of Benton, Camden, Cole, Miller, Moniteau, and Morgan comprise the Central district. Although the latter region is the larger of the two, its production of barite is far less than that of the other. The area which is discussed in this report is in the southwestern corner of Cole County.

The main points of the problem were:

1. To determine the features, if any, which apparently controlled the localization of the barite deposits in Township 42 North, Range 13 West of Cole County, Missouri.

2. To devise an economical method of utilizing such features in exploring for undiscovered barite deposits in that area.

3. To propose efficient methods of mining and of beneficiation for the exploitation of the barite deposits.

Most of the hitherto discovered deposits in the area have been completely mined. In June 1946 one mine was in operation, and only two prospects were known to exist. Therefore, it was considered that if information could be obtained about the geologic setting which controlled the occurrence of the barite accumulations, the life of the

mineral industry in the locality might be prolonged because new deposits, which are presently obscured, would be more readily found.

In 1820 lead ore, as either galena or cerussite, was discovered in Cole County; mining of the ore had started by 1827 and was still in progress as late as 1893. However,

Winslow, Arthur. Lead and zinc deposits. Missouri Geological Survey. Ser. 1, Vol. 7, Sec. 2. p. 510. (1894)

for the six years from 1940 to 1945, inclusive, the production of lead in the Central district was less than 1000 tons.

Annual reports. Missouri Department of Mines and Mining. (1940-1945)

Probably the first year in which barite was mined as an ore in itself was 1860. Broadhead recorded that in 1869 a

Tarr, W. A. Missouri University Studies, Science Series. Vol. 3, No. 1. p. 2. (1918)
Broadhead, G. C. Report of the geological survey of the state of Missouri, 1873-1874. Missouri Bureau of Geology and Mines. p. 334. (1874)

barite mill was in operation on the Osage River near Bois Brule Creek. After a period of inactivity the mining of barite was begun again in 1936, and ten years later some of the mines were still in operation.

The Central district is on the northwestern slope of the Ozark Plateau. Winslow reported that the gentle regional dip

Winslow, op. cit. p. 703.

to the north or northwest is changed locally by slight flexures. The stratigraphic series of the region is Cambrian (Proctor), Ordovician (Gasconade, Roubidoux, Jefferson City, and St. Peter), Mississippian (Burlington), and Pennsylvanian.

The Jefferson City dolomite underlies most of the soil in Township 42 North, Range 13 West of Cole County; the Roubidoux outcrops in the northern part of the area. The top of each barite deposit is in the Jefferson City formation.

Three varieties of barite in the district, indicated in the order of their prevalence, are: "Ball tiff", which is white and crystalline; "drybone tiff", white and porous; and "glass tiff", translucent or transparent crystals of barite. The amount of deleterious minerals, such as pyrite, limonite, chalcopyrite, malachite, and galena, in and adhering to the jigs in the milling process, the concentrated barite from the central district is so pure that it is used in the manufacture of glass, whereas the barite from the Southeastern district must be leached by acid in order to have an equal purity.

A map of the area, plate 1, was drawn on the scale of 1:24,000; previously compiled maps which were available were not suitable for field use because the scales were too small. The source material for the map was a "blue-line" print assembled from; 1, United States Agricultural Adjustment Administration photographs of part of the Eugene, Missouri quadrangle; 2, aerial photographs made for the United States Geological Survey; and 3, and plats from the United States General Land Office. The area in which the field work was done is bounded on the northwest by Federal highway 54, on the north by latitude 38°25'00", on the east by State supplementary highway H, on the south by the Chicago, Rock Island

and Pacific Railroad, and on the west by State highway 17. The junction of highways 54 and 17 is 20 miles southwest of Jefferson City.

The pits and quarries in the area were mapped on a scale of one inch to 50 feet by means of a Brunton compass and a tape. Where accessible, the beds were measured for thickness and were examined for lithologic characteristics. Either water or precipitous walls prevented measuring each stratum in most of the pits. Consequently, where strata were inaccessible, their thicknesses and types were estimated.

Joints are the only important type of rock fractures seen in southwestern Cole County. Rock cleavage is not present, and the very few faults that were noticed are so small that they are of little significance. Therefore, joints are considered to be factors of importance with regard to the formation of the barite deposits because ground water probably was directed in its flow along the fractures and apparently where the water encountered a place susceptible to solution, the rock was dissolved and in some places a cave was formed having the shape of an inverted truncated cone. In view of the presence of joints, which are the paramount rock fractures, and the absence of marked regional flexures, it is believed that the joints were the indirect cause of the formation of the caves. Blocks and gragments of wall rock evidently fell into the opening after they had been loosened by undercutting, and thus the broken rock formed a cone of debris in the former cave. The spaces in the cone of rock debris were cemented with barite and with relatively

small amounts of galena, sphalerite, chalcopyrite, and calcite. Such a mineralized deposit is termed a circle or cave. The percentage of those minor minerals in the circle deposits of Cole County is too small to be estimated. Eventually erosion removed the overlying sediments and exposed the top of the circle.

Mather, W. B. Mineral deposits of Morgan County. Missouri Geological Survey and Water Resources. (In preparation)

Tarr described a circle deposit, presumably the Reavis pit at Locality 5, which in 1918 had a maximum depth of 30 feet. He noticed that tension joints are parallel to the walls of the pits; these fractures do not extend away from a deposit but are merely peripheral to it. Such joints were seen at Localities 3, 6, and 7. The fractures seem to bound blocks of wall rock which had not been loosened sufficiently to let them fall and become part of the cone of rock debris.

Tarr, op. cit. p. 65.

Tarr, W. A. Economic Geology. Vol. 14, No. 1. p. 55. (1919)

Ball and Smith in their discussion of joints in Miller County, which adjoins Cole County on the south and west, wrote:

> "In general, it may be said that in the Cambro-Ordovician rocks there is a persistent set of joints striking approximately N. 20° W. and N. 75° E., and a minor set striking N. 45° E. and N. 60° W., the former set being the more persistent."

Ball, S. H. and Smith, A. F. Geology of Miller County. Missouri Bureau of Geology and Mines. Ser. 2, Vol. 1. P. 134. (1903)

The joints in the Jefferson City dolomite did not seem so clear and definite as those in the Gasconade formation; and

Ball and Smith, op. cit, p. 134.

so, inasmuch as the Gasconade did not outcrop in the area where the field work was performed, the conclusion reached by Ball and Smith could not be verified. A satisfactory average strike of the joints in the Jefferson City formation could not be determined.

Ball and Smith, op. cit, p. 75.

In 1929 Weigel reported that the contact between the

Weigel, W. M. Am. Inst. Min. Met. Engr. Trans. Vol. 85. p. 267. (1929)

Roubidoux and the Gasconade formations is sought as an aid in prospecting for barite in the Central district. Although that may be generally true for the district, it is not true for that portion of the region in Cole County because there the deposits are in the lower part of the Jefferson City and in the upper part of the Roubidoux.

GEOLOGY

Locality 1

Half a mile east of Hickory Hill, in NW¼, NE¼, SW¼, section 10 is a quarry that has been abandoned since April 1946. The dolomite in the quarry was pulverized for use as fertilizer on farms of Cole County. An inhabitant of Hickory Hill stated that plans have been made to resume operations in August 1946. The quarry is near the top of the south slope of a ravine.

The sediments in the quarry are mostly dolomite and cotton rock, presumably in the lower part of the Jefferson

"Cotton rock is an argillaceous, silliceous dolomite. It is very fine grained and dense, but relatively soft. It has an earthy or clayey texture, being neither granular nor crystalline. It usually splits with a conchoidal fracture. The color is white, gray, yellow or buff." Ball and Smith, op. cit. p. 71.

City formation. A six-inch layer of brecciated chert in a loosely consolidated dolomite was in the lower part of the quarry. Three feet below the top of the quarry face was a six-inch bed of dolomite which had the appearance of a loose breccia on a fresh surface but had many one-inch pits on a weathered exposure.

The thin bed was recognized in stream channels in sections 11, 17, and 22.

Figure 1 (page 8) is a plan map of the quarry whereon are indicated the joints. A vertical joint is shown as a line and a crossbar that extends on both sides of the line; a dipping joint is shown as a line and a crossbar that is on the side toward which the joint is inclined. The most prominent joints

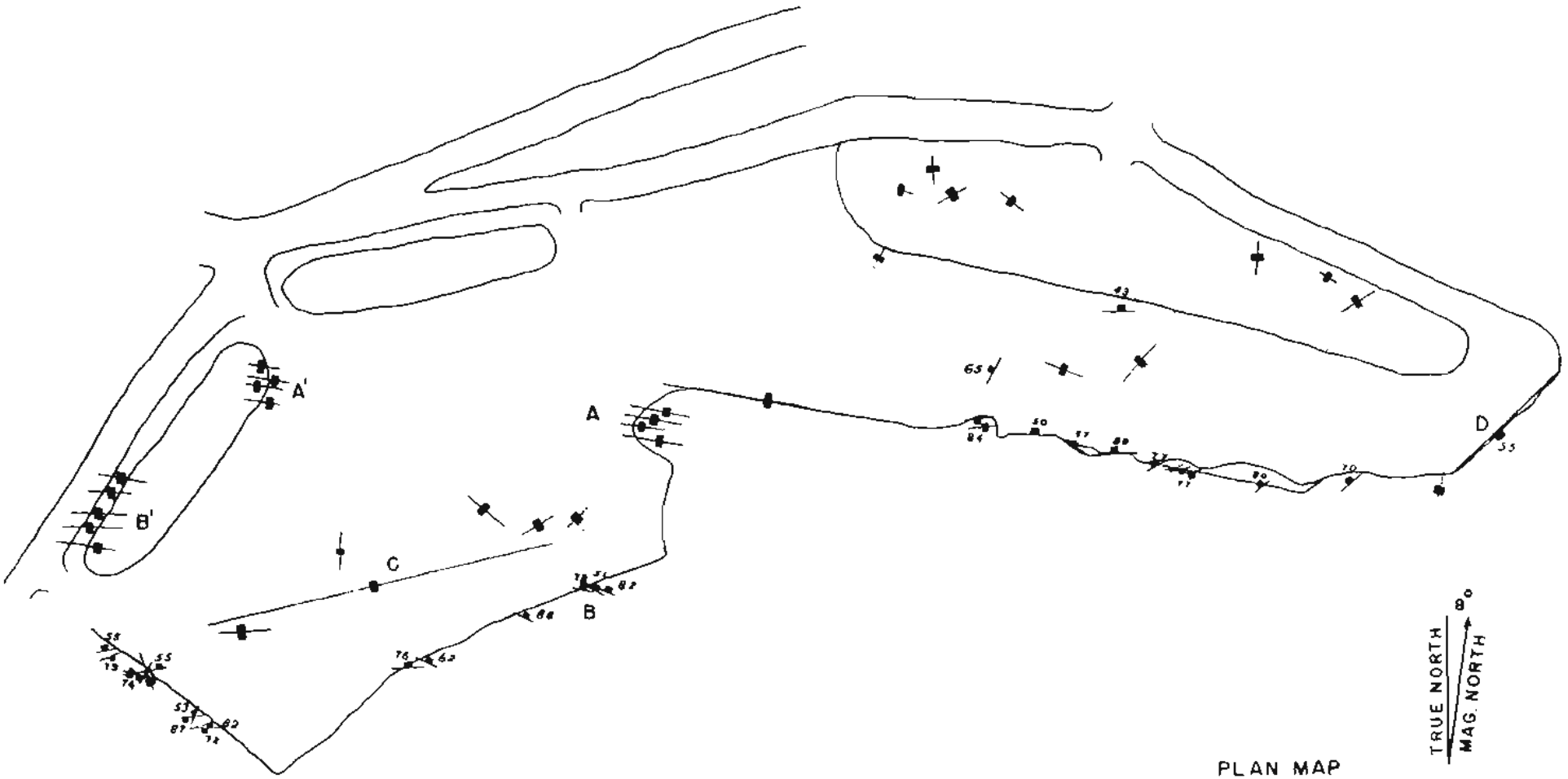

A'
B'
C
A
B
D
TRUE NORTH
MAG. NORTH
8°
PLAN MAP
ABANDONED QUARRY
NE 1/4, SW 1/4, SEC 10
LOCALITY I
SCALE
50
0
50 FEET

Figure 1

are at points A, B, C, and D; at points A' and B' are extentions of those at A and B, respectively. One joint at point A is a quarry face; the same is true of the joint at point D. The joint in the quarry floor at point C was slightly sinuous and very noticeable for 115 feet; it was one half inch wide and was filled with a black material that contained a very few particles of a mineral which seemed to be pyrite. Table 1 is a tabulation of joints that were measured in the quarry. One fracture, N. 42° E., was noticed on the south side of a road, about one tenth of a mile east of the quarry. The joints which were platted on the map of the area, plate 1, have no dip indications because the crossbar would have confused the diagram. The joints which were thus platted are N. 47° E., point D; N. 52° E. and N. 85° E., approximate averages of strikes between points D and A; N. 80° W., point A; N. 74° W., point B; and N. 80° E., approximate average strike between point C and the southwest side of the quarry.

Table 1

Joints at Locality 1

Strike	Dip	Strike	Dip
N. 90° E.	40° N	N. 78° E.	90° *
N. 90° E.	75° N	N. 77° E.	55° N
N. 90° E.	72° S	N. 68° E.	79° S
N. 86° E.	90° *	N. 62° E.	77° N
N. 85° E.	77° S	N. 61° E.	90° *
N. 85° E.	80° N	N. 60° E.	90° *
N. 84° E.	90°	N. 60° E.	90° *
N. 84° E.	87° S	N. 58° E.	80° N
N. 82° E.	84° S	N. 52° E.	70° N
N. 80° E.	55° N	N. 51° E.	90°

Table 1 continued

Strike	Dip	Strike	Dip
N. 47° E.	55° SE	N. 58° W.	90° *
N. 44° E.	90° *	N. 63° W.	51° N
N. 42° E.	90° *	N. 64° W.	86° N
N. 42° E.	90°	N. 64° W.	62° N
N. 33° E.	90°	N. 69° W.	90° *
N. 28° E.	65° NW	N. 70° W.	82° N
N. 28° E.	74° NW	N. 74° W.	90° *
N. 21° E.	53° NW	N. 74° W.	82° S
N. 2° E.	90° *	N. 78° W.	78° N
N. 2° W.	90° *	N. 78° W.	90°
N. 2° W.	90° *	N. 80° W.	90°
N. 20° W.	90°	N. 85° W.	50° N
N. 49° W.	90° *		
N. 51° W.	90° *		
N. 56° W.	57° N		

Note: An asterisk (*) indicates a dip which was estimated.

Locality 2

Figure 2 (page 11) is a plan map of Groose quarry which is in the center of E½, NE¼, NE¼, section 30. The excavation is at the base of a hill that rises in a southeasterly direction. The pulverized dolomite from this quarry is used as fertilizer on farms in Cole County. Mr. Franklin Groose commenced operations in March 1946.

Chert and sandstone are the upper 1½ feet of rock. The layers are not quarried, but they are sufficiently weathered to be easily removed by a bulldozer. The lower sediments, 2 feet of cotton rock and 15 feet of dolomite, are ground as fertilizer. The cotton rock strikes N. 38° E. and dips 13° NW. All the beds except the floor of the quarry seem to become thicker as the excavation is extended into the hill.

Relatively few joints were seen in and near the quarry; only one was noticed in the floor. Three joints were

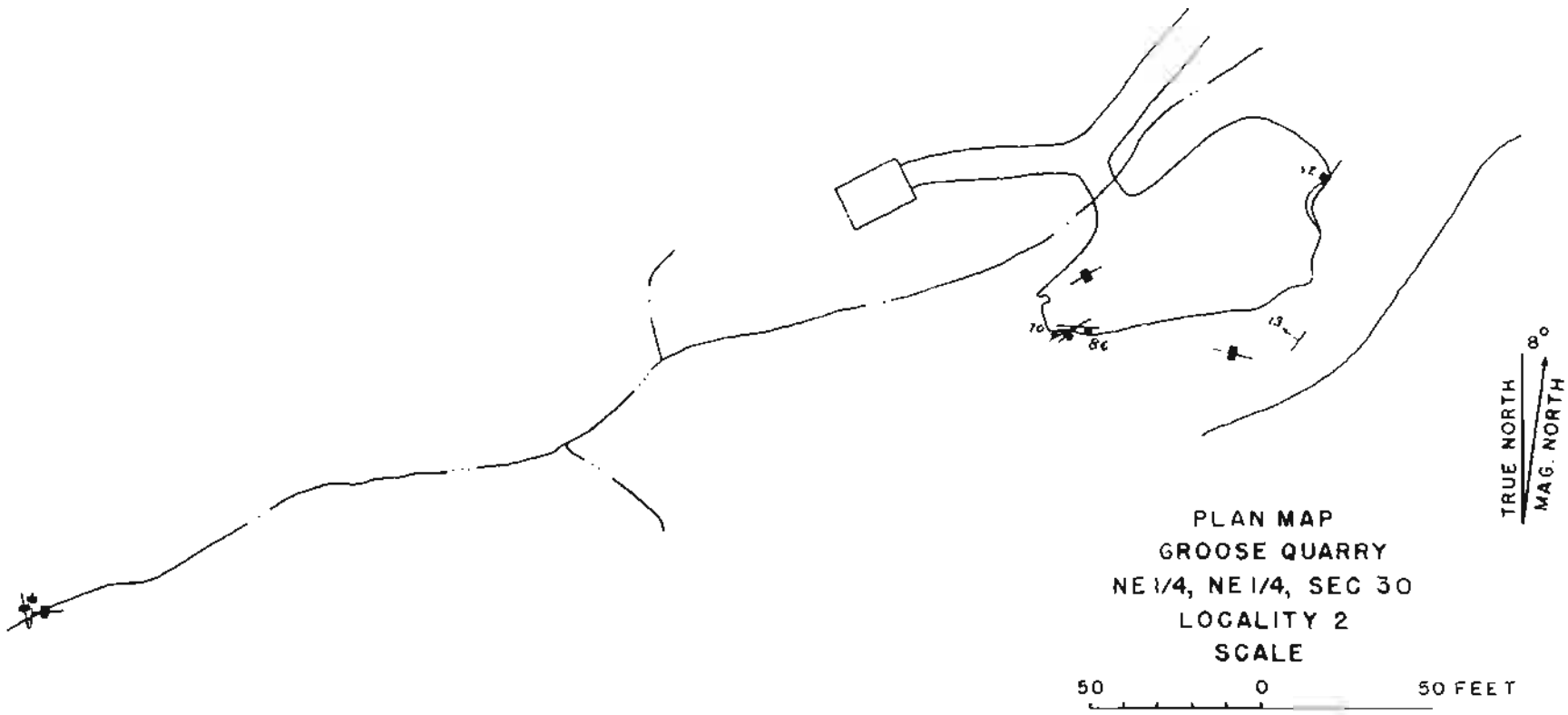

12
10
86
13
8°
TRUE NORTH
MAG. NORTH
PLAN MAP
GROOSE QUARRY
NE 1/4, NE 1/4, SEC 30
LOCALITY 2
SCALE
50
0
50 FEET

Figure 2

measured in the same stratum where it was seen in a stream bed 300 feet west of the quarry.

A pocket of barite, five feet long, about two feet high, and two feet thick, was found in the southwest corner of the quarry; barite was in the upper six inches of the pocket. The overlying dolomite was compact, whereas parts of the lower bed had been dissolved. The barite was separated from the residual fragments of rock by thin layers of soft shale and by a dark red tallow-like clay. The pocket did not seem to lie in a channel nor to have any orientation.

In a stream bed at the southeast corner of section 19 the outcrop of a pitted dolomite had a strike of N. 47° E. and a dip of 4½° NW. The strike of the only joint noticed in the stratum was N. 37° E. The fracture is included in table 2; however, in the plats of joint patterns on the map that joint has been separated from those in section 30 and has been placed in section 19.

Table 2

Joints at Locality 2

Strike	Dip	Strike	Dip
N. 86° E.	90° *	N. 35° E.	52° NW
N. 63° E.	90° *	N. 2° E.	90° *
N. 62° E.	70° N	N. 10° W.	90° *
N. 51° E.	90°	N. 74° W.	90° *
N. 37° E.	90° *	N. 86° W.	86° S

Note: An asterisk (*) indicates joints assumed to be vertical.

Locality 3

The Sestak pit is in the NE¼, NE¼, section 27 on the

east bank of a tributary of Bois Brule Creek. Figure 3 (page 14) is a plan map of the deposit which is elliptical rather than circular in shape. The maximum diameter is 250 feet, and the minimum is 210 feet. The south side is approximately 25 feet higher than the place where the road leaves the pit on the north side.

When Mr. Lloyd Sestak, the present operator, obtained control of the workings in 1943, the pit was full of water. After obtaining a power shovel, an air compressor, and a truck, he dewatered the deposit and began mining operations. In June 1946 this was the only operating pit in Cole County. The capacity of the mill is 42 tons of ore each day; one carload or 42 tons of concentrated barite is shipped every three days. The pit is 80 feet deep on the south side; ore reserves have been proved for an additional 78 feet because a sump in the pit extends through ore for that distance. In June 1946 Mr. Sestak was shipping the concentrated barite to Joliet, Illinois for use in the manufacture of glass.

A pitted dolomite, probably the Quarry Ledge of Lee, is

Lee, W. T. Geology of Rolla quadrangle. Missouri Bureau of Geology and Mines. Ser. 2, Vol. 12, p. 37. (1913)

on the north side of the pit; the base of that member was not seen because it was obscured by ore breccia. The rocks above the pitted dolomite on the south side were estimated to be shale and dolomites; their positions are shown on the map of the deposit. The strata dip toward the south; on the southwest side the dip is 5° SE and on the southeast side 6¼° SW.

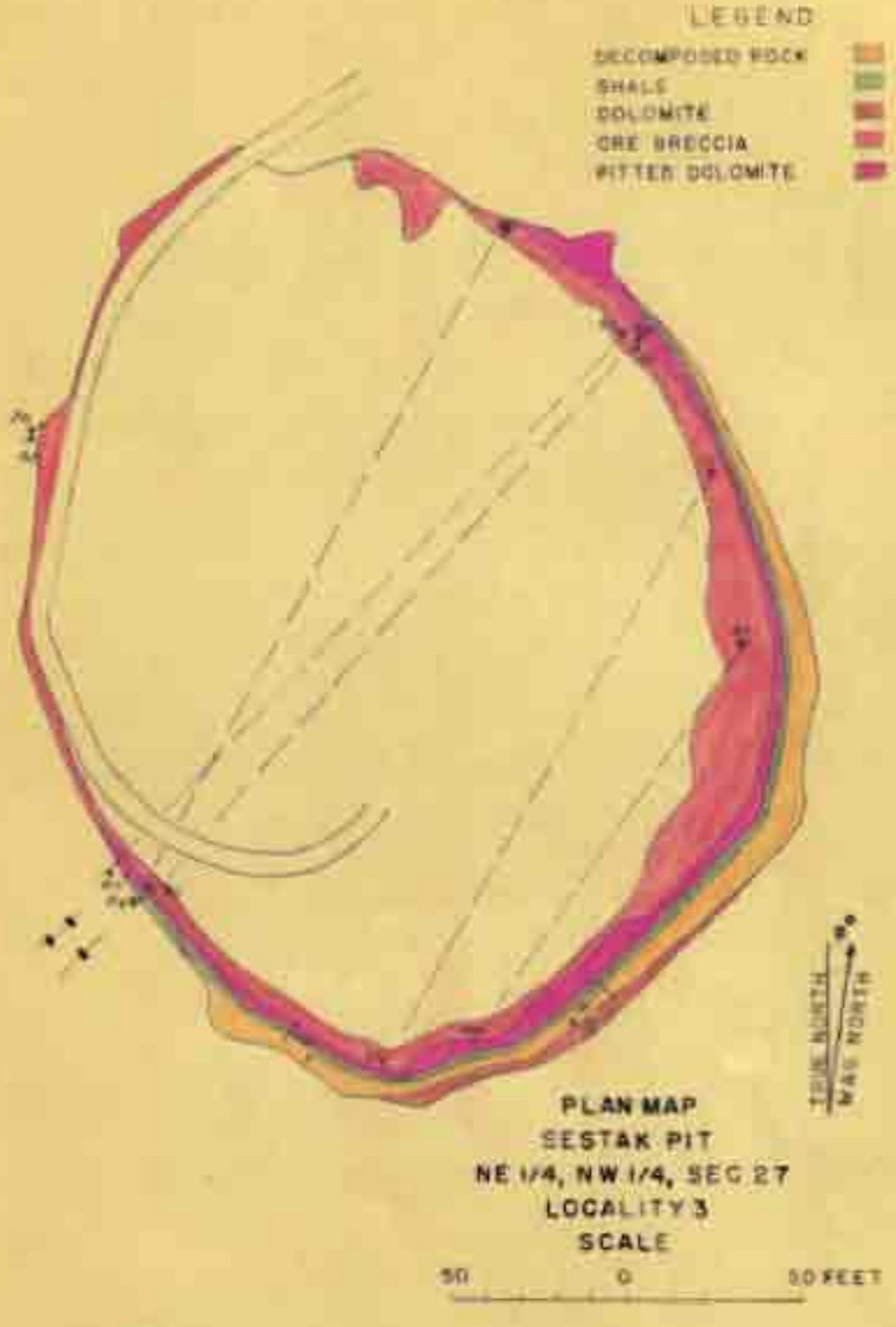

LEGEND
DECOMPOSED ROCK
SHALE
DOLOMITE
ORE BRECCIA
PITTED DOLOMITE
TRUE NORTH
MAG NORTH
PLAN MAP
SESTAK PIT
NE 1/4, NW 1/4, SEC 27
LOCALITY 3
SCALE
50
0
50 FEET

Figure 3

Most of the barite is white and crystalline; very little of the "drybone" and "glass tiff" varieties is in the ore. Limonite and pyrite, one inch and larger in size, are found in the ore so infrequently that, when they do appear, they are removed as curios. Galena is present even more rarely. In 1945 a pocket of massive barite was found in the southwest part of the pit; its purity was so high that the entire pocket was hauled to the rail siding without passing through the mill.

On the map of the area (plate 1) five joints are indicated because they appeared to be the more prominent. Crossbars were not drawn on the joints because they would have obliterated some of the detail. The strikes of the joints, as they were seen on the walls of the pit, are platted on the periphery of the deposit (figure 3). After all the joints had been recorded, those on one side which seemed to be extensions of joints on the other side were connected on the bases of similar strike and of similar definity or sinuosity of dip. On the northeast wall one joint is platted with an inclination of 86° NW and 86° NE because the upper part dipped to the northwest and the lower part to the southeast. Joint N. 42° E. on the northwest wall is platted with a dip of 76° NW and 82° SE for the same reason. The joint nearest the southeast wall seemed to be a solution channel toward the top of the pit.

Two joints were found 25 feet west of the pit; in consideration of their position and strike they were taken

to be the extensions of similar joints found in the pit. One fracture is platted as N. 47°-55° E. because it had a swing from the one position to the other.

In a ravine one eighth of a mile farther west no joints in alinement with those in the pit could be detected; however several others, which are platted on the map, were found in cotton rock and dolomite. The joints are included in table 3 and are prefixed with the letter "A".

Four joints were noticed in a pitted dolomite, the Quarry Ledge, and in a gray dolomite 700 feet northeast of the deposit. The dips of the joints are not indicated on the map due to the confused picture which would have ensued. The fractures are included in table 3 and are prefixed with the letter "B". At the junction of the road west toward the pit and of the road on the east side of section 27 another joint was found, but the strength of the fracture was not sufficiently marked to justify platting it on the map; in table 3 it is prefixed with the letter "C".

Barite is one third of the ore by weight although the millfeed has been as high as 75 percent. The ore is drilled and blasted whenever the supply of broken ore in the pit becomes low, which is usually about once a week. On such days the mill does not function because the two men who work in the mill help in the drilling and blasting operations. A Byers Bear Cat, Jr., power shovel equipped with a 3/8-yard dipper loads the broken ore into 1½-yard Chevrolet dump truck. The distance by road from the bot-

tom of the pit to the hopper at the mill is approximately 600 feet. Blocks of waste are sorted from the ore by hand during the loading operation. The waste rock is hauled to the tailings pile after one to four truckloads or a maximum of six tons have accumulated in the pit. Water flows continuously from the bottom of the pit at the south side and drains into the sump from where it is pumped to the tailings dam north of the mill. The pump is operated only four hours each day; after every rain more pumping is necessary due to the temporary increase in water.

The mill consists of a hopper, a jaw crusher, a trommel, three jigs, and bins for concentrate and tailings. Log washers formerly were used in Cole County, but Mr. Sestak has found that a trommel, besides cleaning the mill-feed equally well, causes less reduction in size of the larger pieces of barite than a log washer. Concentrate is withdrawn from the first and second jigs, and the hutch product of the third is in closed circuit with the first jig. Overflow from the last jig is carried to the failings bin by a bucket conveyor which also acts as a classifier because it elevates the sands but permits the fines to flow to the tailings dam. Water in the fines seeps through the impounded tailings to a pond lower in the ravine from where it is returned to the mill by a 200-gpm centrifugal pump. Power for the mill is furnished by a McCormick-Deering 15-hp tractor. Mr. Sestak has found that the droppings from a small piece of burning inner tube is the best

belt dressing obtainable, much superior to the commercial products.

The mine and mill are operated six days each week. No particular days are designated for inspection and maintenance of the equipment, rather, operation continues until a mechanical failure occurs at which time production ceases until the unit is repaired.

Table 3

Joints at Locality 3

	Strike	Dip		Strike	Dip
A	N. 88° E.	90° *		N. 43° E.	90°
A	N. 82° E.	90° *		N. 42° E.	82° SE - 76° NW
A	N. 76° E.	90° *		N. 41° E.	90° *
B	N. 51° NW	81° NW		N. 39° E.	75° NW
B	N. 50° E.	90°	A	N. 37° E.	
	N. 49° E.	86° NW			
	N. 48° E.	84° NW		N. 35° E.	83° NW
	N. 48° E.	86° NW		N. 33° E.	90° *
		86° SE		N. 29° E.	90° *
B	N. 48° E.	90°		N. 29° E.	90° *
	N. 47°-55° E.	90° *	B	N. 28° E.	90°
	N. 47° E.	90°	C	N. 27° E.	90° *
	N. 45° E.	87° SE		N. 26° E.	82° SE
	N. 44° E.	90° *	A	N. 82° W.	90° *

Note: An asterisk (*) indicates joints assumed to be vertical.

Letter "A" refers to joints in ravine one eighth of a mile west of the pit.

Letter "B" refers to joints 600 feet northeast of pit.

Letter "C" refers to joint at road junction on east side of section 27.

Underlined strikes refer to connections between joints on opposite sides of pit.

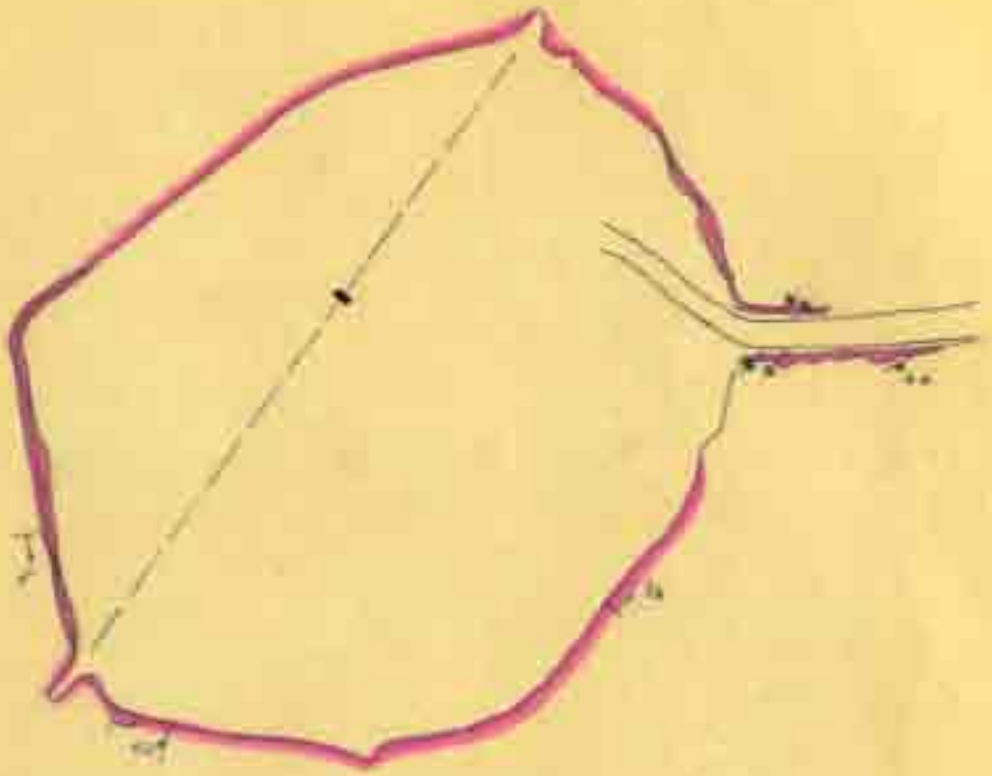
Locality 4

The Campbell pit, figure 4 (page 20), is in the center of the E½, SW¼, SW¼, section 11. It is on the south slope of a stream which joins Bois Brule Creek in section 12. In April 1893, when Winslow visited the deposit, it was known as the Henly bank; he remarked that the production of the bank was barite and an insignificant amount of galena. The last year in which the mine was operated was 1945; in June 1946 it was almost completely filled with water.

Winslow, Arthur. Lead and zinc deposits. Missouri Geological Survey. Vol. 7, Sec. 2, p. 704. (1894)

Ore breccia was noticed for 8 to 10 feet above the water around the periphery of the pit. Above the ore breccia are thin beds of cotton rock and gray dolomite, and 15 feet of pitted dolomite (Quarry Ledge). The beds dip toward the south. Pockets of red tallow clay, which have a maximum length of two feet, are on the northeast wall. The barite on that wall is predominently white and crystalline. Impurities in the barite are galena and malachite; the crystals of galena have a maximum size of one half of an inch, and malachite is present as particles.

The most conspicuous feature of the deposit is a solution channel which strikes N. 35° E. The channel in the southwest corner cannot be examined because of the steep wall, but the northeast end has thin layers of decomposed shale and dolomite which appear to have slumped into their present positions. No topographic indication of the solu-



LEGEND

PITTED DOLOMITE

ORE BRECCIA

TRUE NORTH

MAG NORTH

PLAN MAP
CAMPBELL PIT
SW 1/4, SW 1/4, SEC 11
LOCALITY 4
SCALE

50 0 50 FEET

Figure 4

tion channel is present on the land surface in the vicinity of the deposit. The joints in the pit are indicated in table 4. The prefix "A" denotes those joints which were noticed in a stream bed 800 feet northeast of the pit.

Table 4

Joints at Locality 4

	Strike	Dip		Strike	Dip
	N. 62° E.	64° S		N. 35° E.	90°
A	N. 62° E.	90° *		N. 17° E.	62° W
	N. 42° E.	90°	A	N.-S.°	90° *

Note: An asterisk (*) indicates joints assumed to be vertical.
Letter "A" refers to joints in stream bed 800 feet northeast of pit.

Locality 5

Figure 5 (page 22), is a plan map of the Reavis pit which is in the center of the NE¼, SE¼, section 28. The west end of the pit is approximately 30 feet higher than the east end.

In 1874 the deposit, then known as the Sand diggings, was in operation at irregular intervals. The name of Sand diggings was applied to it because the galena ore was above and in fissures filled with clay and sand. In 1943, when

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Broadhead, G. C. Report of the geological survey of the state of Missouri. Missouri Bureau of Geology and Mines. p. 333. (1874)

---

the recent operation was ended, the depth to the floor was 150 feet. One report has it that the mine was closed due

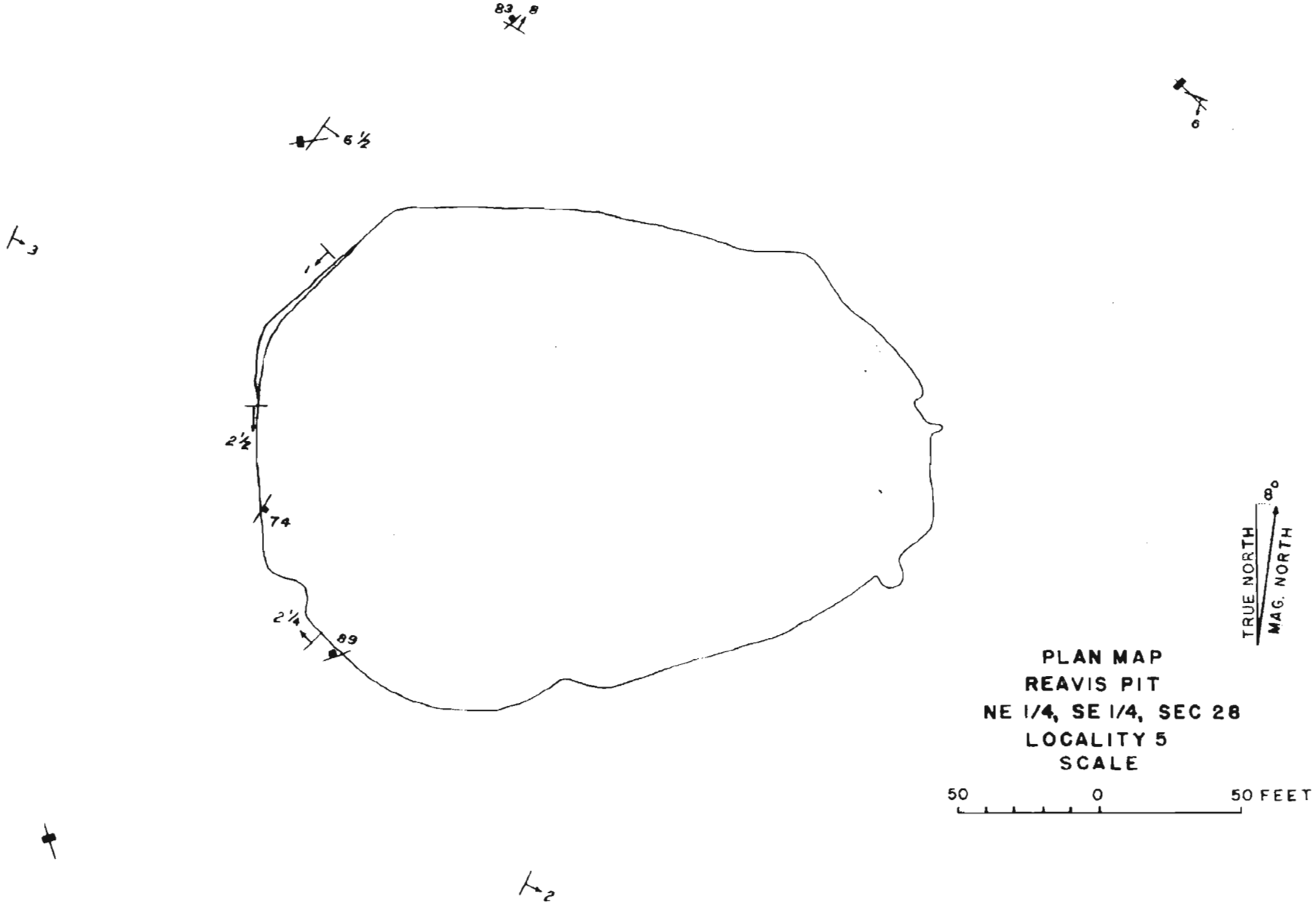

83
8
6 ½
6
3
1
2 ½
74
2 ¼
89
2
8°
TRUE NORTH
MAG. NORTH
PLAN MAP
REAVIS PIT
NE 1/4, SE 1/4, SEC 28
LOCALITY 5
SCALE
50
0
50 FEET

Figure 5

to the frequency of rock falls and the concomitant excessive premium for insurance. Since then water has filled the pit.

The rocks above the water in the pit are much-weathered dolomites and shales, whereas those on the west slope above the pit are compact fine-grained gray dolomites. The water prevented a close examination of the sediments in the pit. Presumably the Quarry Ledge is below the water level because it is present at Locality 6, which is at a lower altitude. In the southwest part the beds dip toward each other from the west and from the south as is indicated on figure 5.

Joint H. 46° W., 135 feet northeast of the pit, actually is a solution channel one foot wide; it contains no mineralization, only soft clay, decomposed shale and dolomite. The observed vertical extent was two feet. Table 5, a list of joints in and near the mine, includes two that were found near the private road west of the pit; the prefix, "A", denotes the two joints.

Table 5

Joints at Locality 5

Strike	Dip		Strike	Dip
N. 83° E.	90° *		N. 15° W.	90° *
N. 69° E.	89° N	A	N. 24° W.	85° E
N. 49° E.	83° NW		N. 46° W.	90°
N. 32° E.	74° SE	A	N. 81° W.	90° *

Note: An asterisk (*) indicates joints assumed to be vertical.
Letter "A" refers to joints near private road, west of pit.

Locality 6

Locality 6 is in the NW¼, SE¼, SE¼, section 28, 1000 feet southwest of the Reavis pit. A plan map of the deposit, figure 6, is on page 25. Water trickling from the south side of the pit, which is 15 feet lower than the north side, flows into Little Tavern Creek in section 33.

In 1840 the place was known as Smith's diggings; 34 years later it was called the Old Circle diggings. Possibly the recess in the southeast wall is the large shaft which was sunk in 1874; the reasons for so believing are the smoothness of its walls and the timbers which seem to be in place immediately below the water level. At present the pit is known as the Lead circle.

Broadhead, op. cit. p. 333.

In a few places around the periphery of the deposit the Quarry Ledge, which is four feet above the water level, is overlain by a decomposed dolomite. The dips measured in the pit are not positive and definite because the rocks probably have been moved from their original positions during the formation of the circle.

Table 6 is a compilation of joints measured at Locality 6. In all probability the joint on the south side is the bounding plane of a small block of rock because the fracture, which contains barite, is peripheral to the pit. The Quarry Ledge is exposed in fields northwest and southeast of the pit; measurements of joints were made in both places. Two fractures, not shown on figure 6, are designated by the prefix, "A", in the table; they are joint N. 65° W., at

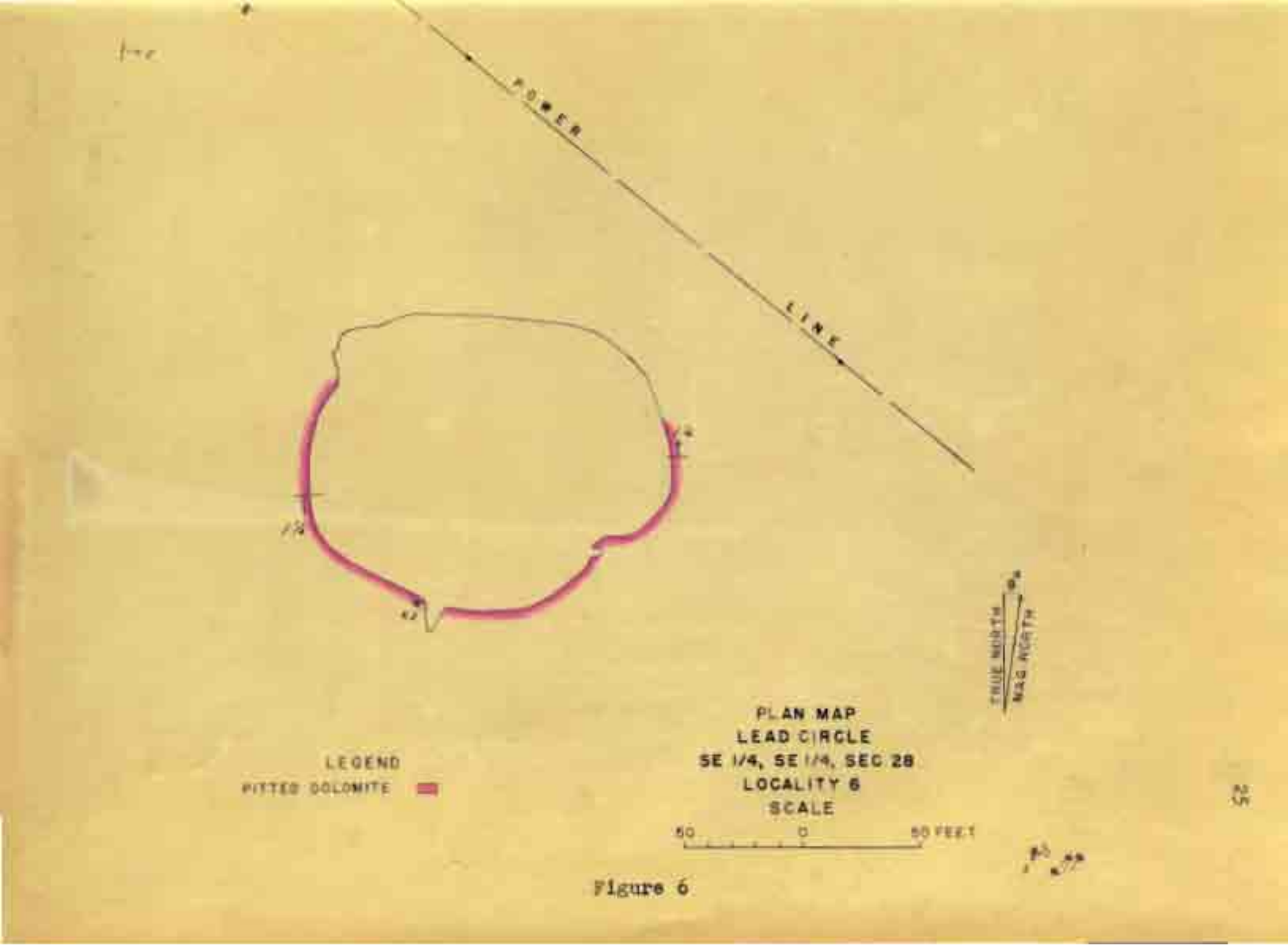

POWER
LINE
TRUE NORTH
MAG NORTH
LEGEND
PITTED DOLOMITE
PLAN MAP
LEAD CIRCLE
SE 1/4, SE 1/4, SEC 28
LOCALITY 6
SCALE
50
0
50 FEET

Figure 6

the north edge of the field northwest of the pit, and joint N. 3° W., 320 feet south of the pit. The strike of the latter was determined by measuring the strike of a stream which flowed through soft, decomposed dolomite for 100 feet; immediately south of the decomposed rock the stream deviated to the west and the rock changed to a hard, fresh dolomite. The observations lead to the inference that the stream flows on top of a solution channel.

Table 6

Joints at Locality 6

	Strike	Dip		Strike	Dip
	N. 40° E.	90° *	A	N. 65° W.	90° *
	N. 35° E.	90° *		N. 68° W.	90° *
	N. 24° E.	90° *		N. 74° W.	90° *
	N. 3° W.	90° *		N. 75° W.	62° S
A	N. 3° W.	90° *		N. 84° W.	90° *

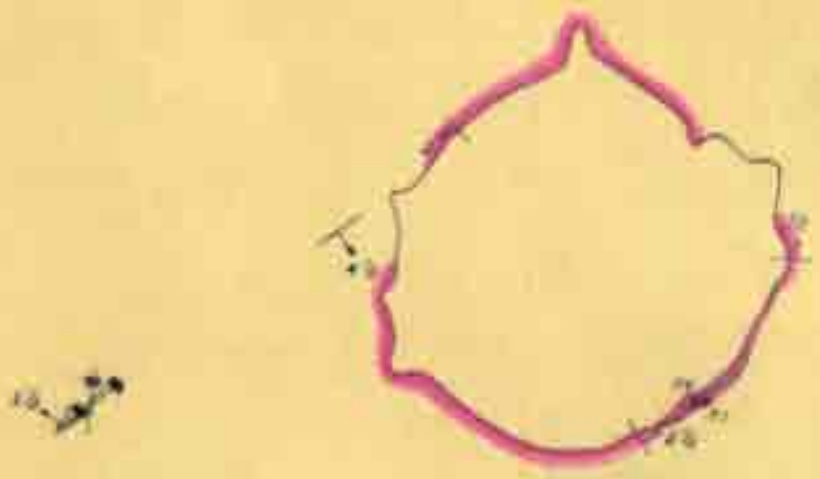
Note: An asterisk (*) indicates joints assumed to be vertical.

Letter "A" refers to one joint at north edge of field northwest of pit and to another joint 320 feet south of pit.

Locality 7

The Little mine, figure 7 (page 27), is 700 feet southeast of the Reavis pit and adjacent to the east side of section 28. The north side of the pit is at the base of a slope which rises southward. The difference in height between the north and south sides is 15 feet.

The only information obtainable about the deposit is that it was worked during the last ten years; it is now



LEGEND

PITTED DOLOMITE



PLAN MAP
LITTLE MINE
SE CORNER, NE 1/4, SE 1/4, SEC 28
LOCALITY 7
SCALE

50 0 50 FEET

Figure 7

filled with water. The local residents term the pit the Little mine because of its size in comparison to the others in the vicinity; consequently that name has been used in this report to designate the deposit.

Above the Quarry Ledge, which is the lowest stratum observed in the pit, are thin layers of shale and dolomite, all in various stages of decomposition. Here, as at the Lead circle, the dips are not certain because of the probable movement of the rocks during the formation of the deposit.

The joint on the southeast wall is platted with dips toward the southeast and northwest because the inclination of the fracture reversed itself. Table 7 is a list of the joints found in Locality 7. The joint with the prefix, "A", was noted 210 feet northeast of the pit; the fracture is platted on plate 1 but not on figure 7.

Table 7

Joints at Locality 7

	Strike	Dip	Strike	Dip
	N. 50° E.	90° *	N. 46° E.	71° SE -
A	N. 49° E.	83° SE		79° NW
	N. 48° E.	90° *	N. 7° E.	90° *

Note: An asterisk (*) indicates joints assumed to be vertical.
Letter "A" refers to joint found 210 feet northeast of pit.

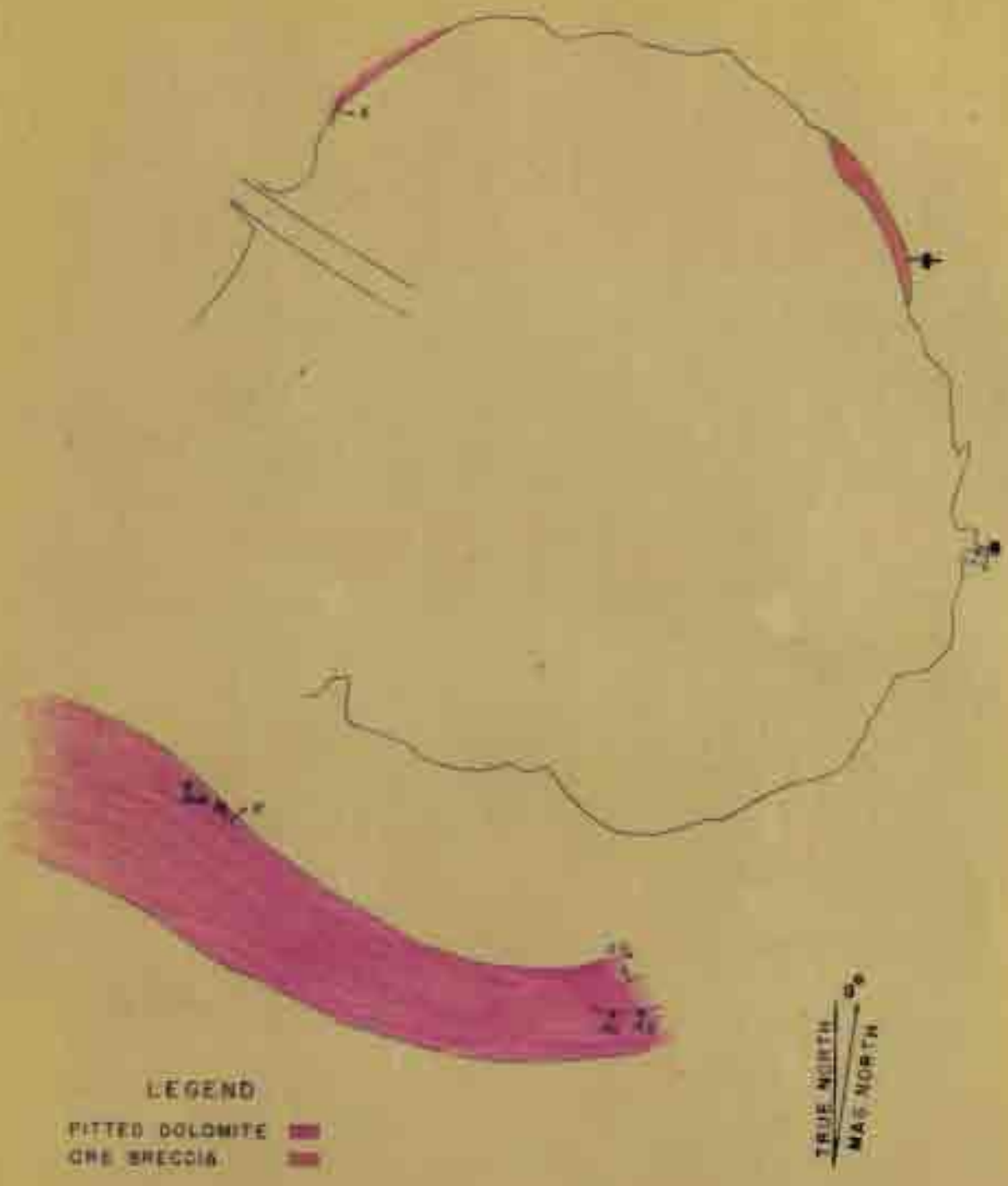
Locality 8

The Aubrey Scott prospect, shown in figure 8 (page 30), is in the NE¼, SE¼, SW¼, section 14. It is 700 feet east of Bois Brule Creek on a slope inclined toward the east.

Control of the prospect is held by the Campbell brothers who in June 1946 were operating a barite mine at Cole Camp in Benton County. The decayed remnants of shaft cribbing on the south side lead to the inference that galena was probably mined at the prospect, possibly 50 years or more ago. The maximum height of the bank, 15 feet, is on the south side; from there it decreases around the deposit toward the west where the edge of the prospect is not determinable.

Subsoil forms the floor of the prospect except in the east central part where blocks of dolomite lie at all angles. A pocket of red tallow clay was found under a block near the east side. Ore breccia was noted along the periphery on the northeast wall. The Quarry Ledge of pitted dolomite is exposed only on the south, and it probably extends around the deposit on the east side as is indicated by the radial dip of the bed into the deposit. Both the white and the translucent varieties of barite are scattered throughout the pit. Transparent crystals, 2 to 4 mm in size, lie on the east slope.

An outcrop of weathered pitted dolomite, which contains barite and limonite in cracks, is on the northwest side; probably it is not in its original position in relation to



PLAN MAP
AUBREY SCOTT PROSPECT
SE 1/4, SW 1/4, SEC 14
LOCALITY 8
SCALE

50 0 50 FEET

Figure 8

the ledge south of the pit. The two joints on the east side are solution channels. Red tallow clay, stratified green shale, and brecciated chert nodules in clay and shale are in the vertical exposure of the north channel, and decomposed dolomite and cotton rock are in the other channel. The sediments exposed east of the south channel dip into the deposit at an inclination of 10½°. Four joints were measured in the west exposure of the Quarry Ledge; on the map of the area, plate 1, joint N. 11° W. is platted. The joints and solution channels of Locality 8 are listed in table 8; the fractures seen near the road east of the deposit are indicated by the letter "A".

Table 8

Joints at Locality 8

	Strike	Dip		Strike	Dip
	N. 80° E.- N. 87° W.	89° S		N. 11° W.	90° *
				N. 18° W.	90° *
A	N. 71° E.	79° S	A	N. 30° W.	90° *
A	N. 28° E.	90° *	A	N. 65° W.	90° *
	N. 4° E.	90° *		N. 83° W.	90°
	N. - S.	90° *		N. 88° W.	90°

Note: An asterisk (*) indicates joints assumed to be vertical.
Letter "A" refers to joints near road east of deposit.

Locality 9

The Frank pit is on the east side of the NE¼, SE¼, SE¼, section 15, at the top of a flat ridge which drops steeply to the north and slopes gently to Bois Brule Creek

on the east and south. Figure 9 (page 33), is a plan map of the deposit.

In 1891 galena ore was being mined by means of shafts at this, the Farmer diggings as it was then known. More recently the mine was worked for barite by an open-pit method, but operations ceased in 1945, presumably for lack of ore, whereupon the pit became filled with water. The average height of the bank above the water level is 10 feet.

Winslow, op. cit. p. 704.

The lowest stratum exposed above the water level is a pitted dolomite, the Quarry Ledge. Overlying it are a total of 5½ feet of shales and dolomites. The beds are inclined toward the north.

The few joints noticed in this locality are listed in table 9. Joint N. 57° E. is unusual in comparison to all others found in the barite pits in that its inclination is 37° whereas the minimum dip elsewhere is 62°.

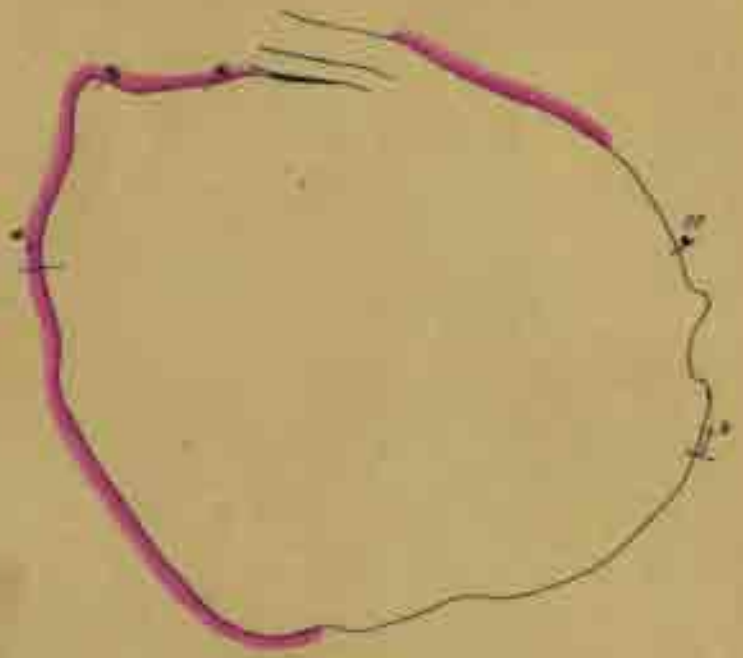
Table 9

Joints at Locality 9

Strike	Dip	Strike	Dip
N. 57° E.	37° N	N. 35° E.	90°
N. 48° E.	90°		

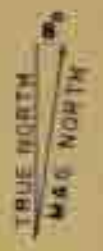
Locality 10

Figure 10 (page 34), is a map of the Hale prospect in the center of the N½, NE¼, SE¼, section 21. The deposit



LEGEND

PITTED DOLOMITE



PLAN MAP
FRANK PIT
NE CORNER, SE 1/4, SE 1/4, SEC 15
LOCALITY 9
SCALE

50 0 50 FEET

Figure 9


LEGEND
PITTED DOLOMITE
BARITE, FLOAT
POND
FENCE
TRUE NORTH
MAG NORTH
PLAN MAP
HALE PROSPECT
NE 1/4, SE 1/4, SEC 21
LOCALITY 10
SCALE
50
0
50 FEET

Figure 10

is on the farm of Walter R. Hale in a flat valley 1000 north of Bois Brule Creek.

The prospect had been worked before Mr. Hale bought the land about twenty years ago. The last lessee mined four carloads of barite in 1932. Mr. Hale stated that operators are disinclined to open the prospect due to the abundant flow of water which is present just below the surface. In order to dispose of the tailings, a long dam must be built on the flat bottom land; consequently much good farming land would be destroyed by the tailings. The largest of the three ponds on the prospect serves as a source of drinking water for the stock.

Exposures of the Quarry Ledge are on the east side of the prospect, in the drainage ditch 50 feet east of the deposit, and in a small stream on the west side. In the stream the dolomite dips toward the northeast. The sporadic occurrences of barite at the prospect are shown in figure 10; the size of the mineral ranges from one mm to one inch. The Quarry Ledge has very few joints in this locality. Table 10 contains the only fractures noted in the area; none were seen in the prospect itself.

Table 10

Joints at Locality 10

Strike	Dip	Strike	Dip
N. 73° W.	90° *	N. 88° W.	90° *

Note: An asterisk (*) indicates joints assumed to be vertical.

JOINTS IN STREAM BEDS

In order to obtain a broad regional concept of the joint systems in southwestern Cole County and of their relation to the barite deposits, the beds of streams which traverse the area were examined for such fractures.

Joints measured in stream channels were platted on the map of the area (plate 1) on the bases of zoning and strength or prominence; those which were not in a zone or had little relative strength were not platted. Table 11 is a list of joints measured in a stream bed south of highway 54 in section 17; for the sake of clarity the dips were not indicated on the map. The brecciated dolomite, noticed in the abandoned quarry at Locality 1, was seen in the creek bed. Fractures were measured in the bed of a creek which flows through sections 26, 23, 24, and 13; the joints noted in the bed of Bois Brule Creek in section 14, 23, and 22, and in section 20; in section 22 the brecciated dolomite was noticed near the junction of Bois Brule Creek and the stream which flows north from Locality 3. Joints were seen along the stream near the east side of section 33; they are indicated in table 14. The same table contains joint N. 76° W. measured in section 34 and solution channel N. 60° W. measured in the railroad cut west of the tunnel in section 31.

Table 11

Joints in Stream Bed South of Highway 54 in Section 17

Strike	Dip	Strike	Dip
N. 90° E.	90° *	N. 25° E.	90° *
N. 90° E.	90° *	N. 24° E.	90° *
N. 90° E.	88° N	N. 22° E.	90° *
N. 86° E.	90° *	N. 14° E.	90° *
N. 84° E.	90° *	N. 10° E.	75° E
N. 84° E.	90° *	N. 6° E.	76° S
N. 81° E.	80° N	N. - S.	83° E
N. 81° E.	82° S	N. - S.	90° *
N. 80° E.	64° N	N. 16° W.	90° *
N. 80° - 59° E.	75° S	N. 19° W.	90° *
		N. 33° W.	90° *
N. 76° E.	75° N	N. 36° W.	77° NE
N. 75° E.	90° *	N. 37° W.	90° *
N. 73° E.	83° N	N. 72° W.	88° N
N. 72° - 67° E.	90° *	N. 73° W.	90° *
N. 72° E.	72° S	N. 74° W.	84° N
		N. 76° W.	90° *
N. 72° E.	90° *	N. 76° W.	90° *
N. 72° E.	90° *	N. 78° W.	56° N
N. 71° E.	90° *	N. 78° W.	87° S
N. 70° E.	75° S		
N. 69° E.	84° N	N. 79° W.	90° *
		N. 79° W.	90° *
N. 68° E.	90° *	N. 79° W.	90° *
N. 66° E.	90° *	N. 79° W.	86° S
N. 62° E.	85° N	N. 82° W.	90° *
N. 61° E.	90° *		
N. 60° E.	90° *	N. 86° W.	90° *
		N. 88° W.	90° *
N. 45° E.	90° *	N. 89° W.	89° N
N. 39° E.	90° *		
N. 35° E.	90° *		
N. 28° E.	73° NW		

Note: An asterisk (*) indicates joints assumed to be vertical.

Table 12

Joints in Stream Bed in Sections 26, 23, 24, and 13

Strike	Dip	Strike	Dip
N. 88° E.	90° *	N. 10° W.	90° *
N. 86° E.	90° *	N. 21° W.	90° *
N. 78° E.	90° *	N. 25° W.	90° *
N. 78° E.	90° *	N. 29° W.	90° *
N. 72° E.	90° *	N. 30° W.	90° *
N. 72° E.	90° *	N. 41° W.	90° *
N. 60° E.	90° *	N. 45° W.	90° *
N. 47° E.	90° *	N. 50° W.	90° *
N. 42° E.	90° *	N. 64° W.	90° *
N. 26° E.	90° *	N. 67° W.	90° *
N. 22° E.	90° *	N. 75° W.	90° *
N. 12° E.	90° *	N. 83° W.	90° *
N. 9° E.	90° *	N. 84° W.	90° *
N. 5° E.	90° *	N. 84° W.	90° *

Note: An asterisk (*) indicates joints assumed to be vertical.

Table 13

Joints in Bed of Bois Brule Creek in Sections 14, 23, 22, and 20

Strike	Dip	Strike	Dip
N. 86° E.	90° *	N. 9° E.	90° *
N. 86° E.	90° *	N. - S.	90° *
N. 79° E.	90° *	N. - S.	90° *
N. 73° E.	90° *	N. 5° W.	90° *
N. 68° - 63° E.	90° *	N. 8° W.	90° *
		N. 23° W.	68° NW
N. 64° E.	90° *	N. 50° W.	90° *
N. 56° E.	90° *	N. 60° W.	90° *
N. 44° E.	90° *	N. 68° W.	90° *
N. 42° E.	90° *	N. 75° W.	90° *
N. 15° E.	90° *	N. 86° W.	90° *
N. 14° E.	90° *		

Note: An asterisk (*) indicates joints assumed to be vertical.

Table 14

Joints in Stream Bed in Section 33

	Strike	Dip		Strike	Dip
	N. 42° E.	90° *		N. 71° W.	90° *
	N. 31° E.	90° *		N. 74° W.	90° *
	N. 27° E.	90° *	B	N. 76° W.	90° *
	N. 17° E.	90° *		N. 81° W.	90° *
	N. 48° W.	90° *		N. 81° W.	90° *
A	N. 60° W.	90°		N. 86° W.	90° *
	N. 68° W.	90°			

Note: An asterisk (*) indicates joints assumed to be vertical.

Letter "A" refers to solution channel in railroad cut west of tunnel in section 31.

Letter "B" refers to joint in section 34.

TECHNIQUE OF PLATTING JOINTS

In 1912 Sheldon examined the joints in the vicinity of Ithaca, New York with reference to the flexures that are in the area. The strikes of the measured joints were tabulated in groups of three degrees each for those in the Fall Creek gorge and in groups of five degrees each for the fractures of the entire area. The plat has the form of a protractor whereon a ray was extended a unit of length toward the center for each joint that fell within the particular range of three or five degrees.

Sheldon, Pearl. Journal of Geology. Vol. 20. p. 64, 66. (1912)

Parker in his study of the systematic jointing in central New York platted the joints which he measured in a manner the reverse of that followed by Sheldon. Parker used ranges of five degrees each; the midpoint of each

range was a multiple of five degrees. Thus the spread of joints covered by any one range consisted of those which fell between minus 2½° and plus 2½° of the midpoint. Each joint within a range was not platted toward the center, as Sheldon did, but radially from the center on the midpoint of the range. The midpoints of adjacent ranges were connected by straight lines; if a particular range had no strikes platted on it, the midpoints of adjacent ranges were connected to the center of the plat.

Parker, J. M., III. Geological Society of America, Bulletin. Vol. 53, p. 384-385, (1942)

Sheldon's plat has the appearance of a semicircle cut into many, uniform segments, whereas a plat drawn by Parker has the appearance of a multi-bladed aircraft propeller.

The joints of the area in Cole County, Missouri, were platted in accordance with the method outlined by Sheldon, but little information resulted. Then a diagram was made for each section of the area following Parker's method; the joints were platted on the midpoint of each five-degree range on both sides of the center of polar coordinate paper. The shortest ray in a section is equivalent to one joint; a greater number of joints is indicated by a like multiple of the unit of length for the shortest ray. The diagram in section 28 can be taken as an example: ray N. 85° E. is one joint in length; and ray N. 5° W., two joints; ray N. 70° W., three joints; and ray N. 50° E. is four joints in length. The same scale was used for the diagrams in all other sections.

Interpretation

If lines are drawn tangential to the northwest sides of pits 4 and 10 and to the southeast sides of pits 8 and 7, they form a zone that strikes N. 37° E., and within which lie all the known barite deposits. The length of the zone from Locality 4 to Locality 6 is 3.1 miles; the widths of the zone are 4450 feet at Locality 4 and 4200 feet at Locality 6. Localities 3, 5, 6, 7, and 8 lie within a belt 800 feet wide parallel to the main zone. It is worthy of note and is deemed of major import that the average scanned strike of joints in the pits at Localities 3, 4, 5, and 9 is approximately parallel to the strike of the zone. Extensions of the solution channels in Locality 8 either pass near or intersect pit 9.

As the deposits tend to follow a pattern or trend, likewise the main streams of the area show a tendency toward an orientation. Bois Brule Creek strikes N. 79° E. for 14,000 feet eastward from the corner common to sections 19, 20, 29, and 30, and in sections 14, 15, and 16 a north tributary of that creek flows approximately N. 85° W. for 10,000 feet; these two trends are roughly parallel to the more prominent rays of the joint patterns in sections 10 and 17. The average strike of the solution channels in Locality 8 is also alined with the north branch of Bois Brule Creek. Within the zone for 7000 feet. In sections 13, 24, 23, and 26 another tributary of that creek flows N. 44° E. for 6000 feet and turns to N. 15° E. for 3000 feet; the average strike of the

stream from section 26 to the junction with Bois Brule Creek in section 13 is N. 33° E., which is almost parallel to the zone.

CONCLUSIONS

Exploration

The area wherein prospecting would seem to be most favorable is that tract delimited by the zone of pits and extended on the south to Little Tavern Creek and on the north to the stream flowing southeastward in sections 1 and 12. The two streams were selected as the southwest and northeast boundaries, respectively, because they seem to be the limits of the drainage pattern that can be correlated with the joint system. The favorable area was designated on the bases of the position of the pits and of the presence of the pitted dolomite or Quarry Ledge in or near almost all the deposits. The Quarry Ledge was not seen in or near the Reavis pit; however, its position at the adjoining deposits, Localities 6 and 7, permit the inference that the stratum is covered by the water which fills the pit.

In sections 13, 14, 23, 24, and 26 the area that is southeast of the zone of pits and on both sides of the stream flowing northeastward might contain barite deposits because the pattern of the main stream is similar to the pattern of Bois Brule Creek in the Zone of deposits.

Inasmuch as the Roubidoux formation is exposed in the north part of the area and the deposits lie in both Jefferson City and Roubidoux, it seems that in the north part the more favorable ground is that which lies at the higher altitudes, as on the hills, where the Jefferson City has not been eroded away. In the south part the prospecting can extend

into the flat valleys except near the lower reaches of the streams where the Roubidoux is exposed.

The curving rimrock of a circle deposit is an important feature to be observed, if it is on the surface. The rimrock is noticeable on the south side of the Aubrey Scott prospect, Locality 8, but not at the Hale prospect, Locality 10. Blocks of rock lying at all angles are another indication of a prospect.

Perhaps erosion has not removed the sediments overlying the undiscovered deposits; consequently it is possible that geophysical methods of exploration could be used to advantage. The gravimeter and the torsion balance are the geophysical instruments which might be most suitable for use in exploring for barite in Cole County. Electrical methods would seem of little value because not enough pyrite appears to be in the ore. Evidently the gravimeter is better than

Heiland, C. A. Geophysical exploration, p. 55. (1940)

the torsion balance because the latter needs more correction than a gravimeter in dissected topography, like that in southwestern Cole County. A suggested practice is to take readings at each deposit; possibly the mean data would afford a standard which would be used for comparative purposes during exploration. The U. S. Navy has shown the practicability of using an airborne magnetometer; perhaps a gravimeter, mounted in a helicopter, could be stabilized by an electric gyroscope for use in geophysical exploration in Cole County.

Mining

Loading ore by power shovel and hauling it out of a pit by truck is costly and inefficient, especially if the ore is not broken sufficiently to permit a high dipper factor. A more efficient method would be to use a bulldozer in the pit to gather the ore to a position where a clamshell-type crane, mounted on the rim of the pit, could reach it; the crane could swing the clamshell to the hopper for dumping. The disadvantage of such a method is that the ore must be finely broken to permit good or easy digging by the clamshell. Another method would be to use a bulldozer in the pit and a light cableway with two stationary towers mounted on the rim of the pit, the cableway to be equipped with a rectangular bucket that is filled either by the bulldozer direct or by means of a semi-portable ore pocket which in turn would be filled by the bulldozer. The operator could be placed in such a position that he would have a view of the entire pit, the mill hopper, and the waste pile.

In order to forestall the danger of falling rock in deep pits, it might be well to clear the soil from the rim of the pit. At definite intervals a man could be lowered along the sides of the pit by means of a portable hoist to bar down rock which becomes loose because of weathering.

Milling

Inasmuch as the ore is relatively pure, milling does not constitute a problem. Merely by increasing the number of jigs in a mill, the mine production can be raised proportionally.

SUMMARY

The barite deposits in T. 42 N., R. 13 W. of Cole County in the Central district of Missouri were studied to determine if the structures could be correlated with the topography. Examinations were made of 10 pits and quarries and of streams in 14 sections to note the joints and the distinctive beds of rock. The joints in each section were platted to learn whether a pattern is present or noticeable. The average strike of the joints in almost each pit is approximately parallel to the zone formed by the deposits; consequently the zone seems to be the most favorable area for barite prospecting. Southeast of the zone is another area which might be favorable because it has a drainage pattern similar to that of the other area. Features to be sought in prospecting are the Quarry Ledge or pitted dolomite, the curving rimrock of a deposit, and blocks of rock lying at all angles within a small area. A gravimeter might find application in the search for new deposits. Mining efficiency could be improved by the use of a light cableway to hoist the ore from the pit to the mill hopper and of a bulldozer in the pit to gather the ore.

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92°25'00" 92°22'30" 92°20'00" 92°17'30"

38°25'00"

38°22'30"

38°20'00"

LEGEND

- BARITE PIT
- JOINTS, VERTICAL AND INCLINED
- JOINT PATTERN
- STRIKE AND DIP OF STRATUM
- PUBLIC ROAD
- PRIVATE ROAD
- STREAMS, FLOWING AND INTERMINTENT
- BENCH MARK
- POWER LINE
- ABANDONED RAILROAD BED
- FEDERAL HIGHWAY
- STATE HIGHWAY
- STATE SUPPLEMENTARY HIGHWAY

Hickory Hill

Eugene

COLE COUNTY
MILLER COUNTY

COLE COUNTY
MILLER COUNTY

ROCK ISLAND AND PACIFIC

CHICAGO

Little Boils

Bruns Creek

Tavern Creek

TRUE NORTH
MAG. NORTH

T 42 N

T 41 N

R14W R13W R12W

PLATE I

MAP OF BARITE BEARING AREA

TOWNSHIP 42 NORTH, RANGE 13 WEST
COLE COUNTY, MISSOURI
JULY 1946

SCALE
0.5 0 1 MILE
3000 0 5000 FEET

ARTHUR W. BRUNE