

THE 26TH ANNUAL FIELD TRIP
 OF THE
 ASSOCIATION OF MISSOURI
 GEOLOGISTS
 SEPT. 28-29, 1979

SCALE: 1" = 4 MILES

ASSOCIATION OF MISSOURI GEOLOGISTS 1979

26th ANNUAL MEETING

EXECUTIVE COMMITTEE

President - Norman Paarlberg
president Elect - Louis Unfer
Secretary-Treasurer - Christopher Stohr
Past President - Waldemar Dressel
Member at Large - Harold Levin

Guidebook Editor - Norman Paarlberg

Field Trip Committee

Norman Paarlberg
Harold Myers
William Grundmann

PREFACE

The Viburnum Trend ore deposits in southeastern Missouri contain the largest reserves of lead and zinc known in the U. S. today. These Mississippi Valley-type ore occurrences also have minor but significant amounts of copper, silver and cadmium.

The Friday afternoon field trip is to the Amax-Homestake Buick smelter, to observe smelting and refining operations. This is one of two completely new lead smelting and refining operations to go into operation in the United States in over fifty years. Both smelter and refinery were designed and built to treat the concentrate production from Amax-Homestake Lead Companies Buick mine and the Magmont mine of Cominco American-Dresser Ind. Annual capacity is 120,000+ short tons of lead.

The 26th annual field trip will commence on Saturday with mine tours to four of the operating mines in the Viburnum Trend. Descriptions are given for the mine tours of Viburnum No. 28 mine (St. Joe Lead Co.), Magmont mine (Cominco American Inc. and Dresser Industries, Inc.), the Buick mine (Amax Inc. and Homestake Mining Co.), and the Frank R. Milliken mine (Ozark Lead Company). Although similar to the guidebook presented at the recent Viburnum Trend Symposium, 1975, the mine descriptions have been updated, and a description of St. Joe Lead Company's Viburnum No. 28 mine has been offered for the first time.

Acknowledgment of the cooperation and assistance of St. Joe Lead Company, Cominco American Inc., Amax Inc., Ozark Lead Company, and the Amax-Homestake smelter are expressed with appreciation for the opportunity to visit their facilities, and to all the geologists of the Viburnum Trend who helped to insure the success of this field trip.

**THE GEOLOGY AND ORE DEPOSITS OF
SELECTED MINES, VIBURNUM TREND, MO.**

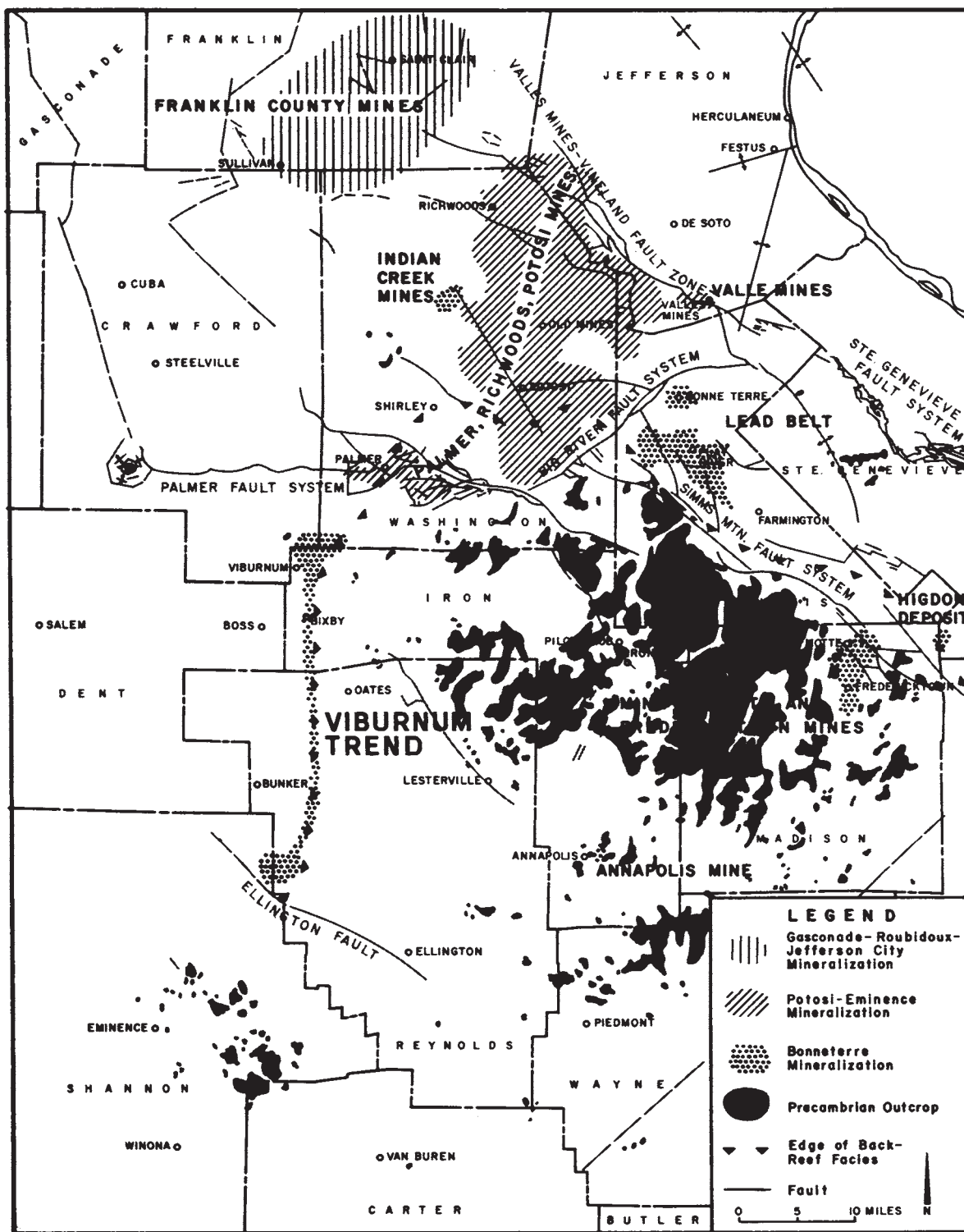


Figure 1
Map of Southeast Missouri Lead district.

INTRODUCTION TO THE SOUTHEAST MISSOURI LEAD DISTRICT

By Heyward M. Wharton, *Geologist*

*Missouri Geological Survey
Department of Natural Resources
P.O. Box 250, Rolla, MO 65401*

LOCATION AND HISTORY

The vital influence of lead mining on the early history and development of the southeastern Missouri region has extended up to the present time. Lead deposits were reported along the Meramec River as early as 1700 by French explorers and missionaries. A French expedition under Philip Renault began mining at Mine La Motte (Madison County area) in 1720, and discovered the lead deposits at Old Mines and Mine Renault (Washington County area) around 1725 (Winslow, 1894). Lead mining has been pursued in the region, now referred to as the Southeast Missouri Lead district, almost continuously ever since. The Missouri Geological Survey and mining companies have usually followed the lead of Winslow whose Southeastern District included all the significant lead and zinc mining areas in southeastern Missouri. Individual areas, such as Mine La Motte-Fredericktown, Valle Mines, the "Old" Lead Belt, Indian Creek, and the Viburnum Trend are treated as subdistricts (Kiilsgaard, Hayes and Heyl 1967; Snyder and Gerdemann, 1968). See figure 1.



With the discovery in 1763 of rich, near-surface lead deposits at Mine à Burton, the major activity shifted from Mine La Motte to the new mining center, now the site of Potosi in Washington County (Broadhead, 1874). Moses Austin obtained a Spanish land grant covering many of the important mines around Potosi in 1798, and introduced improved mining and smelting techniques. Lead and furs were the most important exports from the region in its early years as a United States territory.

Lead mining was first reported in St. Francois County in 1742, but it was on a minor scale until the early

THE GEOLOGY AND ORE DEPOSITS OF SELECTED MINES, VIBURNUM TREND, MO.

1800's. The Valle Mines lead and zinc deposits, which straddle the St. Francois-Jefferson County border, were discovered in 1824 and were mined intermittently until 1948, principally for zinc after 1870 (fig. 1). Lead deposits along the Meramec River in Franklin County were first prospected in 1827 and many mines were developed between 1830 and 1840. Lead and zinc production from this area was negligible after 1900. The Annapolis mine in Iron County, an unusual geologic occurrence, was a significant lead producer from 1915 through 1931.

ST. JOE LEAD FORMED

The St. Joseph Lead Company was formed in New York in 1864 to develop lead-mining properties at Bonne Terre in St. Francois County. This marked the beginning of mining of the large and extensive, disseminated lead deposits in St. Francois County, destined to earn the title of Missouri's Lead Belt. During the decade of 1870-1879, mine output was only slightly more than in Madison County, but it easily surpassed Washington County, the foremost lead producer for nearly 100 years previously.

During the 1870's, sizeable shipments of barite were begun from the lead-mining areas in Washington County. Barite is generally the major constituent of these deposits, and has been recovered mainly from barite-galena occurrences in the residual clays. In the early years, barite was used as an extender in white lead-based paints. As lead mining declined in the area, the barite output picked up. Eventually, the total cumulative production from the Washington County Barite district became the largest, not only in the U.S., but in the world, based on estimates compiled by Brobst (1970).

MO. FOREMOST LEAD-MINING STATE

Starting in 1907, Missouri replaced Idaho as the foremost lead-mining state, and has retained the lead up to the present time, except for 1962, when output was curtailed by a long strike in the Lead Belt. The state's total lead production was supplemented for many years by mine output in the Tri-State Zinc-Lead district in southwestern Missouri. However, the Missouri sector has been inactive since 1957. In any event, the state has held the lead in mine output of lead during 68 of the past 69 years.

Many companies were active in the Lead Belt in the early years, but by 1933 St. Joe had secured control of the entire subdistrict. The National mine of the St. Louis Smelting and Refining Co. was the last survivor. This company, a division of National Lead Co. (now N L Industries Inc.), later operated the Madison mine in Fredericktown from 1944 through January 1961. Cobalt, nickel and copper were recovered in addition to lead and zinc. The first reported shipments of cobalt, nickel and copper ores and matte from the Mine La Motte area were in 1844. The Baroid Division of N L Industries has been one of the major barite producers in Washington County for many years.

National Lead had a half interest with St. Joe in the mining projects of Mine La Motte Corp. in Madison County from 1925 until suspension of operations in 1958. The former company announced the discovery of the lead-zinc deposit at Higdon, Perry County, in 1963. Mine development was begun in 1965, with The Bunker Hill Co. participating as operator, but work was suspended in 1967. See figure 1.

LEAD BELT RESERVES DEPLETED

By the end of World War II, ore reserves in the Lead Belt were being seriously depleted. A geology department was organized by St. Joe in 1946 under Dr. John S. Brown. The geology and ore deposits were carefully studied to help guide exploration outside the subdistrict. The Upper Cambrian Bonnetterre Formation, the dolomite host rock for most of the major lead deposits in the Southeast Missouri Lead district, had been subdivided into numbered zones by R.E. Wagner and J.E. Jewell some years earlier. The expanded prospecting efforts by St. Joe achieved quick returns. Commercial lead deposits at Indian Creek in north-central Washington County were discovered in the fall of 1948. Mine development followed and production began in December 1953.

Prospect drilling continued and the initial discovery near Viburnum was made by St. Joe in September 1955, within the boundary of one of the Clark National Forest districts. A number of mining companies were soon attracted to the area by the rumors of a major discovery, and vigorous competition for favorable

lands ensued. A detailed account of the Viburnum Trend discovery and events leading up to it have been published by Weigel (1965).

It should be mentioned here that the American Metals Co. (later to merge with Climax Molybdenum and become American Metals Climax) conducted drilling in 1946-47 in the Shirley area, and in the early 1950's in the vicinity of Viburnum, but with inconclusive results. In the late 1950's, the Bear Creek Mining Co. division of Kennecott Copper focused attention on areas bordering the Precambrian outcrops ("high") near Eminence in Shannon County, about 50 miles south of the St. Joe discovery. The company's drilling campaigns and eventual ore discoveries were largely independent of the activities to the north. Ozark Lead Co. was the name selected for Kennecott's new operating subsidiary.

NEW MINES, MILLS, SMELTERS OPEN

The initial ore production in the new area was from St. Joe's Viburnum No. 27 mine in Crawford County in mid-1960. Output from the newer (western) mines barely exceeded that of the Lead Belt for the first time in 1964 and, by then, the other major ore bodies along the 45-mile length of the Viburnum Trend had been delineated. Construction of new mines, mills and smelters, including a 32-mile railroad link, followed in rapid succession. By 1970, there were two new smelters (AMAX-Homestake and Asarco) and five new mine-mill complexes in full operation. Mine-mill

operators, in addition to St. Joe, are: Ozark Lead Co. (Kennecott Copper Corp. subsidiary) and joint ventures of (a) Cominco American, Inc. and Dresser Industries, Inc. and (b) AMAX, Inc. and Homestake Mining Company. The American Smelting & Refining Co. controls a segment of one of the ore bodies near West Fork in Reynolds County. The new production facilities will be described in a later section.

St. Joe's Federal Division at Flat River, the last operation in the "Old" Lead Belt, was shut down in October 1972, marking the end of 108 years of mining there by St. Joe. In November 1973, St. Joe's Brushy Creek mine and mill, newest along the Viburnum Trend, went into full operation. New production records for the district are being made each year. In 1974, all four products — lead, zinc, copper and silver — were at record highs for the Southeast Missouri Lead district. Mine production of zinc from the new mining area was the largest in the U.S. in 1973, and was just below New York in 1974. Lead production in 1974 (562,097 tons of metal in ores and concentrates) was 85 percent of the nation's total mine output, up from 80 percent in 1973. Annual lead production from the Viburnum Trend is leveling off at well over twice the record high from the "Old" Lead Belt and the Missouri Tri-State productions combined (233,564 tons in 1917). Not surprisingly, the Viburnum Trend has become the largest lead-mining area in the world, accounting for over 15 percent of the total recorded output.

GEOLOGIC SETTING

The Southeast Missouri Lead district is located in the central Mississippi Valley area, which is part of the stable interior region of the United States. The Ozark uplift is the dominant structural feature in Missouri, and has had a major influence on marine deposition in the area beginning in early Paleozoic times. The resulting sedimentary and tectonic features are considered to have had an essential role in localizing the

Mississippi Valley-type deposits in the district (Snyder and Gerdemann, 1968; Gerdemann and Myers, 1972). The St. Francois Mountains, about 70 miles south of St. Louis, constitute a core area of the uplift near its northeastern limit. The highlands area is composed of volcanic rocks, mostly rhyolites, intruded by granite in Precambrian times. Evidence indicates it emerged as an island complex in Upper Cambrian seas. Its

THE GEOLOGY AND ORE DEPOSITS OF
SELECTED MINES, VIBURNUM TREND, MO.

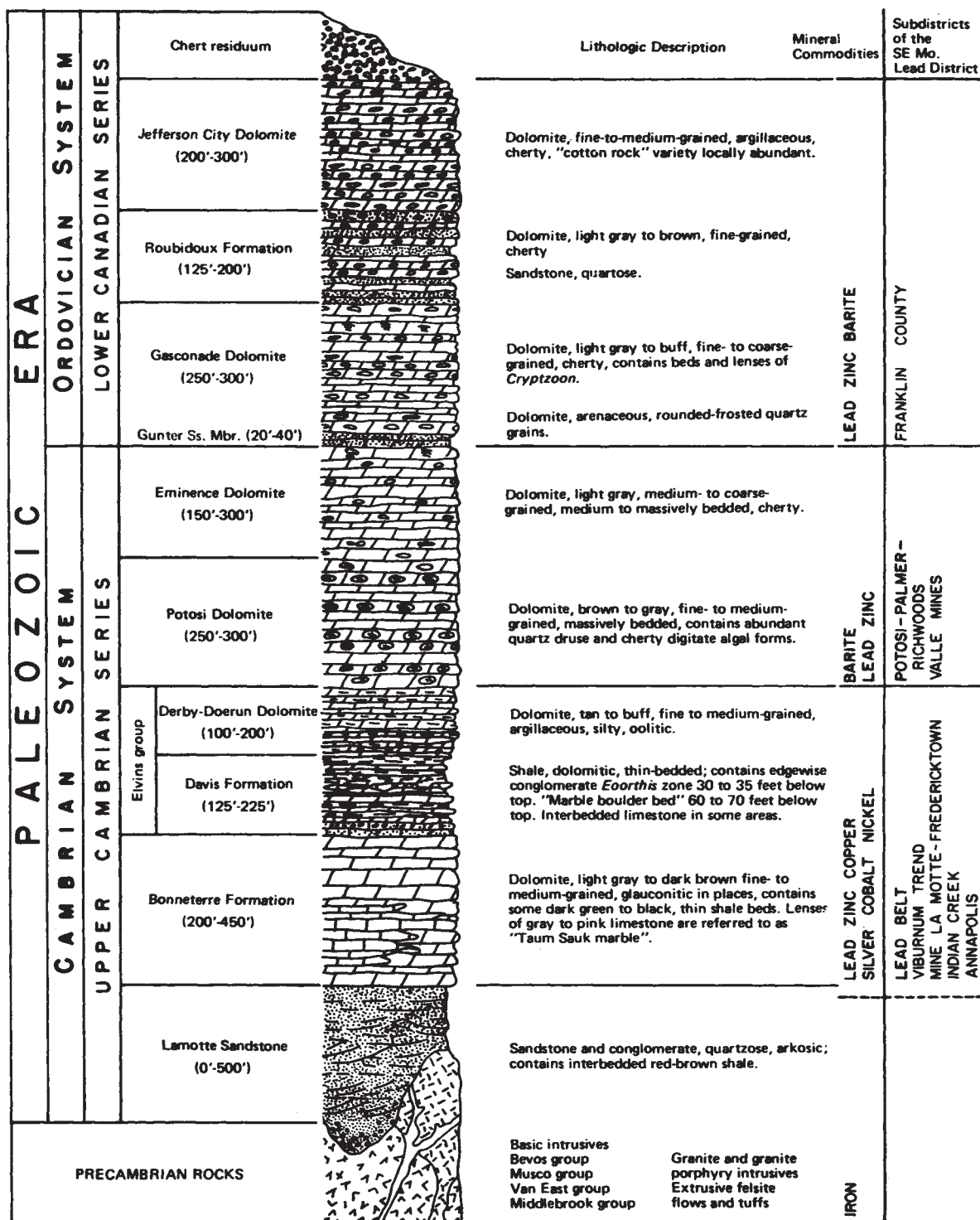


Figure 2

Generalized stratigraphic column of Viburnum Trend area (adapted from Hayes, 1961, p. 8).

exposed surface and fringe areas were irregular and had high relief when deposition of the Lamotte formation began. See figures 1 and 2.

The Bonneterre Formation overlies the Lamotte with a transitional contact. At the time of deposition, it was composed of lime sands, algal deposits and some lime muds. It was the first of a moderately thick sequence of carbonate rocks deposited in shelf environments, which makes up most of the Cambrian and Ordovician Systems in the area. Bonneterre dolomites, peripheral to the highlands, are host rocks for the largest and most important lead-zinc deposits in the district. It was not until the early 1950's that algal structures, planar and digitate stromatolites, were positively identified in the Bonneterre (Ohle and Brown, 1954). Since then, their importance in localizing mineralization has been well established. Dr. Wallace B. Howe (1968), then Assistant State Geologist, published one of the earliest, definitive stratigraphic studies titled: *Planar stromatolite and burrowed carbonate mud facies in Cambrian strata of the St. Francois Mountain area*. In the illustrations of Gerdemann and Myers (1972), the three most productive subdistricts (Old Lead Belt, Mine La Motte-Fredericktown and the Viburnum Trend) are positioned in the vicinity of a barrier reef-like environment formed by the algal structures in Bonneterre times (fig. 1). In the off-shore direction, the Bonneterre is dominantly limestone rather than dolomite.

DAVIS FORMATION IS LOWER UNIT

The Elvins Group overlies the Bonneterre Formation. The lower unit is the Davis Formation, a relatively impermeable sequence of alternating thin layers of shale and dolomite. It is often thought of as a barrier which has confined ascending ore-forming solutions to the Bonneterre. However, Buckley (1908) and other early investigators considered it an aquiclude which, when present, restricted the passage of descending mineral-bearing solutions into the Bonneterre. The argillaceous and silty Derby-Doerun Dolomite overlies the Davis Formation.

The two uppermost Cambrian formations in the mining district (in ascending order) are the Potosi and Eminence Dolomites. Both are vuggy and have abundant algal structures. The Potosi has prominent

zones of digitate stromatolites in which cavities lined with chalcedony and then quartz druse are characteristic. The upper Potosi and lower Eminence are the host rock of most of the barite-lead and lead-zinc-barite deposits in the district.

Formations assigned to the Lower Canadian Series of the Ordovician are next in succession above the Eminence formation in southeastern Missouri (fig. 2). The Gasconade, Roubidoux and Jefferson City formations are mostly cherty dolomites, but there are prominent sandstones in the Roubidoux. Mineralization, usually galena and/or sphalerite accompanied by barite, is sometimes present in all three formations in the Franklin County subdistrict.

STRUCTURAL FEATURES

The major structural features in southeastern Missouri are best shown in the Geologic Map of Missouri (1961) and Structural Features Map of Missouri (1971), both in 1:500,000 scale. They were compiled by Mrs. Mary H. McCracken and published by the Missouri Geological Survey. Major faults displace Precambrian and lower Paleozoic rocks, particularly on the northeastern and northern edges of the St. Francois Mountains (fig. 1). Faulting is particularly common in the "Old" Lead Belt. The sedimentary rocks dip gently away from the highland area, except where modified by faulting. The Simms Mountain and Ste. Genevieve fault systems strike northwest, which is the dominant direction of faulting throughout the state. However, there are important northeast and east-west trending faults in the lead district and elsewhere. Segments of the Ste. Genevieve and Palmer fault systems appear to generally coincide with the 38th parallel lineament of Heyl (1972); Heyl, et al. (1965) and Snyder (1970).

Gerdemann and Myers (1972) recently reviewed available information on post-Precambrian igneous activity in southeastern Missouri. This includes the Avon dikes and diatremes in the Ste. Genevieve County vicinity, and explosive volcanic activity in Upper Cambrian times in the Southeast Missouri Lead district. The diatremes are mostly small, circular breccia pipes containing varying amounts of ultramafic igneous material. They are thought to be Devonian in age. The three known episodes of explosive volcanism in the Southeast Missouri Lead district all took place in early Bonneterre time; two are subsurface occurrences known only from drill core data.

STRATIGRAPHIC AND FACIES NOMENCLATURE OF THE VIBURNUM TREND, SOUTHEAST MISSOURI

By Kenneth G. Larson, *Chief Geologist*

*Ozark Lead Company
Sweetwater, MO 63680*

INTRODUCTION

The Upper Cambrian Bonneterre, the host formation of the major lead deposits of Southeast Missouri, has been actively studied in and around the Old Lead Belt (Ohle and Brown, 1954; Snyder and Odell, 1958; Snyder and Gerdemann, 1968). The apparent close association of ore with stratigraphic traps, structural highs and "reef" in the Old Lead Belt provided the basis for an exploration rationale in the search for new ore bodies. Along with the discovery of the ore deposits of the Viburnum Trend, differences in the sedimentation and stratigraphy between the Old Lead Belt and the Viburnum Trend became more apparent. Data gathered from extensive drilling and from mine mapping have provided new information about the depositional history and new insights into local and regional facies relationships of the formation – (Howe,

1968; Gerdemann and Myers, 1972; Lyle, 1973; Davis and Brown, 1973; Larsen, 1973).

During the exploration phase, companies working in southeast Missouri developed stratigraphic nomenclature that met their individual needs in the area of their drilling activities. Although geologists working in the area generally understood the terminology developed by the various companies, no attempt has ever been made to relate or correlate the stratigraphic and facies nomenclature used in the district. The purpose of this paper is to take a first step in an attempt to accomplish this end, and to improve communications by and between the participants and those attending this symposium.

FACIES RELATIONSHIPS

The structural setting of southeast Missouri strongly influenced the sedimentary patterns developed on the Viburnum Trend. The highstanding Precambrian mountains, which lie to the east of the Trend, and a shallow basin to the north and west, produced depo-

sitional environments which resulted in the observed facies patterns of the Bonneterre Formation.

Figure 1 represents a grossly simplified typical cross section across the facies of the Trend and is a com-

**THE GEOLOGY AND ORE DEPOSITS OF
SELECTED MINES, VIBURNUM TREND, MO.**

posite of sections by Gerdemann and Myers (1972), Lyle (1973), and Larsen (1973). Four major facies have been differentiated on the section. In general, geologists working in the area concur with this facies classification, but due to local variations and importance in relationship to ore localization several geologists prefer to make further differentiation. Table 1 is an attempt to relate each organization's facies nomenclature to the regional facies patterns. Regardless of the terminology used, there is general agreement as to the depositional environments, taking into account the variation in energy levels locally and in time. The depositional environments and energy levels are shown below the listing of the facies nomenclature in table 1.

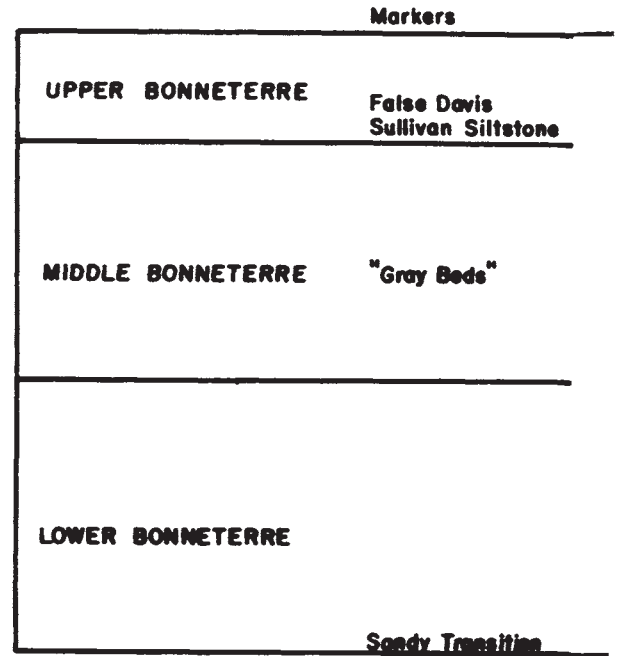


Table 1

Facies Nomenclature

	(See figure 1 for numerical positions)			
	1	2	3	4
Missouri Geological Survey	(Shaly Carbonate)? "Micrite and Shale"	Calcarenite "Oolite"	Digitate Stromatolite "Reef"	Planar Stromatolite and Burrowed Lime Mudstone
Cominco American	Basal Gray	Calcarenite	Reef	Back Reef
Amax Lead Co.	Fore Reef	Calcarenite (2A Off Reef Sand or Bar)	Reef Complex	Back Reef
St. Joe Minerals Corp.	Off Shore	Upper Bonneterre Clastic Carbonate (2A Off Reef Bar)	Reef	Back Reef
Ozark Lead Co.	Shaly Lime Mudstone	Clastic Carbonate	Digitate Boundstone	Planar Boundstone and Burrowed Lime Mudstone
Depositional Environment	Subtidal Below Wave Base	Subtidal Above Wave Base	High Subtidal to Intertidal	Intertidal to Supratidal
Energy Level	Low Energy	High Energy	High Energy	Low Energy

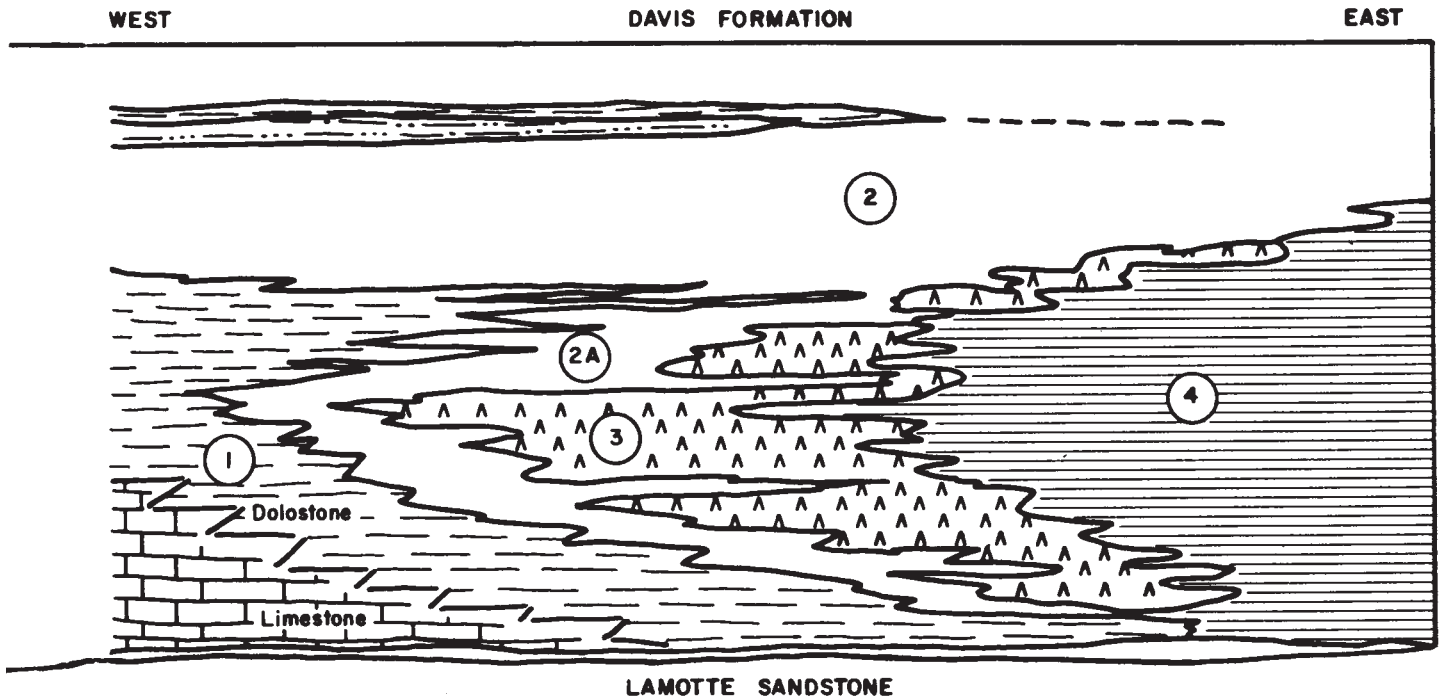


Figure 1
Facies of the Bonneterre Formation, Viburnum Trend, southeast Missouri (not to scale).

MINE STRATIGRAPHIC NOMENCLATURE

The lack of development of a uniform stratigraphic nomenclature for the Viburnum Trend has been due to a variety of reasons. Differences in sedimentation limited direct application of the stratigraphic system worked out in the Old Lead Belt to the Viburnum Trend. Locally the steepness of the depositional slope affected the rapidity of the facies changes normal to the strike of the Trend, and units recognizable at one end of the Trend are absent or poorly developed at the other end. As each mine occupies a slightly different point in relation to the facies pattern, each mine has a unique stratigraphic column.

The competitive situation between companies during the exploration phase, when the stratigraphic columns were being developed, limited communication between geologists. Consequently, companies tended to develop terminology that fit their individual situations, and as a result some units recognized throughout the Trend have a variety of names assigned.

A more uniform nomenclature for the Bonneterre appeared desirable, and through cooperative effort a table of comparative columnar sections was developed as a first step toward this end. The columnar sections in

THE GEOLOGY AND ORE DEPOSITS OF
SELECTED MINES, VIBURNUM TREND, MO.

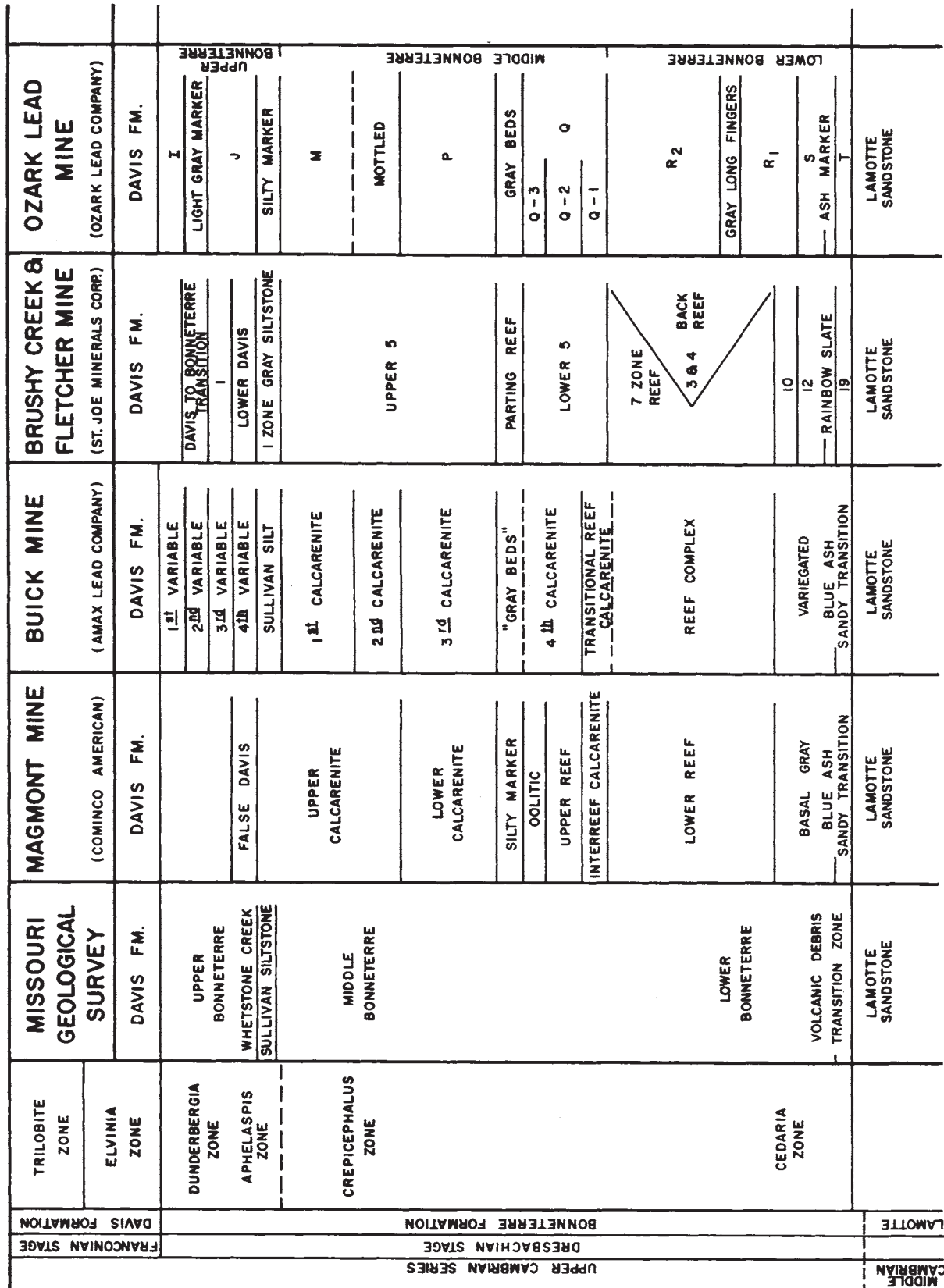


Figure 2
Mine columnar sections, Viburnum Trend, southeast Missouri (not to scale).

figure 2 represent generalized sections for each designated mine. The alignment (left to right) is from the north end to the south end of the district. The Missouri Geological Survey's classification of the Bonnetterre, as well as the trilobite zonation, are also shown for reference.

Agreement as to the Lamotte-Bonnetterre contact appears to be generally consistent, but differences in the definition of the Bonnetterre-Davis contact exist. The apparent reasons for the lack of agreement are

the transitional nature of this contact and the facies changes of Davis-type lithologies across the Viburnum Trend.

Within the Bonnetterre Formation certain marker beds can be recognized in most mines. If not present, the stratigraphic position of these markers can generally be identified in the immediate vicinity of the mine. These markers and the facies relationships formed the basis upon which the tentative correlations in figure 2 are made.

REFERENCES

- Davis, James H.**, and **William J. Brown**, 1973, Ore Control breccias at the Buick Mine (abstract): Geol. Soc. Am., Abs. With Programs, North-Central Sec., v. 5, n. 4, p. 310.
- Gerdemann, P.E.**, and **Harold E. Myers**, 1972, Relationships of carbonate facies patterns to ore distribution and to ore genesis in the Southeast Missouri Lead district: Econ. Geol., v. 67, n. 4, p. 426-433.
- Howe, Wallace B.**, 1968, Planar stromatolite and burrowed carbonate mud facies in Cambrian strata of the St. Francois Mountain area: Mo. Geol. Survey and Water Resources, Rept. Inv. 41, 113 p.
- Kurtz, Vincent E., et al.**, 1975, Traverse in Late Cambrian Strata from the St. Francois Mountains, Missouri to Delaware County, Oklahoma: Mo. Dept. of Nat. Resources, Geological Survey, Rept. Inv. 55, 118 p., 4 figs., 1 app., 1 pl.
- Larsen, Kenneth G.**, 1973, Depositional environments of the Bonnetterre Formation in southeast Missouri - An example of epeiric sea sedimentation: Geol. Soc. Am., Abs. With Programs, North-Central Sec., v. 5, n. 4, p. 330-331.
- Lyle, John**, 1973, The facies geometry and carbonate petrology of the Bonnetterre Formation in western Iron, northern Reynolds and eastern Dent Counties, Missouri: unpubl. Masters thesis, U. Mo.—Columbia.
- Ohle, E.L.**, and **J.S. Brown**, eds., 1954, Geologic problems in the Southeast Missouri Lead district: Geol. Soc. Am. Bull., v. 65, n. 3 and n. 9, p. 201-222 and 935-936 (supplement).
- Snyder, F.G.**, and **J.W. Odell**, 1958, Sedimentary breccias in the Southeast Missouri Lead district: Geol. Soc. Am. Bull., v. 69, n. 7, p. 899-926.
- Snyder, F.G.**, and **P.E. Gerdemann**, 1968, Geology of the Southeast Missouri Lead district, in Ore deposits of the United States, 1933-1967 (Graton-Sales Volume), J.D. Ridge, ed.: Am. Inst. Min. Eng., v. 1, p. 326-358, 13 figs., 5 tabs.

ACKNOWLEDGMENTS

The accomplishment of the task of gathering the necessary information for this paper was dependent on the wholehearted cooperation and support of the various company managements, organizations and geologists involved. A special thanks is due Dr. Wallace B. Howe, State Geologist, and members of the Survey staff — namely, Heyward Wharton, Kenneth Anderson and Joseph Thacker — for their encouragement and cooperation. Special thanks are due to the company

geologists who supplied detailed information for their mines — namely, Paul Gerdemann, Harold Myers and Lanny Evans of St. Joe Minerals Corporation; James Davis, Robert Rogers and William Brown of Amax Lead Company; Peter Sweeney, Milton Bradley and Edward Harrison of Cominco American; and Malcolm Mouat and C.W. Clendenin of Ozark Lead Company. Any errors in the interpretation of the data supplied are the responsibility of the author.

*THE GEOLOGY AND ORE DEPOSITS OF
SELECTED MINES, VIBURNUM TREND, MO.*



MAGMONT MINE

(Cominco American Inc. & Dresser Industries Inc.)

MAGMONT MINE
(COMINCO AMERICAN INCORPORATED &
DRESSER INDUSTRIES), VIBURNUM TREND,
SOUTHEAST MISSOURI

by Peter H. Sweeney
Edwin D. Harrison
Milton F. Bradley

Mine Geologists
Magmont Mine, Bixby, MO 65439

INTRODUCTION

The first discovery of a lead deposit in the Viburnum Trend was made by St. Joe Minerals in 1955. This 45-mile belt runs north and south about 50 miles west of the Old Lead Belt. Cominco American Incorporated (as Montana Phosphate Products Company) and Dresser Industries, Incorporated (as Magnet Cove Barium Corporation) jointly began exploration in Missouri in 1960. From these original companies comes the name "Magmont". First drill intersection of the deposit occurred in September 1962 and over 200 holes were drilled and 23 miles of core were taken to prove the ore body, about 1,200 feet below the surface. Primarily galena (lead sulfide), the deposit contains lesser values in zinc, copper, and silver.

The Magmont mine is located in Sections 13, 14 and 23, T.34N., R.2W. in western Iron County, Missouri. Production began in 1968 when the first ore from initial development work became available for milling. Capacity of the mine-mill complex is 1,000,000 tons per year and production continues at this rate.

Mining practice at the Magmont mine is the basic room-and-pillar, trackless method used in several mines in the Viburnum Trend. All ore is beneficiated in the Magmont mill where separate lead, zinc and copper concentrates are produced. Lead concentrates are smelted on a toll basis at the AMAX-Homestake Buick lead smelte located $\frac{1}{4}$ mile southwest of the mine. Zinc concentrate goes to National Zinc Company, Bartlesville, Oklahoma, and copper concentrate is presently exported.

STRUCTURE

A basement structure, defined by a Precambrian high which extends westward from Bixby, Missouri, to Boss, Missouri, and the presence of several Precambrian knobs to the east and southeast of Bixby, roughly outlines the so-called Buick embayment. The Magmont mine is located within the north-central part of this embayment.

No Precambrian rocks are exposed in the Magmont mine and none of the features exposed in the Bonneterre Formation can be related to Precambrian surface irregularities.

Incipient penecontemporaneous slumping occurs within the gray beds (Silty Marker unit), along the west edge of the mineralized trend where calcarenite sand bars formed local highs during sedimentation. Breccias induced by solution and subsequent collapse are apparent in all areas of extensive mineralization.

Within the Magmont mine, fracture patterns, except for the high ore area, consist of a few distinct fractures which can be followed for some distance. Innumerable smaller fractures which are more properly a joint system are oriented at about N.50°E. and N.30°W.

One through-going fracture striking N.10°W. can be traced for about 2,500 feet. It is open along much of its length and partially filled with calcite. No vertical displacement can be seen but slickensided material showing horizontal movement has been taken from it.

The bounding faults of the high ore zone can be traced continuously for about 4,500 feet in the Magmont mine and extend north and south into adjoining property. This does not imply that these faults are continuous as individual fractures. They are an interlaced series of connected faults. All the high ore along this 4,500 feet is marked on both east and west sides by these distinctive shale-filled subsidence fractures. A few well defined, northeast trending, near-vertical fractures turn abruptly into the bounding faults. Others are traceable across the slumped areas and apparently existed prior to the major vertical movement within the breccia piles. It appears that the pre-existing fracture system has, to a certain extent, influenced the development of the slumped areas and has been responsible for the increased east-west widths of the breccia areas where northeast-trending fractures are conspicuous. See figures 3, 4 and 5.

STRATIGRAPHY

Figure 1 describes briefly and illustrates the stratigraphic sequence of rocks in the Magmont mine area. Figure 2 provides a short summary of the rock types of the Bonneterre Formation and the nomenclature used at the Magmont mine. Total thickness of the Bonneterre averages about 285 feet in the Magmont mine area.

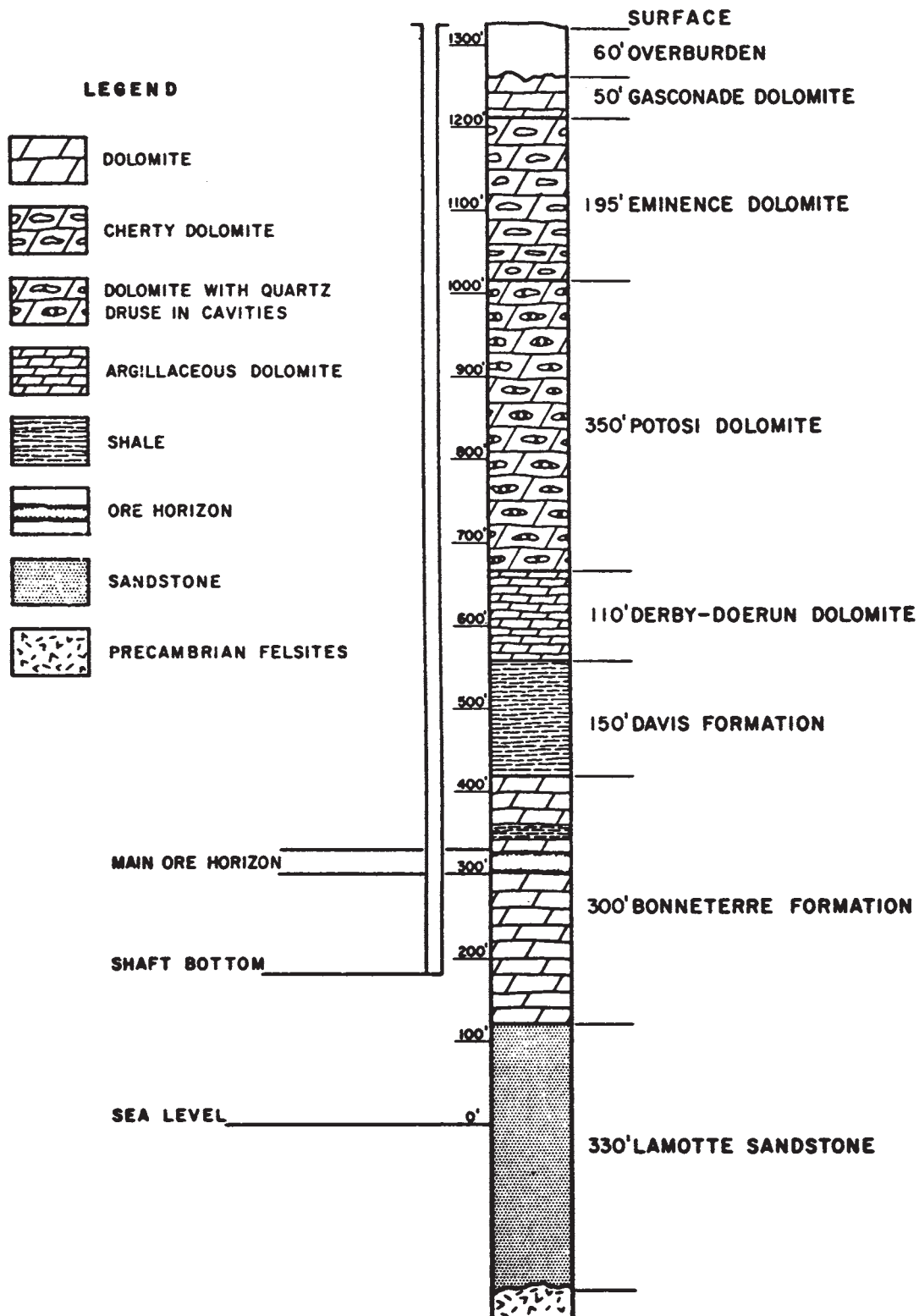


Figure 1
 Typical stratigraphic section, Magmont mine.

BONNETERRE FORMATION	Davis Formation	Grayish brown, medium to finely crystalline, moderately porous dolomite. Small dolomite pebbles and thin shale partings are characteristic.
	Variable	Brown-gray dolomite with irregular brownish shaly seamlets.
	False Davis	8 to 10 feet of gray dolomite with gray-green shale interbands
	Upper Calcarenite	About 50 feet of brown, medium crystalline dolomite characterized by a patchy porosity. Clastic fragments and pin hole vugs are more prominent in the lower 20 feet.
	Lower Calcarenite	
	Silty Marker	5 to 14 feet of gray, finely crystalline, dense dolomites with interbands of brown, porous oolitic dolomite.
	Oolitic	Porous, light brown, oolitic dolomite.
	Upper Reef	Brown, medium crystalline dolomite, comprised of an upper and lower unit separated by a calcarenite band. Digital stromatolites are recognizable against the lighter background of detrital material in both upper and lower reef units.
	Interreef Calcarenite	
	Lower Reef	
	Basal Gray Blue Ash Sandy Transition	Includes about 60 feet of gray, mostly finely crystalline, muddy dolomites with numerous black shaly separations. A blue ash seam separates the basal gray from transitional sandy unit.
	Lamotte Sandstone	

Figure 2

Summary of rock types of Bonneterre Formation and nomenclature used, Magmont mine.

ORE DISTRIBUTION

Mineralization within the mine area is almost totally restricted to the Bonneterre Formation with very minor mineralization in the Davis Formation and Lamotte Sandstone.

Three ore zones, all aligned about parallel to the north-south axis of the Viburnum Trend, occur within the Magmont mine (figs. 3 and 5). East-west distance across these three trends is about 2,000 feet. Vertically the ore is divided into A, B, C and D horizons which are defined as follows:

- A - From base of Davis Formation to base of slumped False Davis
- B - Base of slumped False Davis to base of Silty Marker
- C - Base of Silty Marker to base of Upper Reef
- D - Base of Upper Reef to base of Lower Reef

"B" is the main ore horizon and the west, central and east ore trends are well mineralized within this interval.

WESTERN ORE ZONE

The western ore zone is characterized by incipient slumping along the west edge which appears to be best explained as pencontemporaneous slumping of semi-consolidated material from a slightly raised area which was probably a calcarenite sand bar.

These slumps show randomly oriented, angular blocks of the gray fine-grained units of the Silty Marker inter-bedded in the brown dolomites of the same unit. Above these slumped areas a small amount of brecciation has taken place and fracture filling and replacement have proceeded within the areas of induced open space. Ore thickness within this area is commonly about 35 feet.

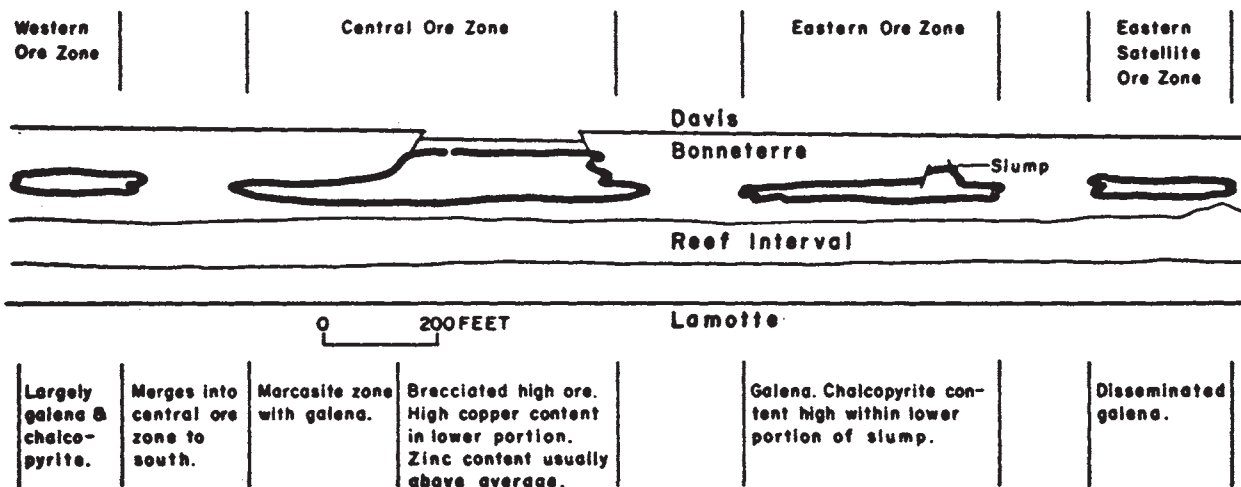


Figure 3
Generalized cross section through ore zones, Magmont mine.

East of the slumped zone the Silty Marker shows irregular bedding with considerable variation in the thickness of the brown dolomites of this unit. Mineralization consists of massive galena bands with lesser amounts of sphalerite and some chalcopyrite. A marcasite area is present along the east side of this trend which merges with the central ore along part of its length.

CENTRAL ORE ZONE

The central ore zone contains the major tonnage of the Magmont mine. It is characterized by mineralization which extends vertically from the base of the Silty Marker up to and above the False Davis. The Silty Marker is well mineralized but shows a marked thinning beneath the high ore area. Brecciated and well-mineralized dolomites of the calcarenite units contain most of the ore above the Silty Marker. A conspicuous feature of the central ore is the slumped central portion of this zone. False Davis shales are dropped vertically as much as 14 feet. Well defined bounding faults of this slump structure are filled by overlying Davis Formation as evidenced by the presence of glauconite. This slump has the form of an inverted graben since the bounding faults dip outward from the graben block instead of inward (fig. 4).

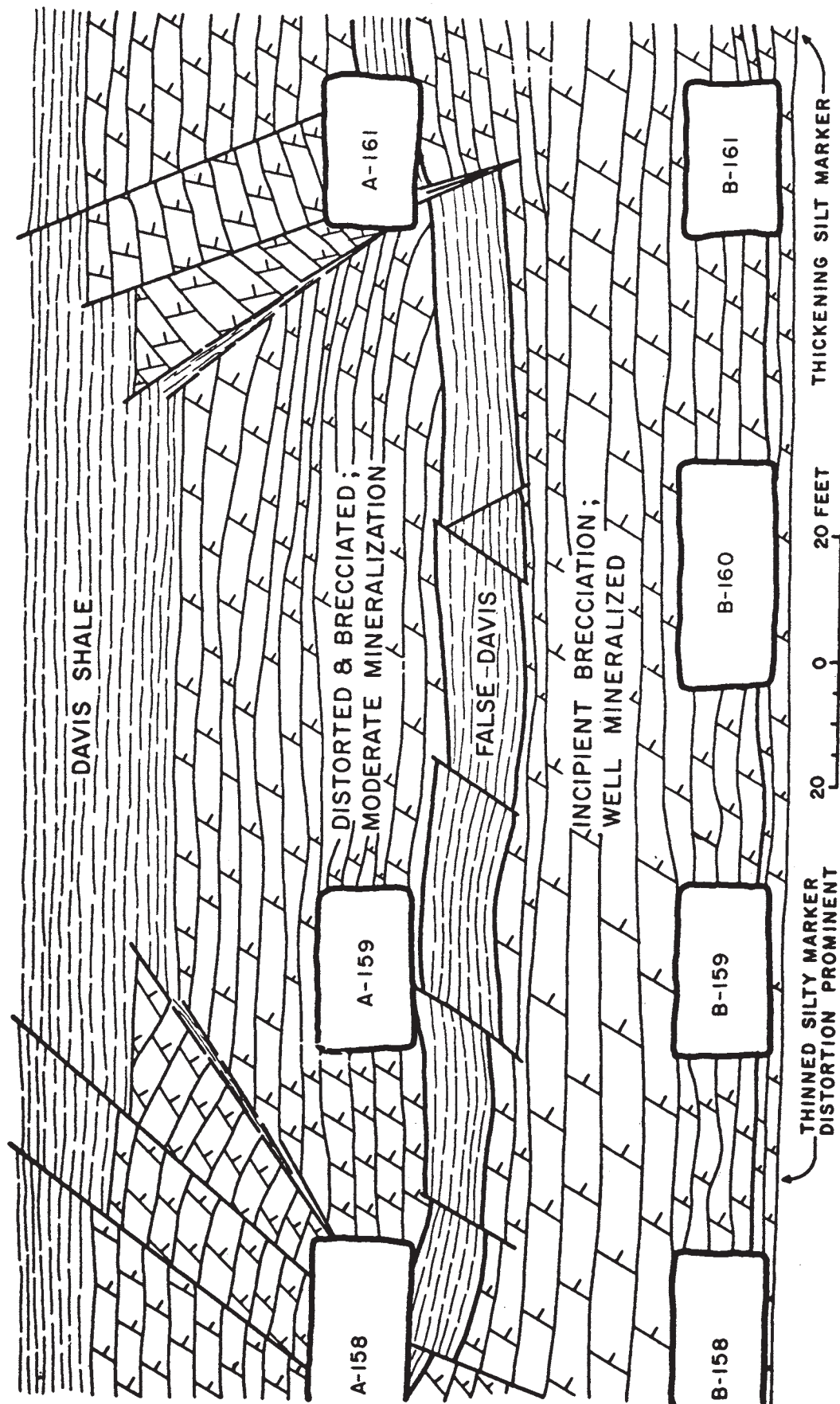


Figure 4
 Cross section, west → east through 498, Magmont mine.

There is no apparent thinning or collapse of any rock units below the Silty Marker. The open space created to permit collapse of the overlying rocks has taken place within the 60 feet of strata between the base of the False Davis and the base of the Silty Marker. The slumping extends to the Davis Formation in some areas of very high mineralization.

Mineralization of the central ore zone consists of galena, sphalerite, chalcopyrite and marcasite. Siegenite is a minor constituent of the chalcopyrite. Drusy quartz makes up much of the cementing material in the interstitial space between breccia fragments and often lines open cavities and vugs.

EASTERN ORE ZONE

This ore trend parallels the central ore zone, but in the southeast part of the Magmont mine swings abruptly west and, at this date, appears to merge with the central ore zone.

The eastern ore zone averages about 200 feet in width in an east-west direction. Maximum vertical thickness is about 50 feet and slumping is on a smaller scale, but similar to that which occurs in the central ore zone. The Silty Marker unit which thins from west to east is about 4 feet thick here, and characteristically it is distorted within the mineralized area.

North-south trending tongues of the ore east of the eastern ore zone are characterized by extremely porous lower calcarenites which contain disseminated galena. The Silty Marker unit is difficult to recognize as the gray bands become progressively thinner to the east. Digital stromatolites within Upper Reef structure have been truncated and make direct contact with the lowest gray bed of the Silty Marker in some areas of the satellite ore zone.

MINERALIZATION OF "C" AND "D" HORIZONS

Ore on "D" horizon within the Magmont mine is known mostly by drilling. To date mineable ore on "C" horizon is restricted to bands of detrital material which separate individual bioherms and fill scour channels within the upper reef horizon.

SUMMARY

Localization of the major ore bodies of the Magmont mine which are on the "B" level horizon are closely associated with an obvious thinning of the Silty Marker beds. Although the bounding faults are not conspicuous in the Silty Marker itself, the area of pronounced thinning and irregular bedding within this unit coincides approximately with the downward projection of these bounding faults. Brecciation of the rock units between the base of the Silty Marker and the overlying Davis Formation developed as a result of partial solution of the intervening rock units.

Mineralization of the strata overlying the Silty Marker is in a general way proportional to the brecciation of these rocks. Brecciation of these rocks is proportional to the amount of collapse that has taken place and collapse in turn is proportional to the amount of solution which has occurred.

Solutions must have followed the more permeable units of the Silty Marker and initiated the ground preparation for a large part of the Magmont ore body as well as providing the plumbing system for the ore-bearing solutions whether they were contemporaneous with or later than the ground preparation.

MAGMONT MINE TOUR

STOP #1

140-442. Pillar exposes irregular contact of reef and overlying detrital unit which is well mineralized.

STOP #2

458-132S. Normal bedded Silty Marker mineralization.
459-133S. Dense fine grained sphalerite exposed on east side of pillar in Silty Marker Unit.

STOP #3

138-463. Pillar exposes mineralized dolomite fragments within surrounding shales which appear to post date the dolomite fragments? This area is within a slump block.

STOP #4

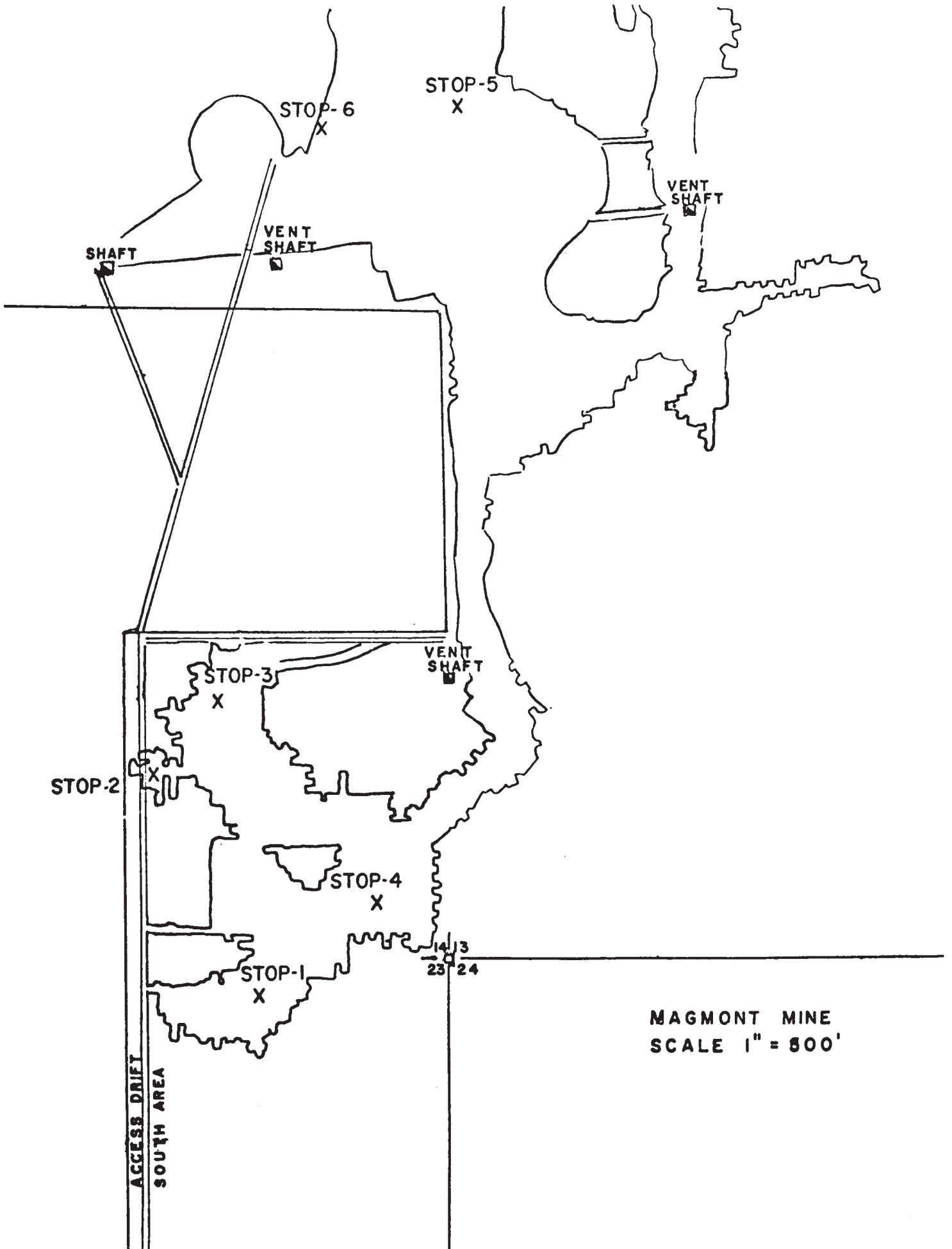
146-450E Area. Mineralization within the central part of a slump area. Note the irregular attitudes of the enclosing dolomites.

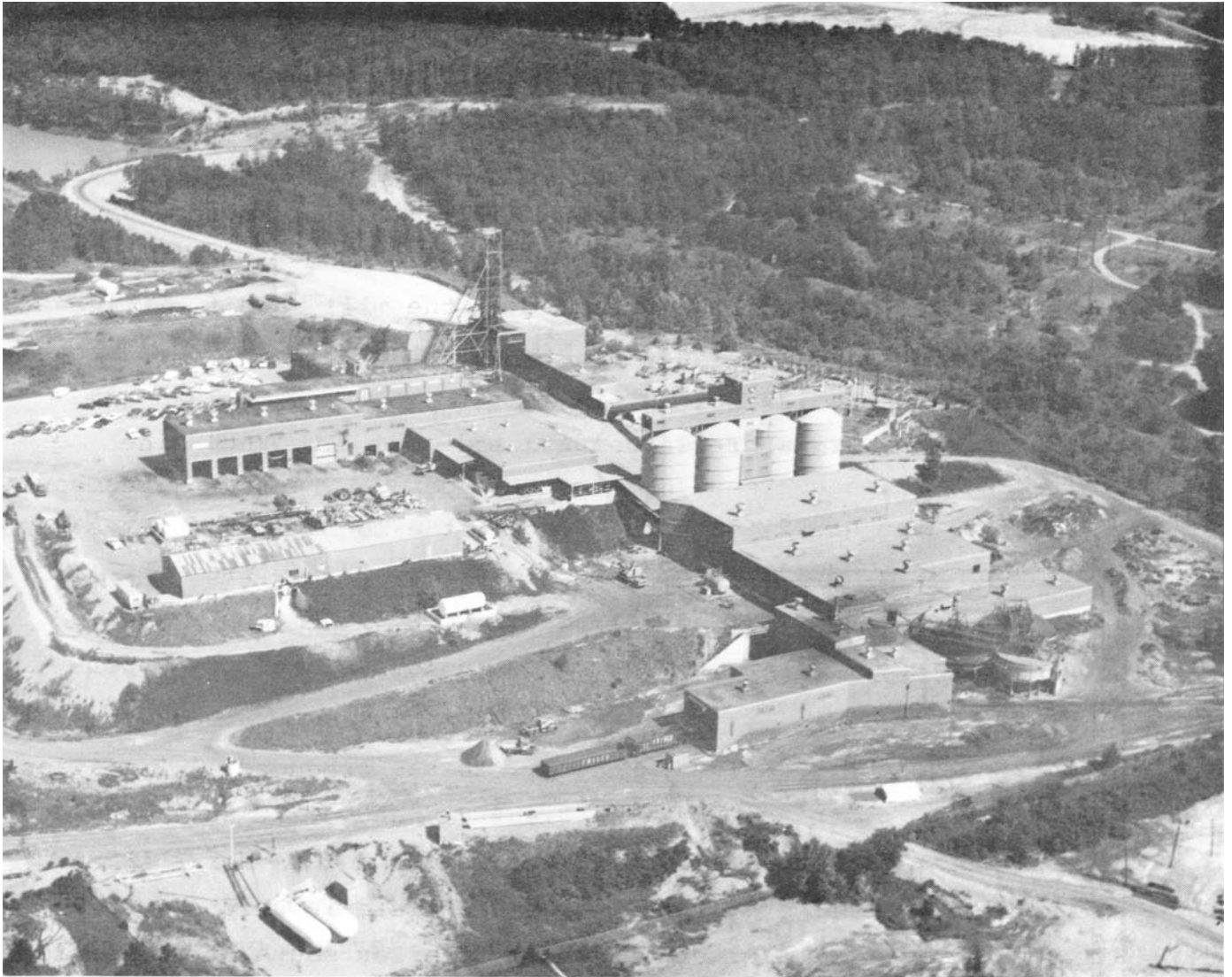
STOP #5

509-158 & 159N. Bounding faults exposed near the top of slump block. Normal faulting within limits of bounding faults. Breccia-type ore is exposed in pillars.

STOP #6

507-146N. Distorted Silty Marker Unit along western edge of ore.





VIBURNUM NO. 28 MINE
(ST. JOE LEAD COMPANY)

GEOLOGY OF ST. JOE VIBURNUM MINE NO. 28

By James Pettus and Keith Rauch

INTRODUCTION

The St. Joe Viburnum Mine No. 28 is in the northern part of the Viburnum Trend in the town of Viburnum. The trend discovery hole, which was drilled in September, 1955, is three miles north-northwest of Viburnum. The prospecting that followed during the next three years outlined the major orebodies and plans were made to develop three main areas near Viburnum. A 6,000 ton-per-day mill was constructed next to the No. 28 Mine shaft and ore was to be transported by truck along the surface from Mine No. 27, which is three miles north-northwest of the mill, and from Mine No. 29, which is three miles northeast of the mill. Production from both mines No. 27 and No. 28 was first milled in 1960 and in 1964 Mine No. 29 started contributing ore. In 1965, mine production increased to over 7,000 tons per day. After September, 1978, when Mine No. 27 was deactivated, the tonnage from the other two mines was gradually increased. Mine No. 28 now produces 4,200 tons per day and Mine No. 29 produces 3,600 tons per day. Each mine employs about 79 men, which includes immediate supervisors.

From 1960 through 1978, Mine No. 28 has produced 11.2 million tons of ore containing 3.99% Pb, 0.45% Zn, and 0.22% Cu. Concentrates can be loaded directly into railroad cars for shipment to the various smelters. The lead concentrate is shipped to the St. Joe Herculaneum smelter, which is 20 miles south of St. Louis on the Mississippi river.

GEOLOGY

The Viburnum mines are 30 miles west of the core of the exposed Precambrian in the St. Francois mountains. The rhyolites and granites in the Viburnum area were deeply eroded to form a rugged topography. The upper Cambrian Lamotte sandstone filled

the valleys with as much as 400 feet of sand. A number of peaks stood as islands during the deposition of the Lamotte and the Bonneterre formation with a few continuing as islands until Potosi deposition. The smaller peaks or knobs were buried during Bonneterre deposition. The higher Precambrian peaks had a strong influence on the depositional features within the Bonneterre with major facies changes controlled by the Cambrian shorelines. The Bonneterre formation is dolomitic throughout the Viburnum Mine No. 28 area where it attains a maximum thickness of 300 feet. Larsen's paper in this guidebook describes the Bonneterre formation and the St. Joe nomenclature used. The various facies have been discussed in several other publications.

The structural contours of the base of the Bonneterre and the subcrop of the Lamotte sandstone and the igneous rocks near Mine No. 28 are shown in Figure 1. Two large knobs that trend northeast-southwest are shown in the immediate mine area. The high that is 3,000 feet north of the shaft is 3/4-mile long with a peak elevation of about 560 feet. Both granite and rhyolite are present in this knob. The other high is 2,000 feet southeast of the shaft with a peak elevation of about 735 feet and a total length of two miles.

Section A-A', Figure 2, illustrates the main mining horizons at this mine. Approximately half the ore occurs in the 7 zone reef and half is in the calcarenites of the overlying 5 zone.

The algal stromatolites of the 7 zone reef are columnar (digitate) and would be classified as separate vertically stacked hemispheroids. The average algal "finger" is about an inch in diameter. Occasionally the head-shaped form, 8-10 inches in diameter, is seen in the mines. The algal stromatolites are brown or tan in color and generally darker at the edges. Algal detritus and other clastics accumulated between the algal columns are generally light-colored with black shale partings and gray spots. The algal reef section is 60-100 feet thick in the mine. Surge

channels (grooves) occur throughout the reef and are filled with clastic sediment. These channels generally trend east-west and the contact between the algal reef and the channel fill is often well-mineralized. Ore grades in the reef averages about 3% Pb.

The clastic 5 zone units are above the 7 zone reef. The tan oolitic crystalline calcarenites of the lower 5 zone are 10-40 feet thick in the mine area but they are very thin or absent three miles to the northeast at Mine No. 29. The parting marker (formerly parting reef) is an interbedded series of gray silty calcarenites and tan to brown crystalline calcarenites that is 10-15 feet thick. The upper 5 zone is a brown-spotted, tan-brown oolitic crystalline calcarenite that is about 40 feet thick in the mine area. Breccia zones in the lower and upper 5 zone beds are important ore structures. These zones generally contain the highest grade ore encountered at Mine No. 28 and they are usually long and narrow, with a general north-south trend. The breccias contain up to 30% Pb in places but the average grade is about 5% Pb.

The ore minerals present at Mine No. 28 are galena, sphalerite and chalcopyrite. These occur in an approximate ratio of 10:1:0.6 respectively. Gangue minerals are calcite, dolomite, pyrite and marcasite. Galena, the principal sulfide, occurs in disseminated and banded deposits with anhedral to euhedral crystals. These occur in part as replacement, but often as open space and fracture fillings.

FIELD TRIP STOPS

STOP NO. 1 - The Conway Fault Zone is 200-300 feet wide in this area with a downward displacement of 20 feet on the southeast side. Several years were required to lower the water pressure in the fault zone and to make the drift crossings.

STOP NO. 2 - This is a long, narrow north-south ore trend in the lower 5 zone oolitic calcarenite and the parting marker horizon. The ore is rich, but spotty, with much leaching and oxidizing present, which is due in part to the close proximity to the Conway Fault just to the north. There is a level below this mining in the reef where the orebody is 100 feet wide. The total thickness of the ore in this area is 80-90 feet - almost as thick as it is wide.

STOP NO. 3 - One of the best areas in the mine to see the non-mineralized 7 zone reef groove and spur structures in the drift back. The general strike of these structures is north 70° east.

STOP NO. 4 - 7 zone algal reef. This is an active mining area, so specific features cannot be described. The ore is associated with groove and spur structures, which are often visible in the stope face. Digitate stromatolites in this area vary from 1-10 inches in diameter.

STOP NO. 5 - This is one of the two places in the mine where the Precambrian igneous rock is exposed. The 7 zone reef lies directly on the Precambrian, which dips into the floor to the west. This point is at the southeast end of Section A-A' in Figure 2.

STOP NO. 6 - A narrow, rich ore trend in the lower 5 zone calcarenites. The orebody lies on the northwest flank of the Precambrian knob (Figure 3). The level 40-feet below this floor mined in the reef. Note the absence of ore in the leached zones.

STOP NO. 7 - This breccia ore in the 5 zone is on the major north-south structural trend in the mine. There are four mine levels here which will mine together in the future to form a stope 100-150 feet high.

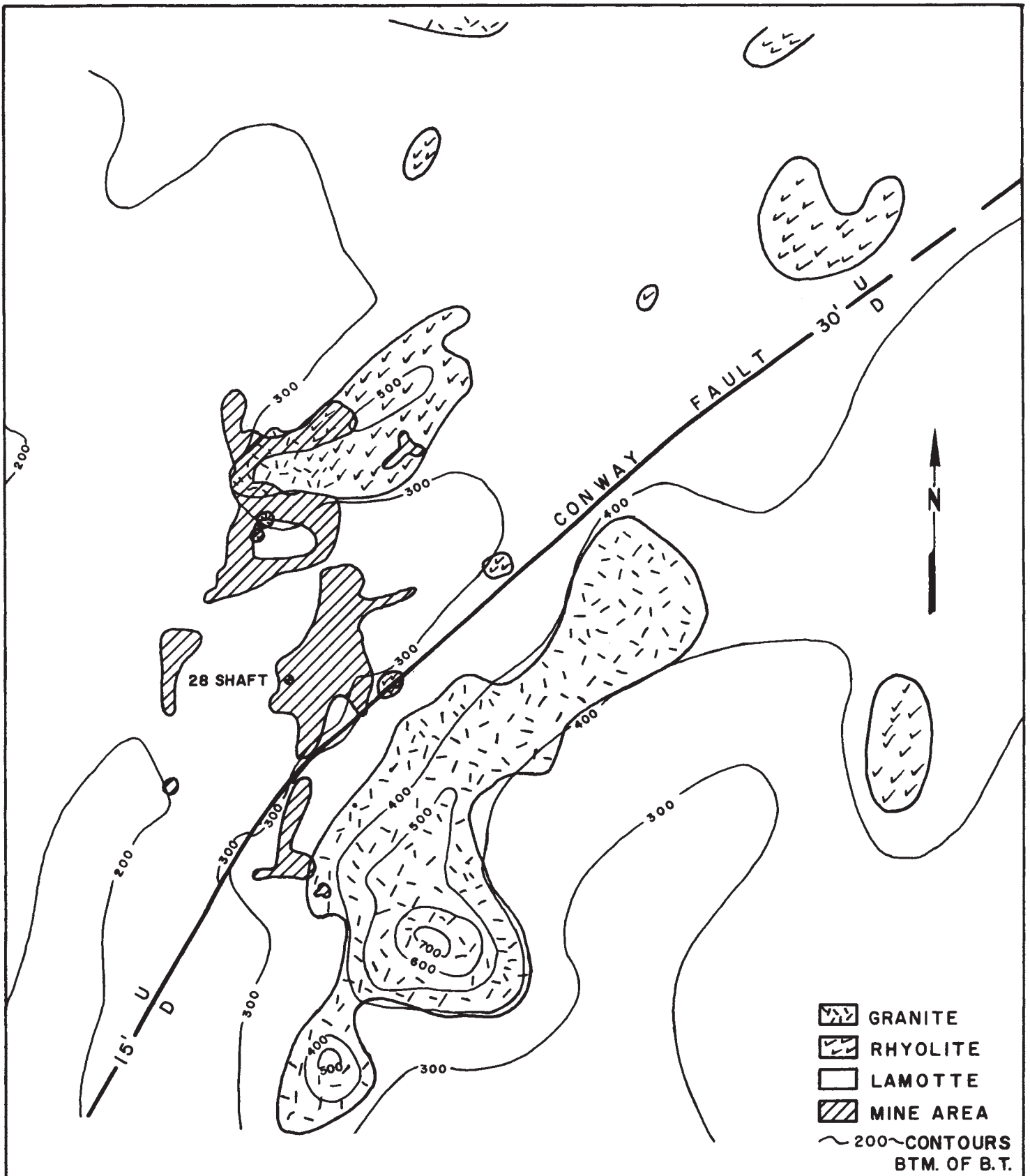
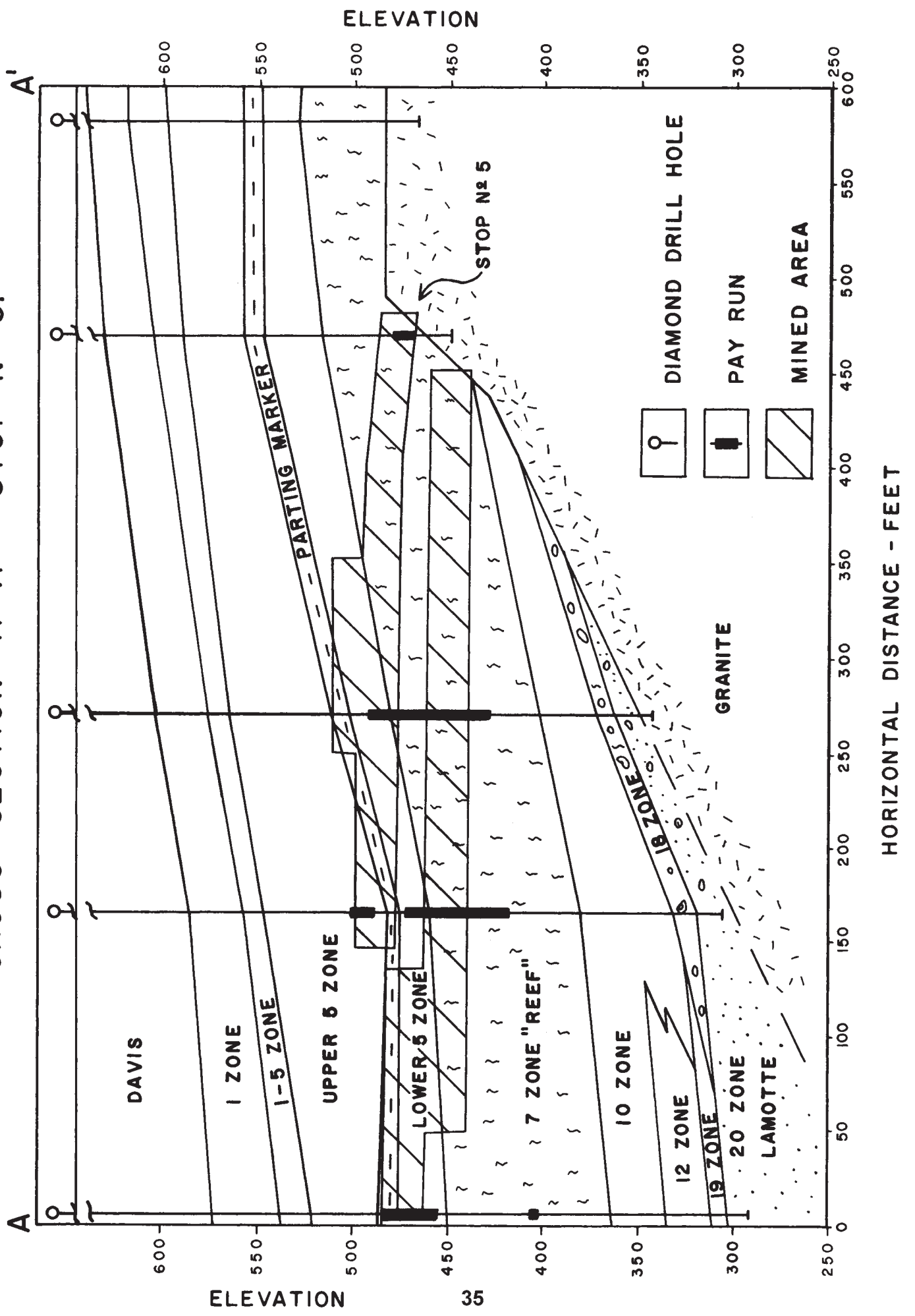
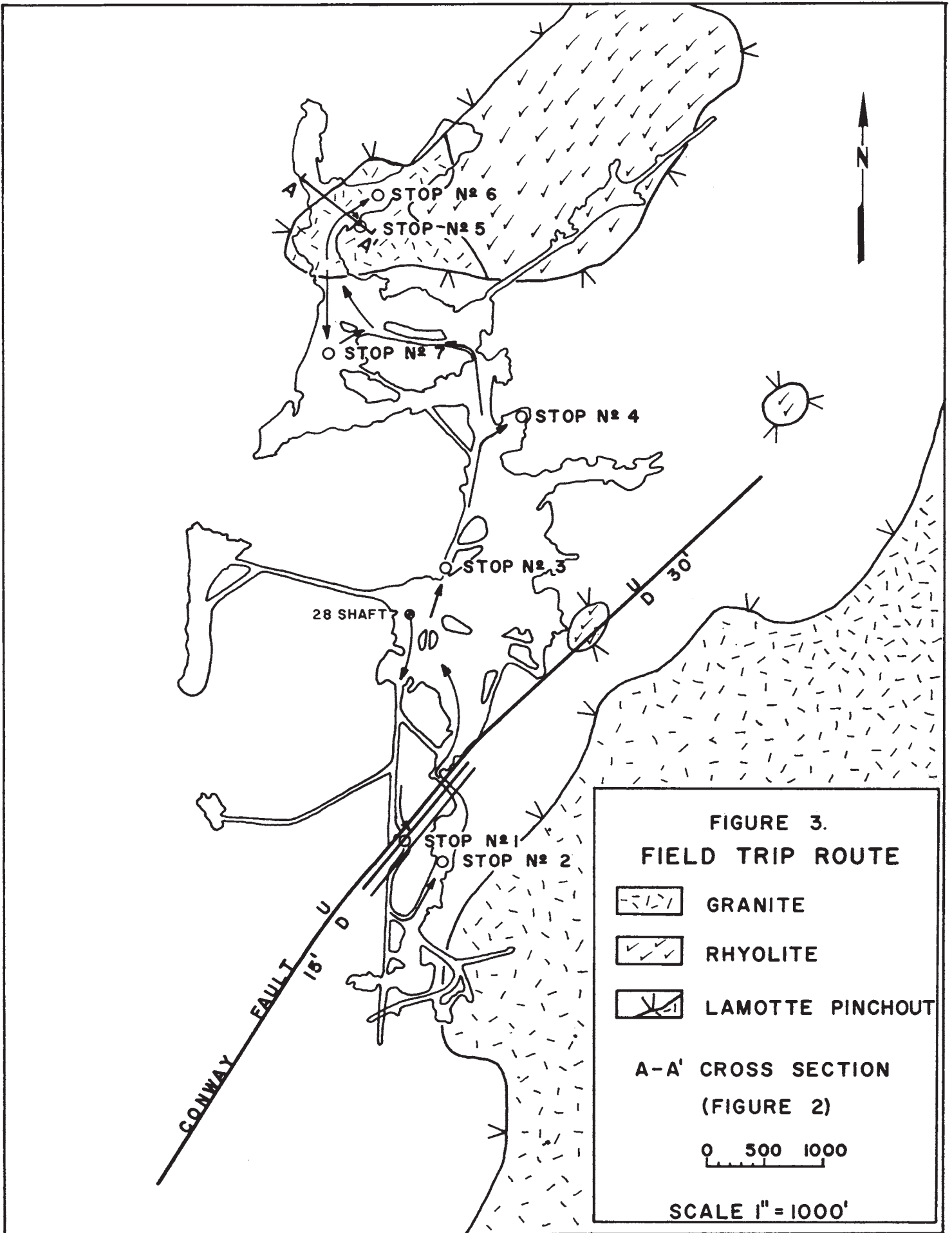


FIGURE I.
28 MINE VIBURNUM DIVISION
BASEMENT AND BOTTOM OF
BONNETERRE FORMATION

FIGURE 2.
CROSS SECTION A-A' - STOP N^o 5.





between the base of the Silty Marker and the overlying Davis Formation developed as a result of partial solution of the intervening rock units.

Mineralization of the strata overlying the Silty Marker is in a general way proportional to the brecciation of these rocks. Brecciation of these rocks is proportional to the amount of collapse that has taken place and

collapse in turn is proportional to the amount of solution which has occurred.

Solutions must have followed the more permeable units of the Silty Marker and initiated the ground preparation for a large part of the Magmont ore body as well as providing the plumbing system for the ore-bearing solutions whether they were contemporaneous with or later than the ground preparation.

MINE TOUR

The tour of the Magmont mine may be revised as conditions warrant (fig. 5).

STOP 1

West edge of ore showing penecontemporaneous slumping of Silty Marker (Gray Bed Unit).

STOP 2

Silty Marker Unit. Shows thinning and distortion of this unit and incipient brecciation of overlying units.

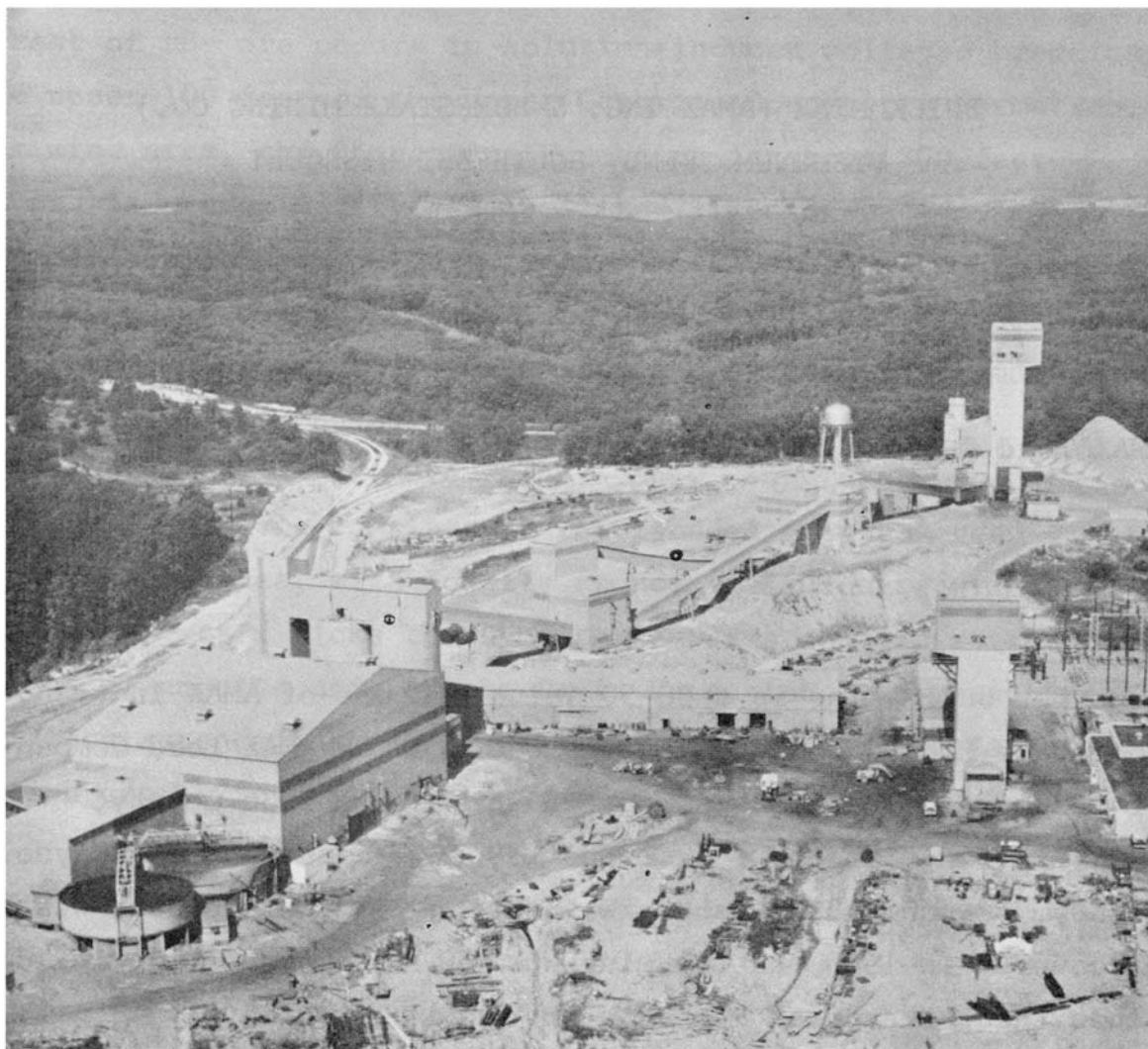
STOP 3

Bounding fault filled with Davis shale and showing collapse of adjacent False Davis due to solution of underlying beds.

STOP 4

Collapse breccia within central high ore between bounding faults.

*THE GEOLOGY AND ORE DEPOSITS OF
SELECTED MINES, VIBURNUM TREND, MO*



BUICK MINE

(AMAX Inc. & Homestake Mining Co.)

BUICK MINE (AMAX INC. & HOMESTAKE MINING CO.)
VIBURNUM TREND, SOUTHEAST MISSOURI

By: Thomas B. Faddies, Chief Geologist, AMAX Lead Co. of Missouri
Douglas N. Mugel, Geologist, AMAX Lead Co. of Missouri

AMAX Lead Company of Missouri
Boss, Missouri 65440

INTRODUCTION

The Buick Mine is a 50-50 joint venture of AMAX Inc. and Homestake Mining Company, and is operated by AMAX Lead Company of Missouri. The mine is located in western Iron County, Township 34N, Range 2W, Sections 23, 25, 26 and 35, and Reynolds County, Township 33N, Range 2W, Section 2. The ore body was discovered in 1960 and the mine was put into production in 1969. Since then, the Buick mine has produced approximately 13 million tons of ore averaging 9.5 percent lead and 3.5 percent zinc. Ore reserves are estimated at approximately 50 million tons of 6.5 percent lead and 2.0 percent zinc. Tons and grade were originally underestimated due to the difficulty in sampling the complexly zoned ore body, and the loss of small amounts of galena in "grinding" of drill core. High mill feed can also be attributed to an effective grade control program developed and operated by the mine geology staff.

GEOLOGIC SETTING

Most of the ore occurs in solution-induced collapse breccias in the upper 100 feet of the Upper Cambrian Bonneterre Formation. In the mine area, the Bonneterre Formation is about 300 feet thick and is predominantly a dolomitized limestone.

Underlying the Bonneterre is the Upper Cambrian Lamotte Sandstone, which consists of well rounded, well sorted quartz grains. Traces of galena, sphalerite, and pyrite are commonly found at the Lamotte-Bonneterre contact.

Overlying the Bonneterre is the Upper Cambrian Davis Formation. The Davis consists of interbedded gray to green shale and carbonates, with locally abundant glauconite. The Buick geology staff picks the Bonneterre-Davis contact at the lowermost glauconite unit of the Davis Formation. In many places, brecciation extends into the Davis; fragments of the Davis Formation can be found within the breccia pile in the Bonneterre.

The upper third of the Bonneterre Formation is shelf facies carbonate sand. The lower two thirds of the Bonneterre consists of three major facies which are (from west to east): a) the fore-reef, b) the reef, and c) the back reef ("white rock zone").

The fore-reef facies, or the variegated unit of Buick mine terminology, lies directly above the Lamotte Sandstone (fig. 1). It is laterally equivalent to the prograding phase of reef development and underlies the reef in the vertical section of the mine. It thickens to the west and is 200 feet thick west of the reef pinchout (Davis, Rogers, and Brown, 1975).

The fore-reef facies is a thinly bedded, fine-grained, gray to brown calcarenite with numerous shaley partings. It represents low energy deposition below wave base (Lyle, 1977). The lower portion of this facies is gradational to the Lamotte Formation, and contains reworked Lamotte sand grains (Lyle, 1977). Buick mine terminology refers to this as the "sandy transition zone". A thin, blue gray ash tuff bed occurs in the lower portion of the fore-reef facies.

A tongue of limestone, which ranges up to 40 feet thick occurs in the fore-reef facies in the central part of the mine area, where the Bonneterre Formation is otherwise entirely dolomitized. The limestone thickens to the west, crossing facies boundaries, and at a point 1 mile west of the ore zone, the Bonneterre is 65 percent limestone, including fore-reef, reef, and shelf lithologies.

The reef facies consists of digitate algal stromatolites with interbedded oolitic calcarenite or fine grained burrowed calcarenite. This "reef complex" is 40 to 100 feet thick in the Buick mine area, (fig. 1), thickens to 150 feet to the east, and wedges out into the fore-reef facies $1\frac{1}{2}$ miles to the west of the ore zone. A few bleached horizons within the reef facies suggest periodic emergence. Thin zones of reef debris on top of the reef, the transitional reef calcarenite (TRC) of Buick mine terminology, are locally ore bearing.

The back-reef facies is composed of planar algal stromatolites interbedded with burrowed carbonate sands and muds, with localized soft green clay (Howe, 1968). Both stromatolites and interbedded calcarenites, to varying degrees, are bleached, dolomitized, and

recrystallized. Therefore, the term "white rock" is applied to this facies. The western limit of the back reef facies is approximately 1 mile to the east of the ore zone; it thickens rapidly to the east. The back reef facies is interpreted as representing a low-energy zone above wave base, in shallow water with restricted tides and circulation (Lyle, 1977).

The upper third of the Bonneterre Formation records the transgression of the Late Cambrian sea as shelf facies sediments are deposited over the retreating reef and back reef facies (Lyle, 1977). In the mine area, the shelf facies overlies the reef facies (fig. 1), and it is within the shelf facies that the breccias and ore occur. Within the ore zone, the shelf facies is in part an off-reef sand bar (Davis, Rogers and Brown, 1975).

The Buick geology staff subdivides the shelf facies into four "calcarenite" units, and four "variable" units. The fourth calcarenite, which directly overlies the reef facies, is predominantly composed of oolites and reef detritus. Thickness averages 40 feet or more. The upper 15 feet of this unit generally contains three gray, silty, marker beds, known in Buick mine terminology as "gray beds". These gray beds, ranging from less than one-half to two feet in thickness, originate at the tops of reefs to the east, and contain reef detritus and minor quartz silt (Rogers and Davis, 1977). The base of the breccia bodies typically lie within this gray bed horizon.

Above the top gray bed are the third and second calcarenites, which are interbedded grainstones and burrowed mudstones. High energy sediments dominate the third calcarenite; low energy sediments dominate the second calcarenite. This cyclic nature of high-energy and low-energy sedimentation is interpreted as the

result of water depth fluctuations in an environment near wave base (Lyle, 1973). The total combined thickness of the third and second calcarenites is approximately 50 feet.

The first calcarenite overlies the second calcarenite and is a high energy, oolitic grainstone facies. This unit is not present in some parts of the mine area, and where present, it is usually no more than 10 feet in thickness.

The upper 30 feet of the shelf facies, known as the variable unit, is transitional to the overlying Davis Formation. The fourth variable sub-unit, overlying the calcarenites, is a green shale interbedded with coarse grained, trilobitic grainstone. This is similar to Davis lithology, and is known as the False Davis in other parts of the district. At the base of the fourth variable, the Sullivan Siltstone occurs southwest of the ore zone, but is absent in the mine area.

The top three variable sub-units show an increase in grain size upwards, with a gradational contact between the coarse grained trilobitic first variable and the Davis Formation. A thin green shale bed commonly occurs at the base of the second variable.

ORE BODIES

The most significant ore controls in the Buick mine are complex, solution-induced collapse breccias in the upper Bonneterre shelf sediments (fig. 2). Ore bodies of this type are narrow, subparallel and sinuous bodies with excellent north-south continuity. Two to four distinct ore zones are present in cross section; typically there are three. Individual ore zones are as wide as 300 feet and range from 30 to more than 85 feet in thickness.

Most breccias are well developed with fragments clearly displaced and rotated. However, some breccias are more subtle

in appearance, and a few zones within the mine do not have the appearance of a breccia at all. In most cases however, the breccia is well developed. The lower portion of the breccia bodies usually consists of small, fine grained, early-lithified calcarenite fragments in a coarser grained flowage matrix. Dark brown to black clay, interpreted as an insoluble residue, is common in the matrix of the breccias (Rogers and Davis, 1977). The upper parts of the breccia bodies display a brittle style of fracturing, with larger fragments and numerous open spaces. Downward displacement in the breccias is from 3 to 10 feet at the base, and up to 30 feet at the top. The main structural elements of the breccia bodies are the basin shaped bottoms and outward dipping fractures at the flanks, locally termed "boundary fractures". These fractures, although not always present, commonly are occupied by downward tapering wedges of mixed lithology, including variable and Davis shales. Inward dipping slump breccias are common at some boundaries, but undisturbed, unmineralized beds are present at the fracture boundary elsewhere.

Below the breccia ores, the transitional reef calcarenite is locally mineralized. This "reef top" ore occurs in elongate zones, eight to ten feet thick, but does not appear to have the same degree of north-south continuity as the breccia ores. Because this ore zone is below the main mining level, it has been exposed only locally by mining, and the geometry and mineral zoning are not yet well understood.

A thin, blanketlike ore body occurs at the southern end of the property at the reef-calcarenite contact, and overlies a buried Precambrian knob. This ore zone, dominantly galena, is from 4 to 24 feet thick, and has not yet been exposed by mining.

MINERAL ZONING

The ore minerals in the Buick mine are galena, sphalerite and chalcopyrite. Other sulfides present are pyrite, marcasite, siegenite, polydymite, vaesite, bravoite, bornite, and arsenopyrite. Gangue minerals are dolomite, calcite, quartz, and the clay minerals kaolinite and dickite.

Throughout the length of the Buick mine, individual ore zones merge, diverge, and rarely terminate. Each ore zone has its own structural and mineralogical characteristics, (fig. 2 & 3), and when two merge, the composite ore zone's mineral assemblage contains identifiable characteristics of each. Although, north-south continuity is good, there are characteristic differences in mineral zoning patterns between ore zones presently being mined at the north and south extremities of the mine. Figure 2 illustrates the usual case as it has been mapped in the more thoroughly studied central parts of the mine.

The west ore zone typically has two ore shoots and a weakly mineralized core. The west side grades west to east, from galena to galena-sphalerite through a narrow interval. Along the upper west flank of this ore zone, galena-pyrite mineralization occurs in an eastward dipping slump breccia, known as the west "wing" of the west ore zone. The eastern shoot, (cobalt-nickel zone), contains galena, sphalerite (assaying high in cobalt and nickel), traces of siegenite and erythrite, (cobalt bloom), chalcopyrite, pyrite, and rarely polydymite. This mineral zone grades upward into a galena-pyrite zone. The core of the west ore zone, where brecciation and porosity are as well developed as anywhere in the mine, contains sub-ore grade galena, sphalerite, and chalcopyrite.

Open space mineralization is characteristic in the upper part of the west ore zone. Galena and pyrite line and fill vugs and near vertical fractures. Mineralization in the lower two-thirds of the ore zone occurs as a replacement of the coarse-grained "flowage breccia" matrix. Displaced coherent beds in the west ore zone exhibit an inward dipping "sag", or synclinal

structure. Mineralization in the east flank occurs along westward dipping bedding planes related to this structure. (Rogers and Davis, 1977).

The central ore zone is generally thicker than the east and west ore zones. Locally, ore grade mineralization extends from the base of the Davis Formation through the breccias, and to the top of the reef. Mineral zoning is less complex than in the west ore zone. The upper part contains open space galena and pyrite. Replacement of breccia matrix by galena and, to a lesser extent, sphalerite characterizes the lower portion of the ore zone. Sphalerite occurs in higher concentrations along the margins.

In the north-central portion of the mine, a high grade, massive replacement zinc-lead shoot occurs along the lower west flank of the central ore zone (tour stop No. 7). Exposures at the base of this ore shoot suggest that it may be a filled scour channel. The coarse clastics at this location are replaced by sphalerite and galena. This ore shoot is truncated by the central ore zone breccia, and fragments of the earlier mineralization are tightly cemented in a matrix of replacement galena, sphalerite, and unreplaced dolomite. These relationships imply that the high grade ore shoot is pre-breccia replacement mineralization

The east ore zone ranges from 30 to 40 feet in thickness. This zone exhibits tight mineral-zoning patterns, the most distinctive feature of which is a chalcopyrite zone localized on the lower central part. Galena and sphalerite in varying proportions surround the chalcopyrite "core". The west flank is generally zinc-free, and has abundant pyrite. Massive botroidal

pyrite, up to 20 feet thick, locally caps the east ore zone in the north mine. Ore mineralization in the east ore zone occurs mostly as replacement of breccia matrix. Minor amounts of open space filling type mineralization have been mapped at the top of the east ore zone.

Mineral zoning and structural patterns change gradually along the length of the mine, and the ore zones at the present extremities of the mine are similar to, but do not exactly represent the "typical" patterns. At the far south end, the west ore zone is consistent with its typical description. The central ore zone is similar to its typical description, but sphalerite dominates galena. The east ore zone is not present at all.

At the far north end of the mine, north of the "Cominco window", two ore zones are currently differentiated: the west and east ore zones. The west ore zone is significantly different than that at the south end. It is thinner, wider; brecciation is less intense. Mineral distribution also changes. The far west side is a galena-sphalerite zone, with a thick cap of botroidal marcasite and pyrite. To the east, this zone grades into a galena-chalcopyrite zone, which contains sphalerite. Siegenite is intergrown with and replaces chalcopyrite. The far east side of the ore zone is a sphalerite-galena zone, 10 to 15 feet thick, with a thick cap of botroidal marcasite containing minor galena. Ore mineralization in this zone is replacement type; brecciation is very subtle, and much of the mineralization is controlled by bedding.

The east ore zone contains a high grade galena-sphalerite core localized in the basal third, with chalcopyrite irregularly distributed. Peripheral to this is a lower grade galena-sphalerite-chalcopyrite zone. Massive replacement results in sinuous, wavy,

relict bedding. The upper part of the ore zone contains a galena zone, with minor sphalerite and chalcopryrite which grades upward into a pyrite zone, containing minor galena. This part of the ore zone is characterized by brittle brecciation, with galena and/ or pyrite occupying fractures around individual breccia blocks. Displacement of dolomite blocks does not appear to be extreme. However, downward tapering wedges of overlying variable shale fill fractures which strike parallel and less commonly perpendicular to the strike of the ore zone. Displacement of the shale is 30 feet or more.

Paragenesis of the Buick ore is very complex. Where a paragenesis is determined for a small area, it does not represent the entire Buick orebody. Numerous overgrowths of different minerals in vugs is common. Both octahedral and cubic galena crystals are leached and etched in various places throughout the mine. Octahedral casts of chalcopryrite and pyrite suggest remobilization of galena. Mineral zoning in the orebodies is complex, and pre-breccia ore occurs in a matrix of post-breccia ore. It is suggested that more than one mineralizing pulse is responsible for the ores at Buick.

ORIGIN OF BRECCIAS

The Buick geology staff considers the origin of the breccias to be an open question, but recognizes two general schools of thought. One calls for selective dissolution of carbonate material only. The other, the "evaporite model", is as follows:

Shortly before deposition of the "gray beds", an off reef lime sand bar, (tour stop no. 1), occupied a position just west of the west ore zone. A few inlets permitted flooding of the backbar lagoon, where tidal currents scoured channels several feet deep. A change in conditions, (a major storm perhaps), closed the inlets and left the channels partly filled with well sorted sediments and partly empty of sediments. Seepage through the bar sands provided water to the isolated lagoonal channels, where evaporation resulted in accumulation of evaporite minerals. Renewed sedimentation added 40 or 50 feet of calcarenite, conditions changed, the evaporites were dissolved, and brecciation was initiated. The permeability, once established, localized several later periods of solution activity and the compound breccia bodies resulted. In some places, where the channels were sand-filled, little solution occurred, (the breccias are thin, if present), but replacement of channel fill resulted in high grade ore. (Davis, Rogers and Brown 1975)

Another model, not calling on the presence of evaporite minerals, explains the breccias as a result of selective dissolution of carbonates. The breccia bodies are thought to occupy a position over and within the east side of an oolite bar. Fluctuations in sea level and the resulting percolation of water produced an intricate network of permeable channels in the oolite bar. Later fluids migrating through the system dissolved more of the carbonate, initiating the collapse.

MINE TOUR

The service shaft, by which men and materials enter the mine, is 1,335 feet deep, 18 feet in diameter and concrete-lined to the bottom. Its collar elevation is 1,406 feet, and mining-level landing elevation is 270 feet. Electrical power, at 4,160 volts, and compressed air input is here. Ventilation air, at the rate of 425,000 cubic feet per minute, is pulled into the mine through the service shaft and the hoisting shaft. The air flows through the mine workings and down to the haulage level (below the ore body), and is exhausted through two ventilation shafts at north and south ends of the mine. The mine is currently being dewatered at the rate of 3,500 gallons per minute. The service shaft is 300 feet west of the ore body and the bearing of the access drift to the ore body is due east. Ore is hoisted at the production shaft in two counter-balanced 12 ton skips.

Seven tour stops are planned, and most, if not all, are expected to be accessible at the time of the tour. Location of the stops are shown on cross section, (fig. 2), and in plan view, (fig. 4). Following these scheduled stops, the group will visit the more recently opened parts of the ore body north of the "Cominco window". Location of stops in this area is contingent upon mining activities that day.

STOP 1 Access drift from shaft to ore body

Exposed here is a section of a sand bar in the middle part of the shelf zone calcarenites; note westerly dips in ribs and back of the drift.

The bottom of the western "wing" of ore on the west side of the west ore body is also exposed here. This flowage breccia dips eastward toward the main area of subsidence and truncates the underlying beds of the sand bar.

STOP 2 Shop Area

This pillar is in the central part of the west ore zone. Fragments of early-lithified beds in a matrix of "flowage sand" constitute breccia of less than average intensity. Coherent beds were generally finer grained and less well sorted, whereas cleaner, coarser material appears to have been uncemented and to have flowed.

STOP 3 East side of central ore zone (fig. 5)

This stop is at the east side of the central ore zone at the bottom of the breccia zone. The north rib of the drift shows early-lithified beds dislocated at boundary fractures and enveloped by material which was free to flow. The prominent beds are the "gray beds", important marker units throughout the mine and most of the district. They are fine-grained calcarenite with minor quartz silt and are stratigraphically equivalent to a digitate-stromatolite unit present east of the mine.

STOP 4 Eastern boundary, central ore zone

Looking south, follow the undisturbed gray beds east to west until the gray beds are suddenly downdropped 2 to 3 feet. This is the eastern boundary of the central ore zone and this amount of displacement is typical of the base of the breccia bodies. Notice the flowage material at the boundary between brecciated and unbrecciated rock.

STOP 5 West side of west ore zone (fig. 6)

This exposure shows offset "gray beds" at the lower west side of the west ore zone. The boundary of the breccia trends northwesterly across the north-south drift at this point. Undeformed and unmineralized beds are present in the bench face southwest of the pillar. The mined out area above the bench to

the west was the "wing" of ore seen at its base at Stop 1. The west ore zone was 75 feet thick here and has been mined out.

STOP 6 West side of central ore zone

The west and central breccias are separated by only 20 feet at this elevation in this part of the mine; undisturbed beds at the west side of this pillar become broken as they pass eastward into the central breccia. Conspicuous blocks of the "gray beds" occur in various attitudes. An anomalous east-dipping fracture contains minor amounts of green shale derived from beds 75 feet above.

STOP 7 West side of central ore zone (fig. 7)

The base of the high grade zinc-lead ore shoot is exposed here. The truncation of underlying beds by this contact suggests a channel which was filled with sediments that were subsequently replaced by sphalerite and galena. Note the complete absence of sulfides below the contact.

This high grade ore shoot is truncated by the central ore zone breccia. Fragments of the high grade ore are found in the breccia, in a matrix of replacement galena, sphalerite, and unreplaced dolomite.

REFERENCES

- Davis, James H., 1977, Genesis of Southeast Missouri Lead Deposits: Econ. Geol., v. 72, n. 3, pp. 443-450.
- Davis, James H., Rogers, Robert K., and Brown, William K., 1975, Buick Mine (Amax Inc. and Homestake Mining Co.), Viburnum Trend, Southeast Missouri: Guidebook to the Geology and Ore Deposits of Selected Mines in the Viburnum Trend, Missouri: Mo. Dept. of Nat. Resources, Geological Survey, Rept. Inv. 58, pp. 30-39.
- Howe, Wallace B., 1968, Planar Stromatolite and Burrowed Carbonate Mud Facies in Cambrian Strata of the St. Francois Mountain Area: Mo. Geol. Survey and Water Resources, Rept. Inv. 41, 113 p.
- Jordan, Clif J., 1978, Geological Research at the Buick Mine, Viburnum Trend, Southeastern Missouri: 1976-1978, 150 p. Unpublished Report, Amax Lead Co. of Mo. Files.
- Larson, Kenneth G., 1975, Stratigraphic and Facies Nomenclature of the Viburnum Trend, Southeast Missouri: Guidebook to the Geology and Ore Deposits of Selected Mines in the Viburnum Trend, Missouri: Mo. Dept. of Nat. Resources, Geological Survey, Rept. Inv. 58, pp. 15-19.
- Lyle, John R., 1977, Petrography and Carbonate Diagenesis of the Bonneterre Formation in the Viburnum Trend Area, Southeast Missouri: Econ. Geol., v. 72, n. 3, pp. 420-434.
- Lyle, John R., 1973, The Facies Geometry and Carbonate Petrology of the Bonneterre Formation in Western Iron, Northern Reynolds, and Eastern Dent Counties, Missouri: Unpublished Masters Thesis, Univ. of Mo.-Columbia.
- Rogers, Robert K., and Davis, James H., 1977, Geology of the Buick Mine, Viburnum Trend, Southeast Missouri: Econ. Geol., v. 72, n. 3, pp. 372-380.

ACKNOWLEDGMENTS

We wish to thank the management of AMAX Lead Company of Missouri for permission to publish this paper, and for its cooperation in making the necessary preparations for the mine tour.

Our special thanks go to Dr. James Davis, former Chief Geologist of AMAX Lead Co. of Missouri, who constructively criticized this paper. His previous work has had considerable influence in shaping the ideas presently held by the Buick geology staff.

Our knowledge of the local carbonate petrology, depositional environments, and ore controls has been expanded by the two-year research program carried out by Dr. Clif Jordan.

The work of John Lyle has improved our understanding of the carbonate petrology, facies relationships, and diagenesis in the Buick area.

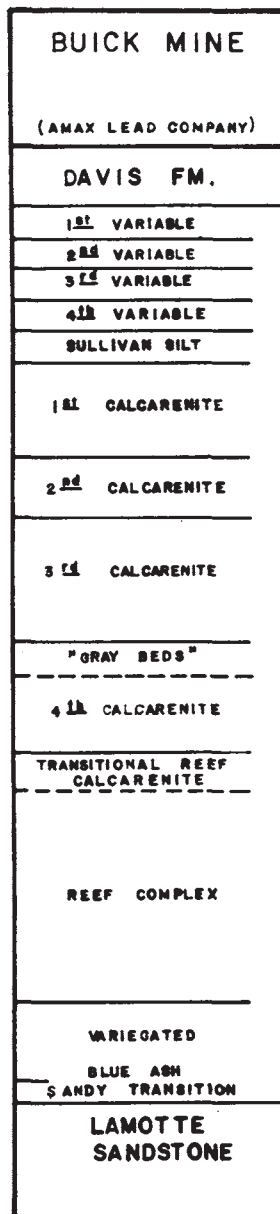


Figure 1

Mine columnar section, Buick Mine, southeast Missouri (not to scale).

(from Larsen, 1975)

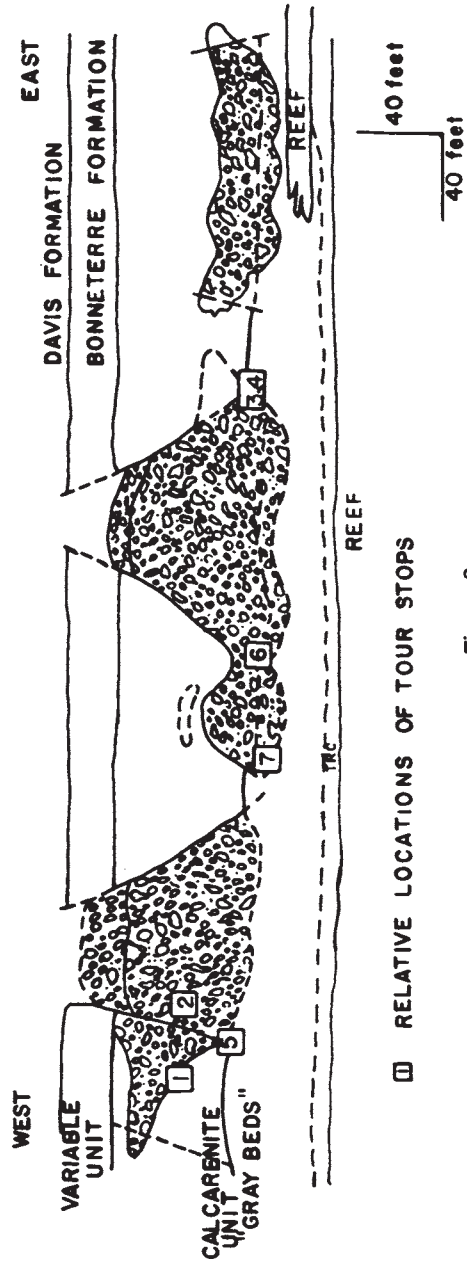


Figure 2
 Generalized cross section of breccia bodies, Buick Mine
 (Modified from Davis, Rogers, and Brown, 1975)

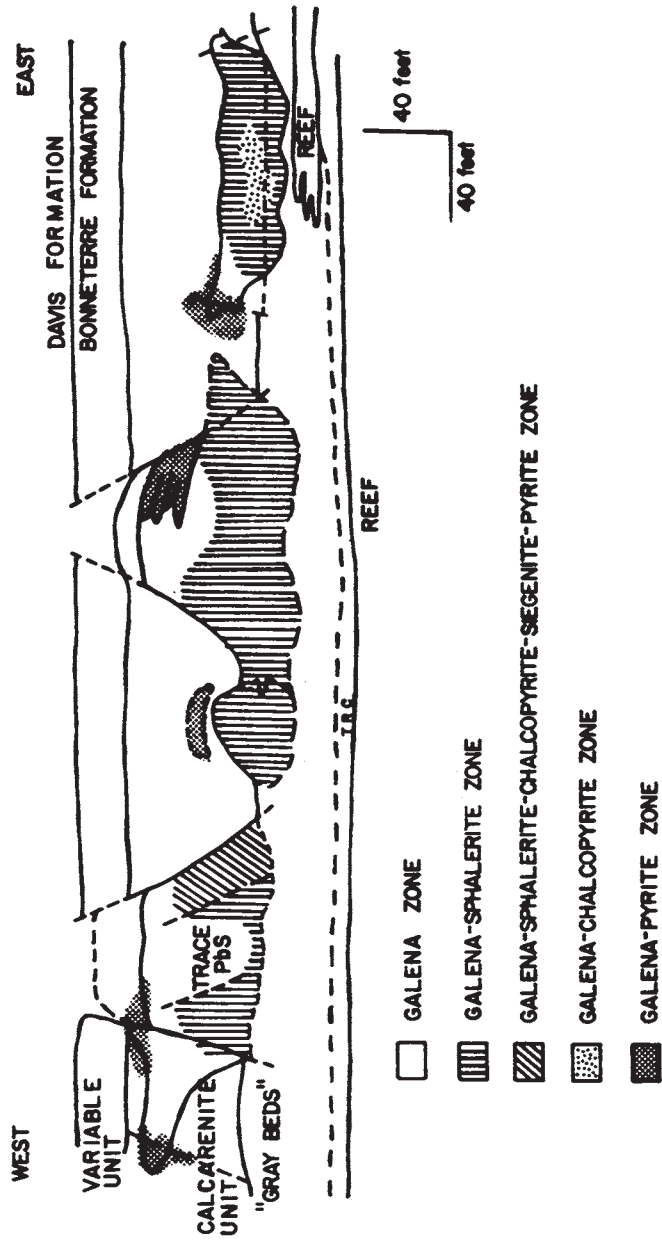


Figure 3

Generalized mineral zoning, Buick mine.
(Modified from Davis, Rogers, and Brown, 1975)

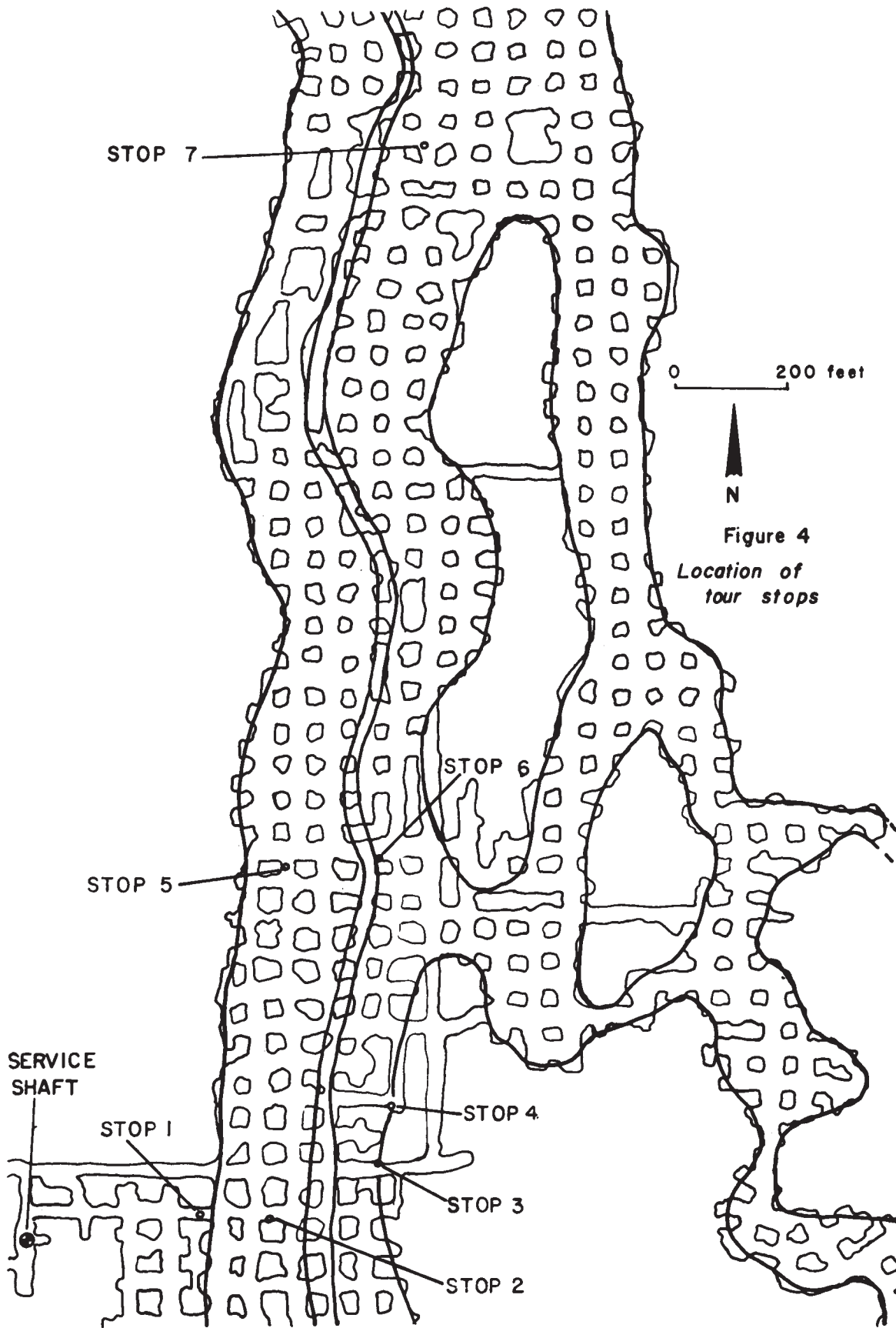


Figure 4
Location of
four stops

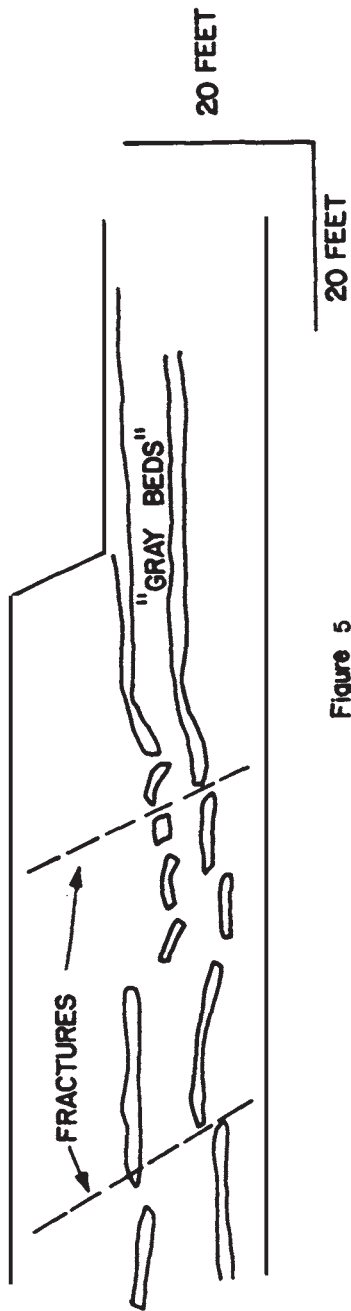


Figure 5
Offset of "gray beds" at Stop 3, Buick Mine
(From Davis, Rogers, and Brown, 1975)

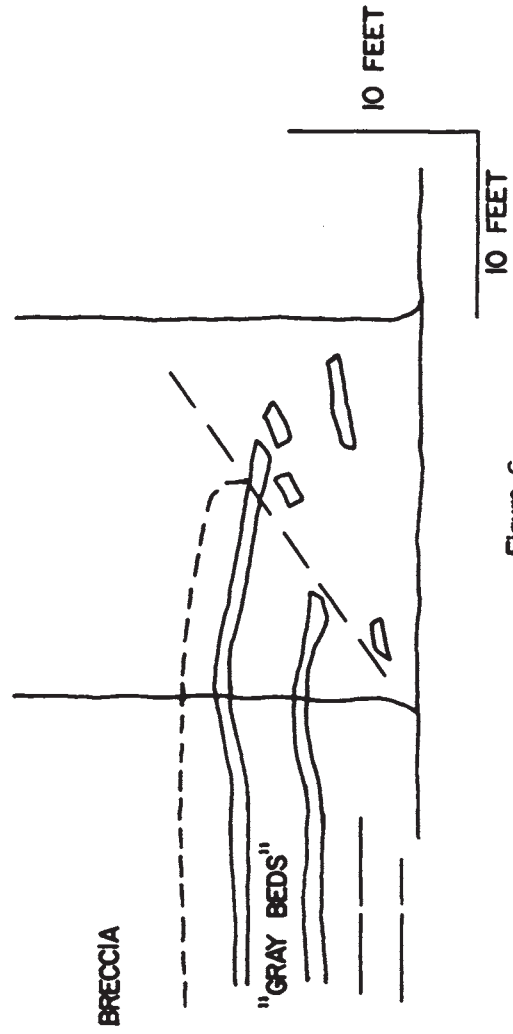


Figure 6
 Offset of "gray beds" at Stop 5, Buick mine.
 (From Davis, Rogers, and Brown, 1975)

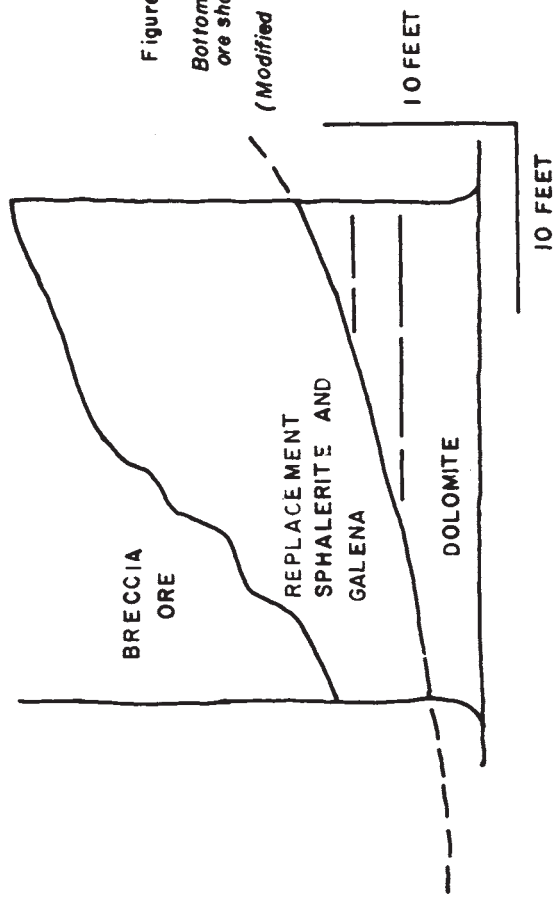


Figure 7

Bottom contact of high grade Zn-Pb ore shoot at Stop 7, Buick mine.
 (Modified from Davis, Rogers, and Brown, 1975)

STOP 4 Mineralization in the upper 5 zone (Stope 68C17)

This stope contains a good grade of lead mineralization in the upper 5 zone. The mineralization occurs along the south end of a north-south trending structural ridge with the better grade of ore on the ridge flanks. The Sullivan Siltstone marker bed is also exposed in this stope. The mineralization is mainly stratiform in nature, although good crosscutting features are present from the 5 zone, through the Sullivan Siltstone and 1 zone to the Davis Formation.

STOP 5 Mineralization within the thin bedded mudstone (Stope 67C42)

This stope contains good mineralization in the 1 zone, thin bedded mudstones. The Sullivan Siltstone, normally expected to be the cap rock for mineralization in the area, has been breached by fractures. Mineralization occurs in this area from the base of the 5 zone brown spotted beds to the Davis Formation, a thickness of 110 feet.

REFERENCES

Gerdemann, P.E., and Harold E. Myers, 1972, Relationships of carbonate facies patterns to ore distribution and to ore genesis in the Southeast Missouri Lead district: *Econ. Geol.*, v. 67, n. 4, p. 426-433.

Snyder, F.G., and P.E. Gerdemann, 1968, Geology of the Southeast Missouri Lead district, in *Ore deposits of the United States, 1933-1967 (Graton-Sales Volume)*, J.D. Ridge, ed.: *Am. Inst. Min. Eng.*, v. 1, p. 326-358, 13 figs., 5 tbls.

Ohle, E.L., and J.S. Brown, eds., 1954, Geologic problems in the Southeast Missouri Lead district: *Geol. Soc. Am. Bull.*, v. 65, n. 3 and n. 9, p. 201-222, 935-936 (supplement).

ORE	ZONE	LITHOLOGY
		Davis Shale
↑ BONNETERRE FORMATION AVERAGE THICKNESS 300' ↓	1	Thin bedded mudstones
	1	Thinly laminated gray siltstone
	5	Brown oolitic grainstone with numerous algal balls
	5	Tan oolitic grainstone
	7	Brown digitate algal stromatolites
	3 & 4	"White Rock" (backreef facies) mixed rock types – mostly bleached clastics & reef
	7	Brown digitate algal stromatolites
	10/12	Lime mudstone & lime grainstones
	19	Transition zone grainstones
	20	Lamotte sandstone

Figure 4

Bonneterre Formation subdivisions, Fletcher mine.

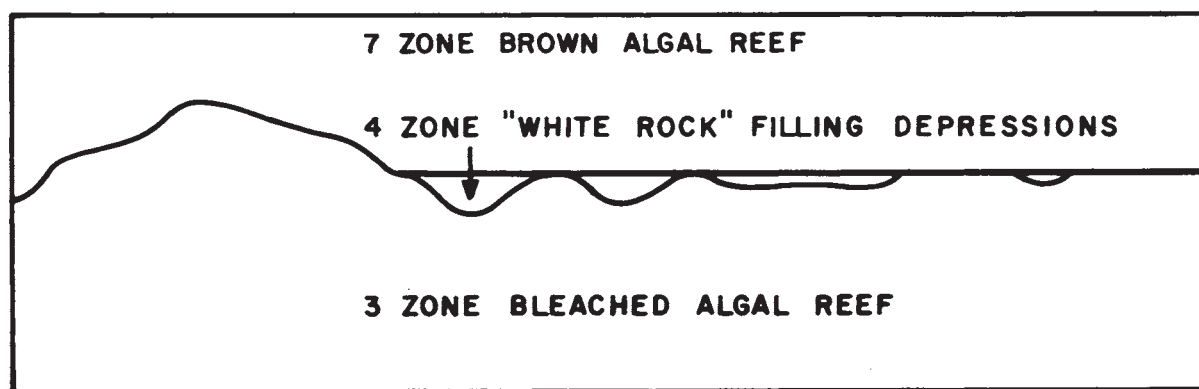
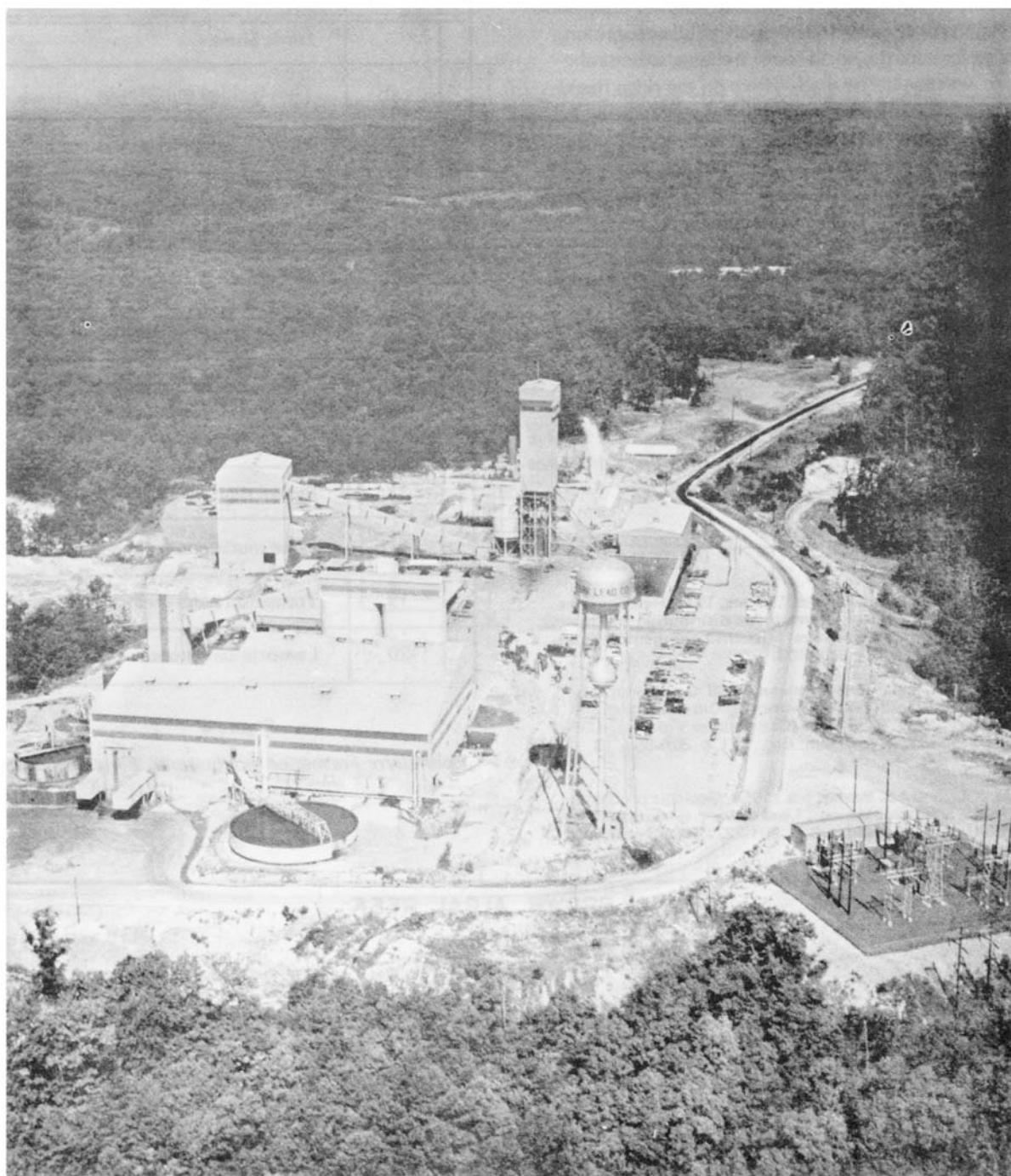


Figure 5

Reef and "White Rock" features at Stop 2, Fletcher mine.

*THE GEOLOGY AND ORE DEPOSITS OF
SELECTED MINES, VIBURNUM TREND, MO*



OZARK LEAD COMPANY MINE

FRANK R. MILLIKEN MINE OF OZARK LEAD COMPANY
NEW LEAD BELT, SOUTHEAST MISSOURI

By K. G. Larsen, C. W. Clendenin, M. M. Mouat,
W. T. Walker, and D. R. Taylor

INTRODUCTION

Ozark Lead Company has the southern most operating mine in the New Lead Belt; and recently, the mine, locally known as the Sweetwater Mine, was dedicated as the Frank R. Milliken Mine of Ozark Lead Company

The ore body was discovered in January 1962 and was put in development in May 1964 with the drilling of a 1250-foot deep, 6-foot diameter development shaft. In April 1967, mine workings driven from this development shaft were intersected by the present 20-foot diameter, three compartment production shaft. The mine began production in June 1968 with a designed capacity of 6,000 tons of ore per day.

GEOLOGIC APPROACH

The geologic approach used by staff geologists to study the ore deposit at Ozark Lead Company is best defined as applied theoretical. This approach is based on interpretation of empirical data stemming from mapping and field observations. Geologic models are developed from these interpretations to provide a working hypothesis for continued study in the mine.

Over the past four years, emphasis has been given to the development of a structural model that would help explain many of the ore controlling structures. The interrelationship of this structural model with the models for both the sedimentary patterns and mineralization is the present working hypothesis used in mine study.

SEDIMENTATION MODEL

Within the Bonneterre Formation, four carbonate and one mixed carbonate-quartz sand facies have been recognized (Larsen, 1977). The various carbonate facies have been described by numerous investigations and can be defined as: 1) a micrite and shale facies; 2) an oolitic facies; 3) a digitate stromatolite facies; and 4) a planar stromatolite-burrowed lime mudstone facies (Kurtz et al, 1975; Larsen, 1975 and 1977; Howe et al, 1975; and Lyle, 1973 and 1977).

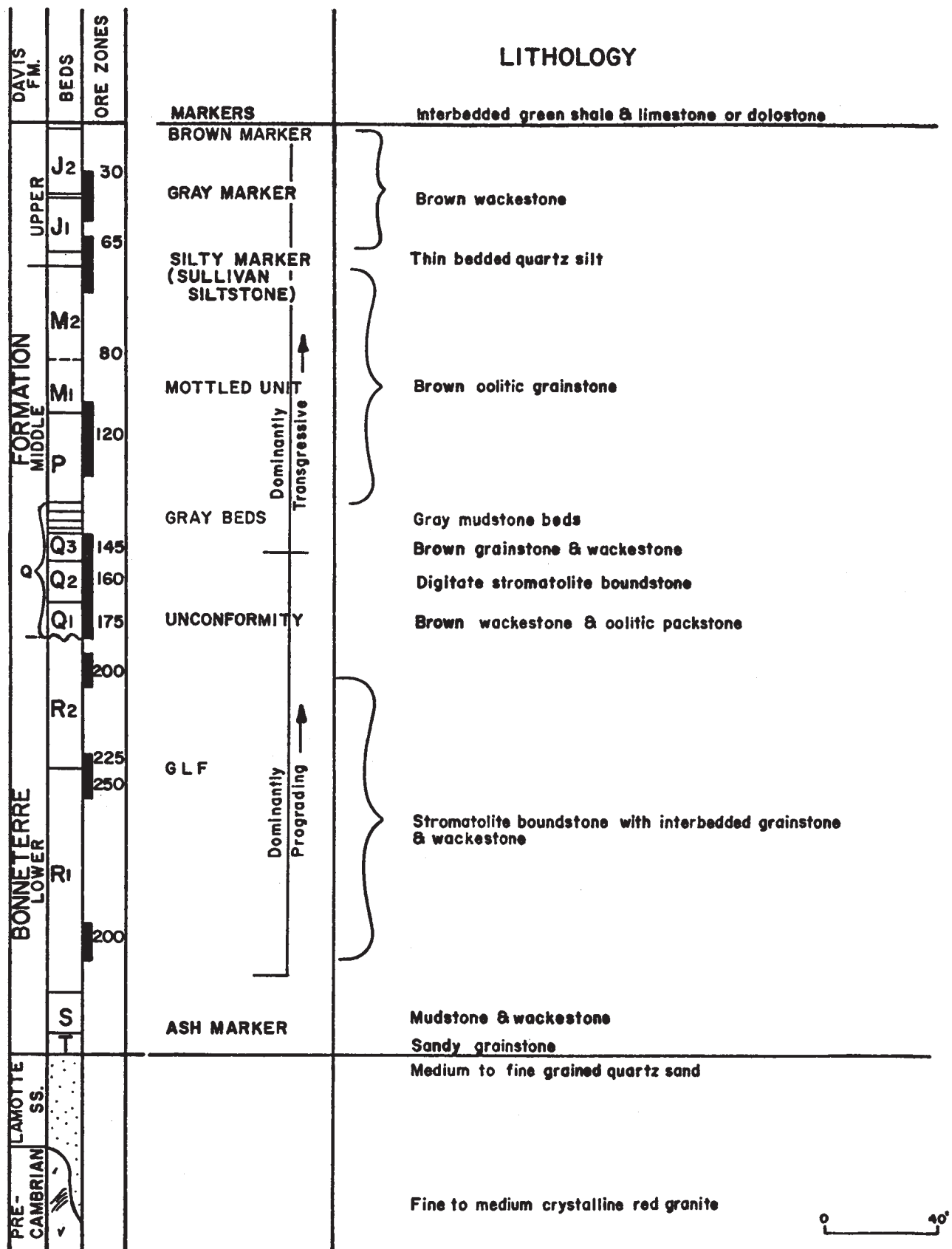


FIGURE 1 Stratigraphic Section

Larsen (1977) suggests that the facies patterns developed in a carbonate platform configuration on a sloping shelf in response to differential subsidence. The carbonate platform is defined by the planar stromatolite-burrowed lime mudstone facies. The digitate stromatolitic facies marks the platform margin. The oolitic facies formed on the slope into the intracratonic basin defined by the micrite and shale facies. Locally, oolitic and patch reefs formed where the basin was shoaled.

In the mine area, the oolitic and digitate stromatolite facies predominate, and stratigraphic relationships record a prograding sedimentary pattern during lower Bonneterre sedimentation (See Fig. 1). Along the eastern edges of the ore body, the planar stromatolitic-burrowed lime mudstone facies interfingers with the digitate facies due to this prograding relationship. Prograding relationships were culminated in the development of a pronounced unconformity on the top of the R2 bed (See Fig. 1).

When sedimentation was resumed, the digitate stromatolitic facies shifted 6000 feet to the east; but stromatolitic development ended after a brief period with the expansion of the oolitic facies eastward (See Fig. 1). The micrite and shale facies, which thickens to the west, was introduced over the mine area in a series of gray beds due to this transgressive sequence. Eastward transgression continued through the rest of middle and upper Bonneterre sedimentation.

STRUCTURAL MODEL

Interpretation of structural features has led to the development of a structural model and a hypothesis on the origin of the structures based on the interaction of initial gravity sliding, modification of these structures by mineralizing solutions and collapse, followed by response gravity sliding (Larsen and Clendenin, 1977).

GRAVITY SLIDING

Gravity movement appears to have developed off of any structural feature that would oversteepen the strata; and physically, gravity slide structures are not very different from those defined by Snyder and Odell (1958). However, interpretations differ in those slides do not appear to be syndepositional and are located in a different stratigraphic position.

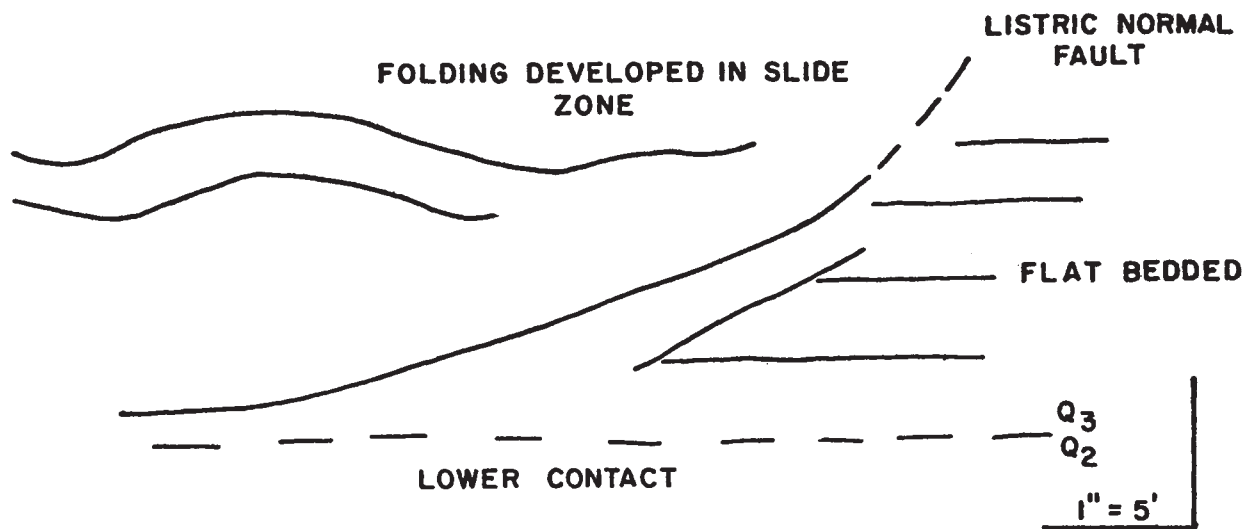


FIGURE 2 Listric Normal Fault

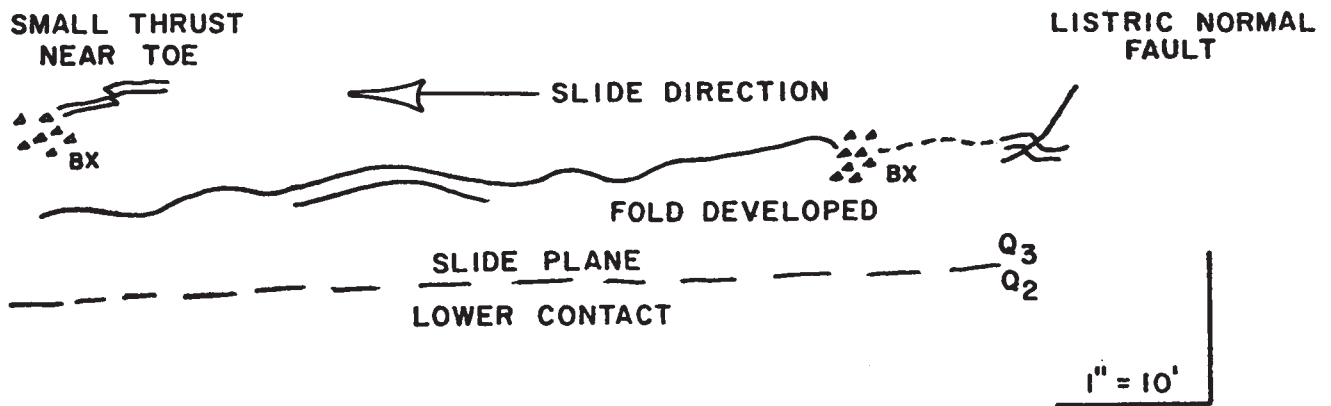


FIGURE 3 Gravity Slide Zone

Initial gravity sliding probably occurred after burial but prior to complete lithofication, In the eastern portion of the mine, multiple gravity slides developed above the R2 and Q2 boundstone contacts; in the west end, a more throughgoing slide appears to be associated with the R2 contact where Q2 boundstone is missing.

Slide zones are defined by an updip listric normal fault and a decollement slide (See Fig. 2). Structures developed by sliding are singular and multiple overthrusts, horizontal slickensides, rectilinear shears, folding, and a well defined toe structure with associated thrusting. The deformation of this zone tended to transport the upper plate downdip; and both deformation and transport helped prepare ground for later mineralizing solutions.

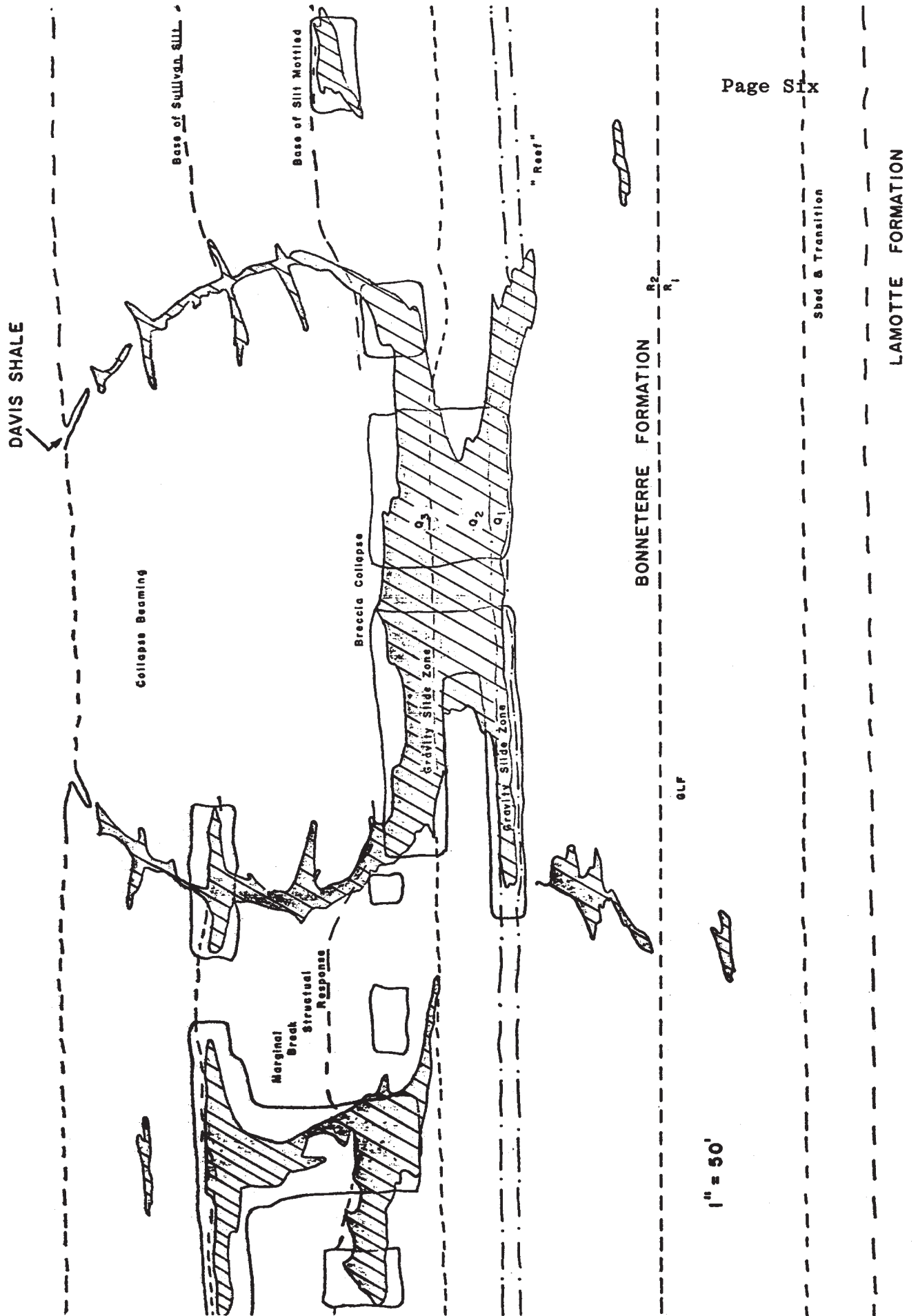
DEVELOPMENT OF THE BRECCIAS

The most pronounced slide zone in the east end of the mine is found above the Q2/Q3 contact (See Fig. 3). The cusp shape of the listric normal fault and the outward thrusting on the toe defines the bowl shaped bottom of the breccia bodies found in the middle Bonneterre (See Fig. 4). Solution collapse in this particular slide zone produced a variety of response structures in the upper Bonneterre. The overlying sediments tended to collapse beam over the solution collapse void producing the passive rolls along the edge of the breccia.

Solution collapse with associated upper Bonneterre beaming reinitiated gravity movement in the upper plate. The rock, having a propensity to move and a place to move to, detached and slid toward the breccia "hole". Detachment was achieved by listric normal faulting (See Fig. 4) and allowed the slide to move without updip retardation. Listric faults associated with initial gravity sliding can be differentiated from those formed due to response gravity sliding. Early listric faults have a deformed hanging wall while later response listric faults have pronounced reverse drag and deformation in the footwall.

Movement produced lateral stresses along bedding planes in the detached block which were deflected by the passive rolls. This deflected movement formed a series of stepping thrust faults that define the upper Bonneterre breccia body configurations (See Fig. 4). Davis shale has been mapped in wedge-shaped openings characteristic of these faults as much as a 120 feet down into the Bonneterre.

FIGURE 4 Generalized Cross Section



Solution activity in the footwall of the response listric normal fault caused minor solution collapse and let down. Once the footwall became unstable, subsequent gravity movement caused thrusting to occur. This movement in some cases offset the detachment fault plane in the upper Bonneterre.

MINERALIZATION MODEL

Field observations and studies of sulfur-lead isotopes indicate changes in the physiochemical parameters of the ore solutions with time (Clendenin, 1977; and Sverjensky et al, 1979). Changes produced different crystal forms for galena, dissolution of previously existing sulfides, and modified precipitation rates.

Changes in the solution can be traced through the Bonneterre. Over a period of time the various mineralizing solutions that entered Bonneterre appear to be less and less saturated with respect to the ore metals. Once inside the Bonneterre, solutions were controlled by the physical character of the rock. In the reef, the ore solution's surface area contact with the country rock was restricted to the various fracture zones. Heavy mineralization is found where the solution had the physical opportunity to spread laterally.

Field observations indicate the first opportunity to react with the rock produced an approximate 1:1 ore-rock replacement. Porosity and permeability is reduced by the plugging of pores with secondary cements (Wilson, 1977) and the precipitation of sulfides may have acted as a secondary cement. As the surface area contact of the initial lateral hosts was restricted, the entry of later undersaturated solutions were forced higher into the middle Bonneterre slide zones. These solutions having a propensity to react with the country rock, but undersaturated with respect to the metals, caused the solution collapse and dissolution of previously existing sulfides. Dissolution remobilization produced saturated hybrid solutions within the breccia bodies. Development of response listric normal faults in the upper plate released the hybrid solutions into the upper Bonneterre response gravity slide structures.

SWEETWATER FAULT ZONE

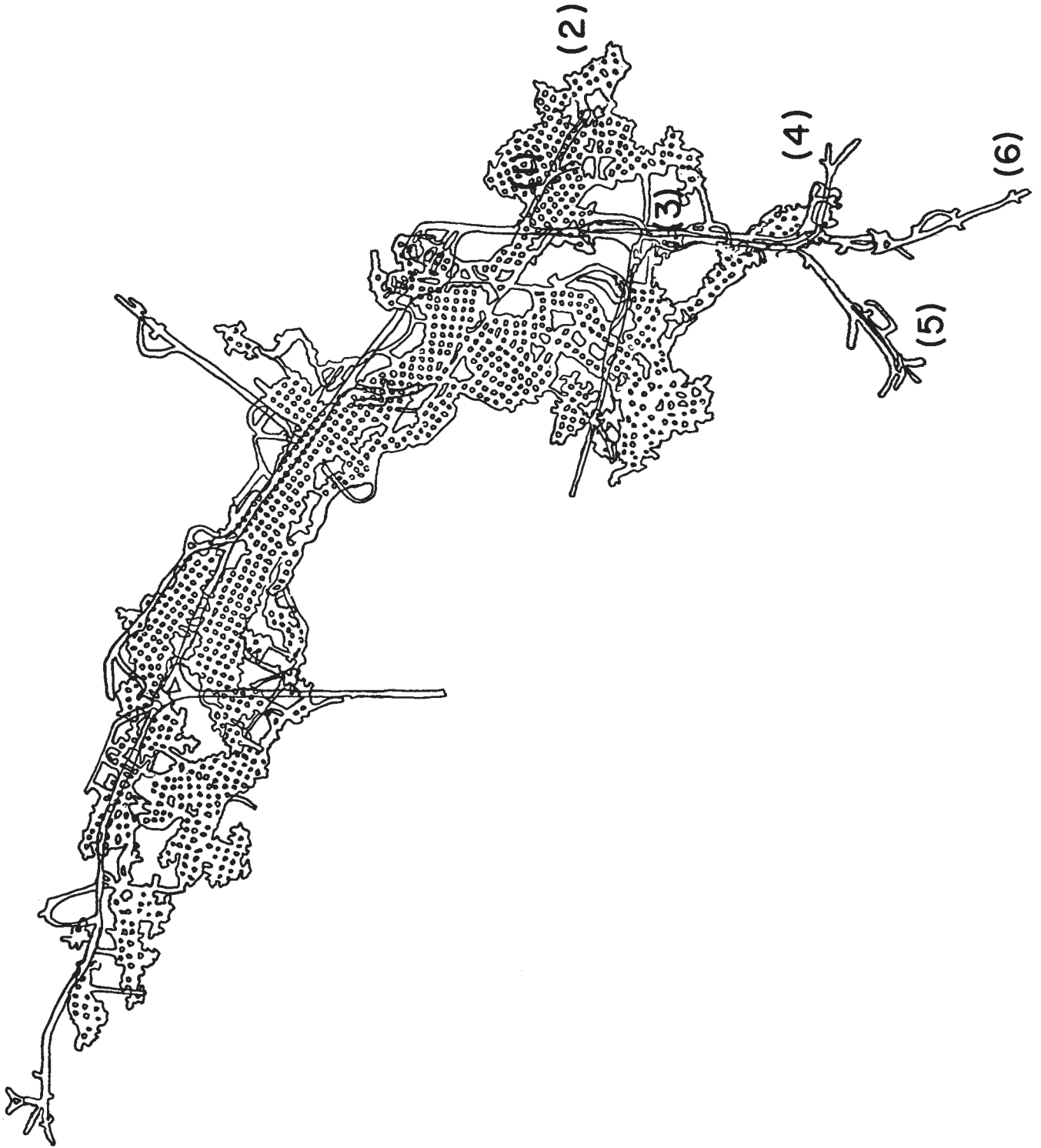
The Sweetwater Fault Zone was first recognized by Bear Creek explorationists in the early 1960's and has been actively studied by Ozark Lead staff geologists for the past two years. Two surface diamond drill hole fences have been drilled to define the fault zone; and like many other structures associated with the Ozark Dome, the zone has been found to be subtly complex. Outward configuration of the fault has been interpreted to be a drape fold fault.

Initial studies indicated a 100 foot reverse fault movement with a wedge of Lamotte Sandstone thrust up along the fault plane. Re-activated movement offset this plane and folding associated with these upthrusts tended to mask the earlier drape deformation of the Bonneterre. Flowage of the Bonneterre was achieved by fracture and brecciation in the fault zone.

Underground mapping indicates the fault zone is even more complex than initially anticipated. Rehealed fault gouge, which is easily recognized in the core, is almost undistinguishable from undeformed country rock. However, four periods of faulting have been recognized and these tend to offset each other. Of the various periods of faulting, the most difficult to recognize has been named lithologic faulting because different zones lie opposite across mere fractures with no gouge developed.

As underground workings approached the main fault zone, six feet of clay gouge was encountered with the Lamotte wedge centered in it. Preliminary studies of this zone indicate at least two periods of movement, and slickensides with a left lateral sense of movement have been mapped on the Lamotte wedge. Study of the fault continues at the present time.

Tour Stops and Explanations



STOP 1 A - AREA

This stop shows the east end stratigraphic relationships of the middle Bonneterre. The Q1/R2 contact, a significant unconformity, is exposed near the base of the pillar. The overlying stratigraphic sequence represents the initial stages of the transgressive sequence that predominated during middle and upper Bonneterre sedimentation. The Q2 boundstone is present and gravity sliding occurred on the R2 and Q2 contacts.

On the left rib a poorly developed listric normal fault is present. The strata is folded and brecciated in the hanging wall of this structure.

STOP 2 K - AREA

In this area, the unconformity at the base of the Q1 is well exposed. Humps and mounds of the underlying rock are bleached, indicating subaerial exposure.

In the Q1, the oolitic grainstone marker has been thrust over itself in a westerly direction. Slickensides at the Q1/R2 contact indicate movement along this plane.

STOP 3 1 SOUTH INCLINE

Exposed in the rib is a good example of the planar stromatolite subfacies of the planar stromatolite-burrowed lime mudstone facies. This rock interfingers with the digitate stromatolite facies and represent the prograding relationships during lower Bonneterre sedimentation.

STOP 4 F - AREA

The most pronounced gravity slide of the middle Bonneterre is exposed here at the base of the Q3. Small scale folds can be seen near the base of the breccia complex above the Q2 boundstone. Massive intergrown lead-zinc mineralization can be seen near this contact. Massive mineralization is representative of changes in the precipitation rates because euhedral crystals of galena and sphalerite can be found in fractures in the underlying Q2.

STOP 5 2 SOUTH INCLINE

A small scale listric normal fault is exposed in the rib above the Q1/R2 contact. The Q1 is nearly destroyed by rectilinear shears in the hanging wall of the fault. Behind the fault the ground is flat and not disturbed. Boundstone mounds appear to retard the development of these horizontal shears.

Up the drift a fault drops the P zone down equal to the Q2 (See Fig. 1). Past this fault a response listric normal fault is exposed in the rib. Pronounced reverse drag can be seen in the foot wall of this fault.

STOP 6 TUNNEL PROJECT (SWEETWATER FAULT ZONE)

Small scale faulting has been mapped almost the entire length of the decline. Earlier periods of faulting have been offset by splaying upthrusts that have a white clay gouge. These upthrusts can be traced to the main fault zone that contain the Lamotte wedge. Pronounced drape can be seen in the foot wall of this fault. Beds roll down at approximately 60°S and then flatten.

REFERENCES

- Clendenin, C. W., 1977; Suggestions for interpreting Viburnum Trend mineralization based on field studies at Ozark Lead Company, southeast Missouri: *Econ. Geol.*, v. 72, pp. 465-473
- Howe, W. R., Kurtz, V. E., and Anderson, K. H., 1972; Correlation of Cambrian strata of the Ozark and upper Mississippi Valley regions: *Missouri Geol. Survey Water Resources Rept. Inv. 52.*
- Kurtz, V. E., Thacker, J. L., Anderson, K. H., and Gerdemann, P. E., 1975, Traverse in Late Cambrian strata from St. Francois Mountains, Missouri to Delaware County, Oklahoma; *Missouri Geol. Survey Rept. Inv. 55*, 112p.
- Larsen, K. G., 1975, Stratigraphic and facies nomenclature of the Viburnum Trend, southeast Missouri; *Missouri Geol. Survey Rept. Inv. 58*, p. 15-19.
- _____, 1977; Sedimentology of the Bonneterre Formation, southeast Missouri; *Econ. Geol.*, v. 72, pp. 408-419.
- _____, and Clendenin, C. W., 1977; The development of breccia bodies in response to gravity sliding and solution activity (abs): *Geol. Soc. America Abstracts with Programs*, v.9, n.5, pp.619-620.
- Lyle, J. R., 1973; The facies geometry and carbonate petrology of the Bonneterre Formation in western Iron, northern Reynolds, and eastern Dent counties, Missouri: Unpub. Master's thesis, Univ. of Missouri - Columbia, 145p
- _____, 1977; Petrography and carbonate diagenesis of the Bonneterre Formation in the Viburnum Trend area, southeast Missouri: *Econ. Geol.*, vol. 72, pp. 420-434.
- Snyder, F. G., and Odell, J. W., 1958; Sedimentary breccias in southeast Missouri lead district: *Geol. Soc. America Bull.*, v.69, n.7, pp.899-926.
- Sverjensky, D. A., Rye, D. M., and Doe, B. R., 1979; The lead and sulfur isotopic compositions of galena from a Mississippi Valley-type deposit in the New Lead Belt, southeast Missouri: *Econ. Geol.*, v.74, pp.149-153.
- Wilson, H. H., 1977; "Frozen-in" hydrocarbon accumulations or diagenetic traps - exploration targets: *A.A.P.G. Bull.*, vol. 61, n.4, pp.483-491.