REPORT OF INVESTIGATIONS NUMBER 58

viburnum trend, missouri

guidebook

THE GEOLOGY AND ORE DEPOSITS OF SELECTED MINES

MISSOURI DEPARTMENT OF NATURAL RESOURCES Division of Research and Technical Information

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guidebook to

the geology and ore deposits of selected mines in the VIBURNUM TREND, MISSOURI

By Heyward M. Wharton, Kenneth G. Larsen, Peter H. Sweeney, Ed Harrison, Milton Bradley, James H. Davis, Robert K. Rogers, William J. Brown, Norman L. Paarlberg, Lanny L. Evans, M.M. Mouat and C.W. Clendenin Jr.

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C O N T E N T S

guidebook to

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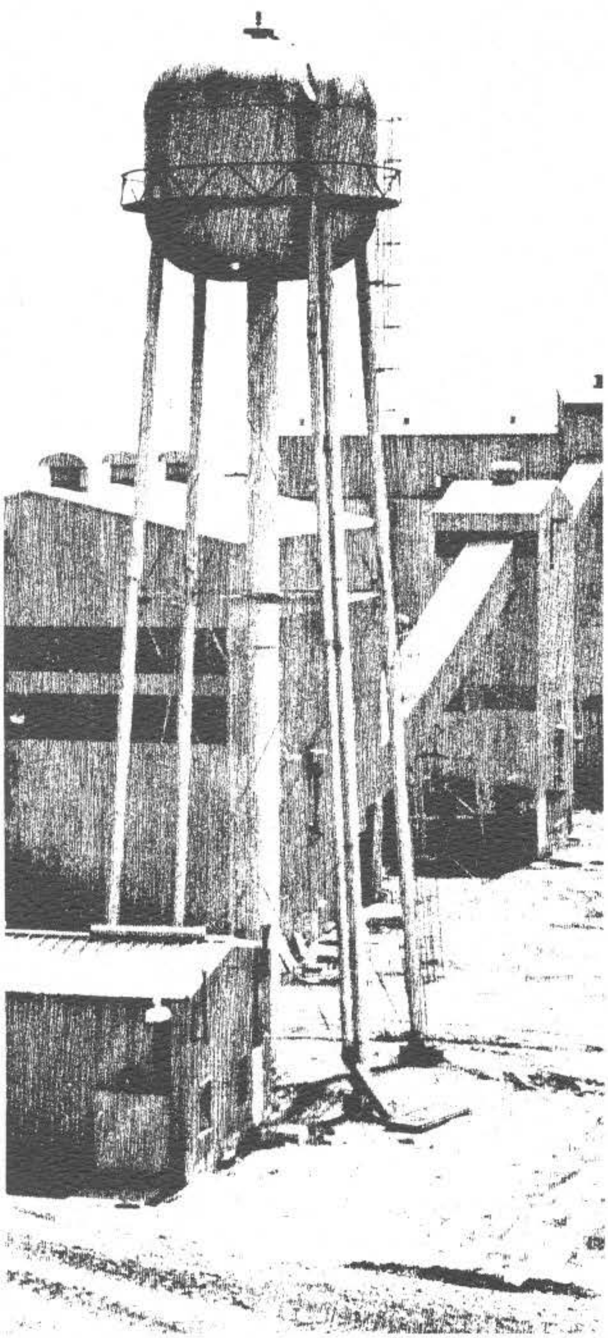
in the VIBURNUM TREND, MISSOURI



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 highly competitive nature of the exploration and development of the Viburnum Trend following its discovery in 1955 resulted in very little detailed geologic information being published. Because of its importance, the Missouri Geological Survey, the Society of Economic Geologists, and the companies with producing mines joined in a cooperative effort to present the first comprehensive review of the new subdistrict at the Symposium on the Geology and Ore Deposits of the Viburnum Trend, Missouri *held in Rolla, Mo. on October 17-18, 1975.*

The guidebook was prepared principally for the four mine tours offered in conjunction with the symposium papers. Mine tours and descriptions are given for the Magmont mine (Cominco American Inc. and Dresser Industries Inc.), the Buick mine (AMAX Inc. and Homestake Mining Co.), the Fletcher mine (St. Joe Minerals Corp.) and the Ozark Lead Company mine (Kennecott Copper Corp.).

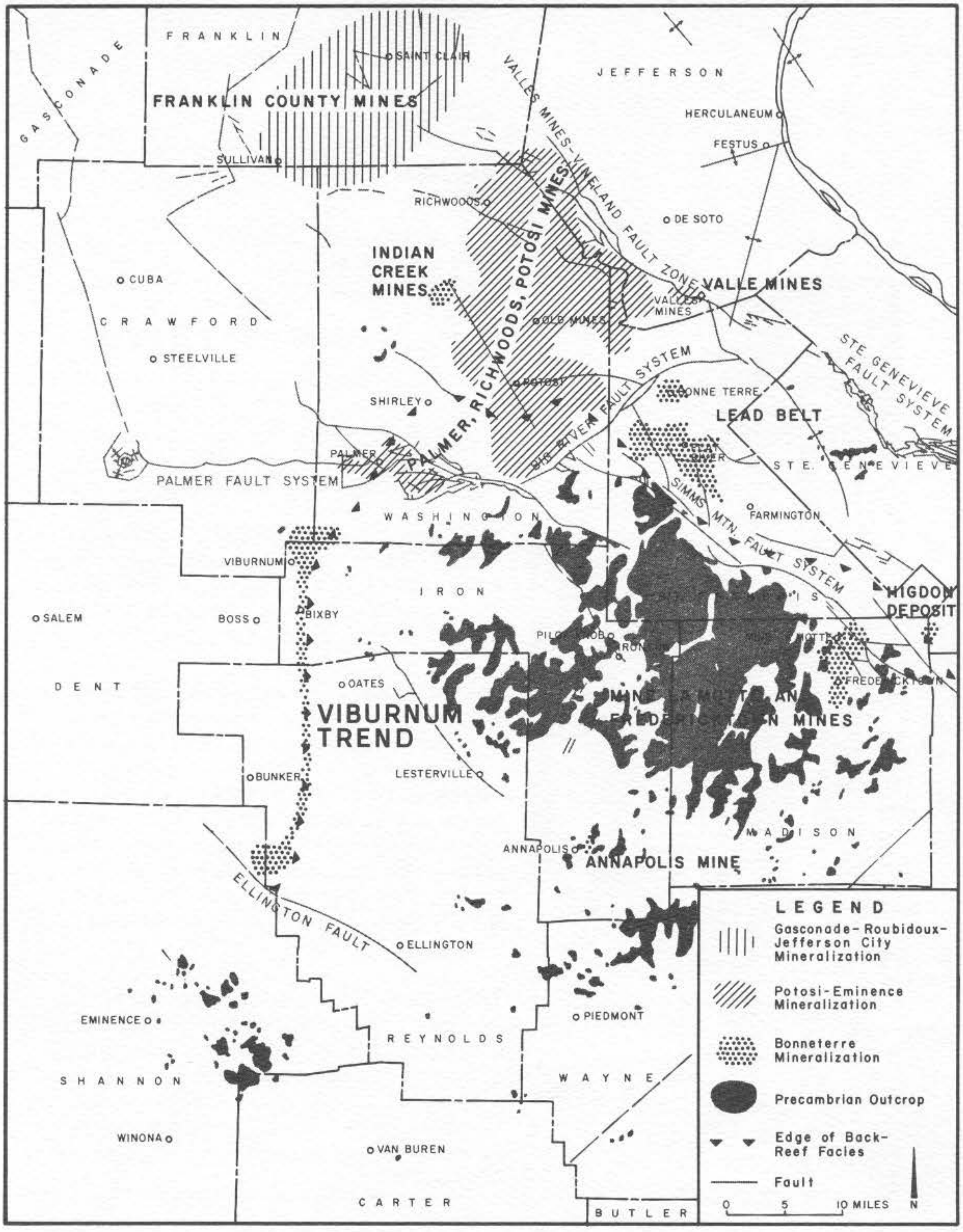


Figure 1

Map of Southeast Missouri Lead district.

INTRODUCTION TO THE SOUTHEAST MISSOURI LEAD DISTRICT

By Heyward M. Wharton, *Geologist*

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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

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 Bonneterre 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 has 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

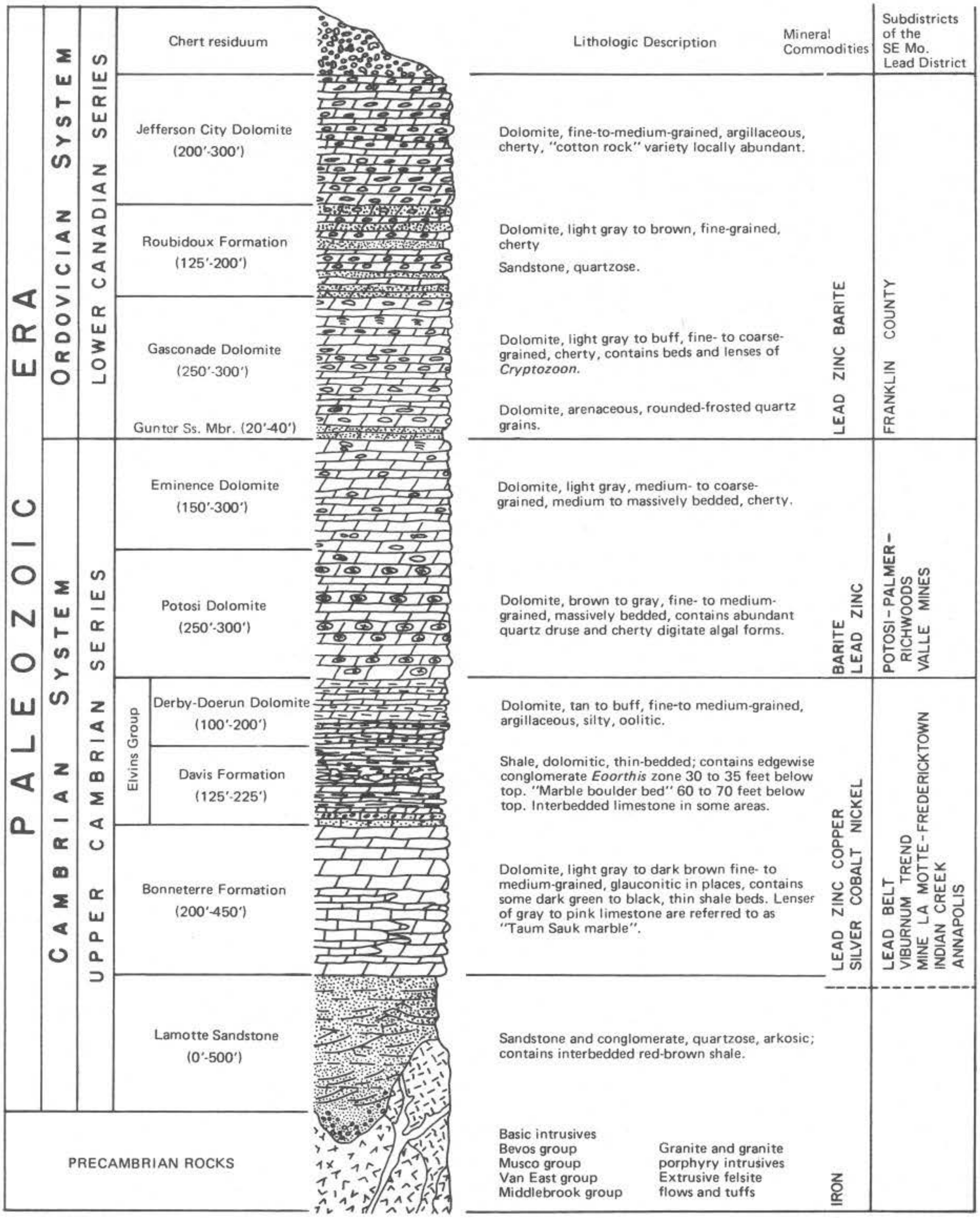


Figure 2

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.

ORE DEPOSITS

It was pointed out previously that there are several separate and distinct types of mineral deposits and mining areas in the Southeast Missouri Lead district (fig. 1). They will now be briefly described under headings of the host rock formations. Snyder and Gerdemann (1968, p. 333-343) present a more detailed review in the Graton-Sales Volume.

BONNETERRE MINERALIZATION

The largest and most productive lead-zinc deposits in the district are found in the Upper Cambrian Bonneterre Formation. The principal mining areas (in order of their discoveries) are: Mine La Motte-Fredericktown, Lead Belt, Annapolis, Indian Creek and Viburnum Trend. Proceeding counterclockwise from Fredericktown, there is a tendency for the mineralization to occur at progressively higher horizons in the Bonneterre. The deposits at Annapolis are anomalous in that they occur in coarsely-crystalline, back reef facies far removed from the barrier reef environment, and usually devoid of mineralization. No additional descriptions of the Annapolis mine will be given. The Indian Creek mines are likewise unusual in being some distance off shore of the main barrier reef zone of the Bonneterre (fig. 1).

In the Mine La Motte-Fredericktown area, the mineralization usually occurs on the flanks of buried Precambrian knobs near pinchouts of the Lamotte Sandstone. James (1949) cites this as evidence that the porous and permeable sandstone may have acted as a "feeder" for the ore-forming solutions. Ore also occurs in the basins related to faulting. The sandy transition zone at the base of the Bonneterre is particularly favorable for the ore deposits which contain zones rich in copper, nickel and cobalt in some of the mines. Last production in this area was from the Madison mine of National Lead Co., shut down in 1961. The Higdon mine, reported to be similar to the others in this area, was under development between 1965 and 1967, but work was stopped after two drilled shafts were completed. Production can be expected at some time in the future.

The Lead Belt or "Old" Lead Belt includes the Bonne Terre mines and the large group of mines to the south, centered around Flat River. These mines have yielded by far the largest tonnages of lead in the district to date, but the total output will probably be surpassed in time by the modern, large-scale Viburnum Trend mines to the west. As pointed out by Snyder and Gerdemann (1968, p. 335), the Lead Belt ore bodies occur in a barrier reef environment and are closely related to a variety of primary and secondary sedimentary features. Faulting and fracturing also appear to influence ore deposition. The lower and middle sections of the Bonneterre are the preferred ore horizons but, in places, mineralization extends a considerable distance downward into the Lamotte Sandstone and upward to the top of the Bonneterre. Mineralized granite boulder beds at and near the base of the Bonneterre were mined at Hayden Creek near Leadwood. Mine production in the Lead Belt was suspended by St. Joe in 1972. It would not be surprising to see a resumption of mining there under changed economic conditions.

St. Joe's Indian Creek Division includes two separate mines. The ore bodies at the Indian Creek mine are within and adjacent to an algal reef in the Bonneterre that developed on the western flanks of a northeast-trending, Precambrian basement ridge. Mineralization in the nearby Goose Creek mine is mostly in the Lamotte Sandstone, but is also in lower Bonneterre beds. The ore occurrences are unusual in being nearly 10 miles north of the main barrier reef zone in the

COMPARATIVE SUMMARY OF MINE PRODUCTION

Estimates of mineral production from the main mining areas in the Southeast Missouri Lead district are given in the following tables (Sources: St. Joe Minerals Corp., publ. repts. and pers. comm.; State Mine Inspector Annual reports; U.S. Bureau of Mines data; and Winslow, 1894.):

Table 1

Bonneterre Mineralization

Subdistrict Mines	Period of Activity	Lead Production (tons contained metal)	*Important Co-products
Lead Belt	1865-1972	8,509,000	Zn, Cu, Ag
Viburnum Trend	**1960-1974	3,007,700	Zn, Cu, Ag
Mine La Motte-Fredericktown	1723-1961	575,000 ±	Zn, Cu, Ag, Co & Ni
Indian Creek	**1953-1974	266,000	Zn, Cu, Ag
Annapolis	1915-1931	29,000	none
	Total:	12,386,700	

Table 2

Potosi-Eminence Mineralization

Subdistrict Mines	Period of Activity	Lead-Zinc-Barite Production	Important Co-products
Potosi-Palmer-Richwoods	1725-1947 **1860-1974	Lead (metal): est. 150,000 tons Barite : 11,824,000 tons	Zinc Lead
Valle Mines	1824-1949 1870-1949 1898-1949+	Lead (metal): 30,000 tons Zinc (metal): 54,000 tons Barite : 3,200+ tons	Barite Barite
	Totals:	Lead : 180,000 tons Zinc : 54,000 tons Barite : 11,828,000 tons	

Table 3

Gasconade-Roubidoux-Jefferson City Mineralization

	Period of Activity	Lead Production (tons contained metal)	Important Co-products
Franklin County	1830-1900	30,000 ± tons	Zn, Barite

*Sulfuric acid and cadmium are recovered at some of the lead and zinc smelters.

**Currently active.

Bonneterre. Lead, copper and silver are now being recovered. Mining has been in progress since the end of 1953 and zinc concentrates were produced until 1971.

The Viburnum Trend ore bodies are mostly confined to the barrier reef-like zone in the Bonneterre which seems to narrow as it swings south about 12 miles west of the St. Francois Mountains. Mineralization is usually found in upper sections of the formation, in the dolomitic calcarenite zone above the reefs and below the Sullivan Siltstone, but there are some important exceptions. West of the reefs, the Bonneterre changes from dolomite to limestone. The mineralized section of the Viburnum Trend is about 45 miles long. Several different types of ore bodies have been identified in the mines. Some of them are described in the symposium papers and in this guidebook. There will be an opportunity to see examples firsthand in the mine tours. The most spectacular occurrences are narrow, sinuous, solution-collapse structures that are traceable for miles along the strike of the Viburnum Trend. They have in turn been mineralized and often contain very high grade lead-zinc ores.

POTOSI-EMINENCE MINERALIZATION

Mineralized horizons in the upper Potosi and lower Eminence Dolomites are the source of the lead-zinc-barite ores in the Potosi-Palmer-Richwoods and Valle Mines subdistricts (figs. 1 and 2). Most of the early mining in Washington County was from surface diggings in ore-bearing residual clays derived from weathering and solution of these horizons. Galena and barite almost always occur together and are usually found in coarsely crystalline aggregates, so hand sorting and cleaning were easily done. Shafts in the residuum were sometimes deepened to mine galena and sphalerite in clay-filled openings and veins in the bedrock. Mining at Palmer occurred later and involved more underground workings. The early lead diggings in the surface clays were mined again for barite using small circular shafts. Barite strip mining of the old hand diggings began in the mid-1920's, and continues to date. Mineralization is very widespread in the county, which is suggested in figure 1.

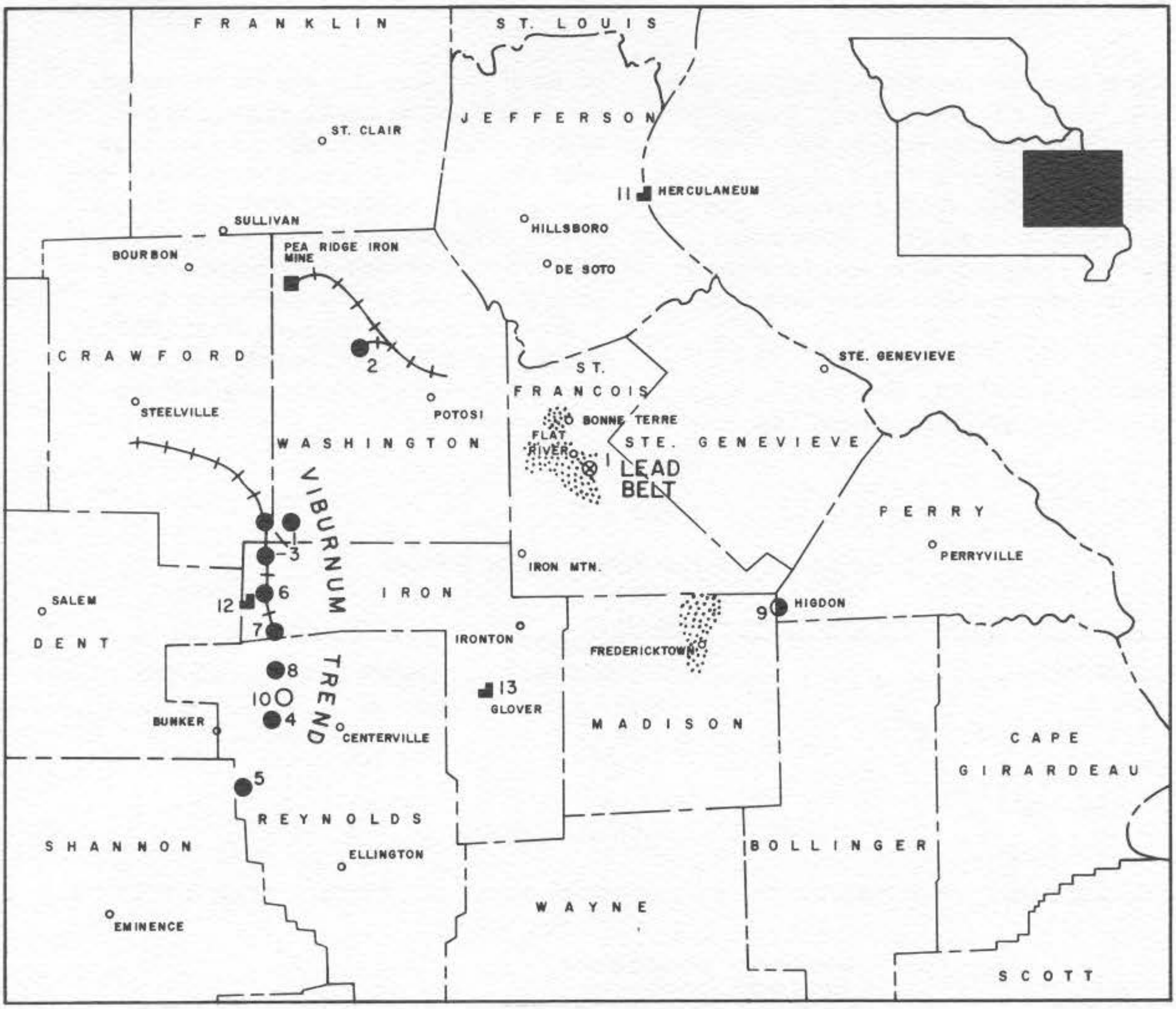
The Valle Mines deposits were less widespread and had to be mined mostly by underground methods. Zinc was abundant, mostly in the oxidized form of smithsonite. Maps and descriptions given in reports of the Missouri Geological Survey indicate that the ore occurred in preferred horizons in the dolomites, usually in open joint systems filled with clay and rubble.

GASCONADE-ROUBIDOUX-JEFFERSON CITY MINERALIZATION

The large cluster of small mines along the Meramec River between Sullivan and Moselle were referred to by Winslow (1894) as the Franklin County subdistrict (fig. 1). The Virginia, Mt. Hope, Short Lode and Cove mines were the best known. The lead-zinc-barite deposits occur in Lower Ordovician (Canadian) rocks, the youngest in the Southeast Missouri Lead district that contain significant mineralization. The deposits are mostly narrow, nearly vertical veins and fractures filled with barite, and including streaks and patches of galena and sphalerite. Most of the lead and zinc production was from mineralization in the Gasconade Dolomite. The size and grade of the deposits were notably inferior to those in the Cambrian formations previously described, and output was negligible after 1900.

PRODUCTION FACILITIES

Lead mine, mill and smelter locations in the Southeast Missouri Lead district are shown in figure 3 and ownership is indicated in the legend. St. Joe Minerals operates three mine-mill divisions along the Viburnum Trend as well as the Indian Creek division some distance north. The 26-mile Missouri Pacific Railroad spur line to the Pea Ridge iron mine, completed in 1960, also serves Indian Creek. The 32-mile "Lead Belt Line" from



LEAD – ZINC – COPPER

1	⊗	Federal Division Mines and Mill	St. Joe Minerals Corporation
2	●	Indian Creek Division Mines and Mill	
3	●	Viburnum Division Mines and Mill	
4	●	Fletcher Division Mine and Mill	
8	●	Brushy Creek Division Mine and Mill	
5	●	Sweetwater Mine and Mill – Ozark Lead Co., Subsidiary of Kennecott Copper Corp.	
6	●	Magmont Mine and Mill – Cominco American Inc. and Dresser Industries Inc.	
7	●	Buick Mine and Mill – AMAX-Homestake: AMAX Lead Co. of Missouri and AMAX-Homestake Missouri Lead Complex.	
9	◑	Higdon Mine – The Bunker Hill Co. and N L Industries, Inc.	
10	○	West Fork Deposit – American Smelting and Refining Co. (Asarco)	

LEGEND

- ⊗ Past Producer
- ● Now Operating
- ◑ Partly Developed
- ○ Undeveloped Deposits
- ┼┼ New Railroad Spurs

LEAD SMELTERS

11	▟	St. Joe Minerals Corp., Herculaneum Division Plant
12	▟	AMAX-Homestake Buick Smelter
13	▟	Asarco, Glover Plant

Figure 3

Major lead deposits and operations in southeast Missouri.

Keysville to Buick, completed in July 1967, was built by the St. Louis-San Francisco "Frisco" Railway Company. Ore concentrates from St. Joe's Brushy Creek and Fletcher operations are trucked to the Buick railhead. Ozark Lead Co. concentrates are trucked to a Missouri Pacific transfer point at Glover in Iron County. This is the site of the American Smelting & Refining Co.'s smelter which processes the lead concentrates.

The headquarters of AMAX Lead & Zinc, Inc. were moved from New York City to Clayton, Missouri in the fall of 1972, soon after the company had purchased the American Zinc Co. zinc smelter and refinery in Sauget, Illinois (east St. Louis area). A rehabilitation and improvement program was undertaken at a cost exceeding $16 million. Smelter and refinery operations were resumed in May 1973. By 1976, the plant is expected to reach its design capacity of 84,000 tpy of special high-grade zinc, 1.35 million pounds of cadmium, and 150,000 tons of sulfuric acid. The plant processes zinc concentrates from the company's Buick mine and the neighboring Magmont mine.

TABLE 4

Design Capacities of Lead Mines, Mills and Smelters
Southeast Missouri
1974 - 1975

Lead Smelters	Annual Capacity (short tons of lead)	Start-Up	County
St. Joe Herculaneum (Modernization and Expansion)	230,000 +	Early 1967	Jefferson
Asarco Glover	110,000 +	7-1968	Iron
AMAX-Homestake Buick	120,000 +	8-1968	Iron
	460,000 + tpy Pig Lead		

Mines and Mills	Daily Capacity (crude ore) tons per day	Annual Capacity (short tons of recoverable lead)	Start-Up Date	County
St. Joe Minerals Corp.				
*Federal		——	Shutdown 10-1-1972	St. Francois
Indian Creek	2500	12,000 +	1953 & 1968	Washington
Viburnum	7500	70,000 +	1960 - 1964	Crawford, Iron Washington
Fletcher	5000	80,000 +	2-1967	Reynolds
Brushy Creek	5000	50,000 +	11-1973	Reynolds
Subtotals:	(20,000 tpd)	(212,000 + tpy) (240,000 + tpy potential)		
Ozark Lead Co.	6000	60,000 +	6-1968	Reynolds
Magmont	4200	60,000 +	7-1968	Iron
Buick	6000	80,000 +	2-1969	Iron
Subtotals:	(16,200 tpd)	(200,000 + tpy) (275,000 + tpy potential)		
Total District Mine-Mill Production Capacity	36,200 tpd	412,000 + tpy (515,000 + tpy potential)		

***St. Joe began mining in the Old Lead Belt in 1864 and operated continuously during the next 108 years until October 1972. The company's Southeast Missouri Mining & Milling Division headquarters in Bonne Terre will be shifted to Viburnum by 1976.**

All the Viburnum Trend mines are underground operations and use the room-and-pillar method of mining. The regional dip of the sedimentary formations away from the St. Francois Mountains is responsible for the increasing depths to the ore horizons in the Bonneterre from north to south. At St. Joe's Viburnum division, the production shafts range between 600 and 910 feet deep. Production shafts at all the St. Joe mines now in operation in Missouri are circular and are 12½ feet in diameter. At the Ozark Lead Co. and Fletcher mines the main shafts are 1,300 to 1,450 feet deep. All of the newest mines have primary crushers at the mining levels. Trackless haulage is employed in the St. Joe and Magmont mines. AMAX and Ozark Lead use sublevel rail systems for part of their haulage. The production and service shafts at the Buick mine are 18 feet in diameter while the main shafts at the Magmont and Ozark Lead Co. mines are 19 and 20 feet in diameter, respectively.

The three St. Joe mills on the Viburnum Trend and the Magmont mill each make three products: galena, sphalerite and chalcopyrite concentrates. The AMAX-Homestake and Ozark Lead Co. mills produce only two: lead-copper and zinc concentrates. Sphalerite and chalcopyrite have much higher silver contents than galena. During 1974, the mines in the Southeast Missouri Lead district produced about 9,110,000 tons of ore. Calculated average ore grades were about 6 percent lead, 1 percent zinc and 0.14 percent copper, so metal ratios were about 45 to 7 to 1.

Design capacities of the mine, mill and smelter facilities in Missouri are given in table 4. Capital investment in the new facilities was in excess of $180 million. Employment is around 3,000 and the annual payroll is about $41 million. State and federal taxes and royalties amount to over $12 million each year. The lead, zinc, copper and silver contained in the ores and concentrates produced in the Viburnum Trend and Indian Creek mines during 1974, had the values shown in table 5, based on figures published by the U.S. Bureau of Mines. The $349.8 million value is over half of Missouri's total mineral production value of about $667.4 million for 1974. There are, in addition, large amounts of sulfuric acid and cadmium recovered at smelters.

Table 5

Annual Mine Production and Value of Metals in Missouri
(recoverable metal content of ores and concentrates)

Metal	1973 Amount	1974 Amount	1974 Value	Percent of U.S. Mine Output
Lead	487,143 short tons	562,097 short tons	$252,943,719	84.7%
Zinc	82,350 short tons	91,987 short tons	66,046,802	18.4%
Copper	10,273 short tons	12,665 short tons	19,579,823	0.8%
Silver	2,057,732 troy ounces	2,387,250 troy ounces	11,243,949	7.0%
			Total $349,814,293	

The importance of the Viburnum Trend to Missouri and the nation are clearly documented by the production statistics. In the context of the long and illustrious lead-mining history in the Southeast Missouri Lead district, it is tempting to ignore the fact that there are finite limits to the ore reserves. At the present rate of production, over a million tons of recoverable lead and 180,000 tons of recoverable zinc are being mined every two years. Concern must certainly be felt about the longevity of the new mining area under this kind of pressure.

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STRATIGRAPHIC AND FACIES NOMENCLATURE OF THE VIBURNUM TREND, SOUTHEAST MISSOURI

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INTRODUCTION

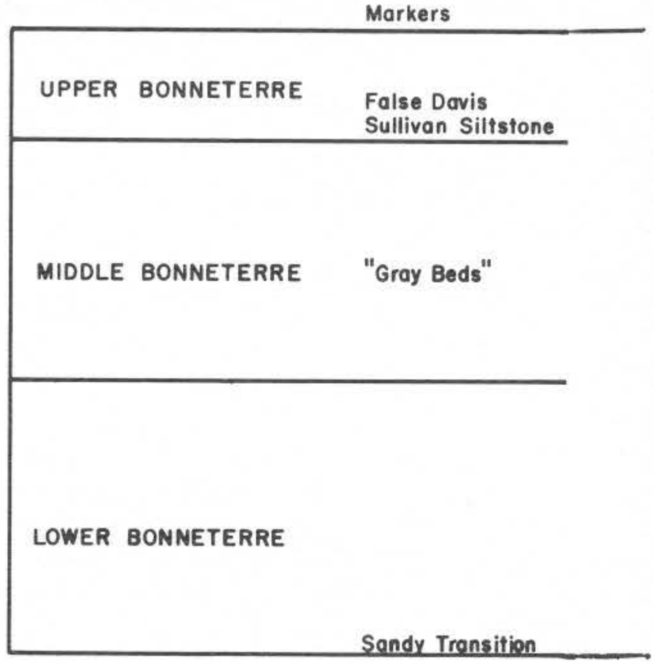
The Upper Cambrian Bonneterre, the host formation of the major lead deposits of Southeast Missouri, has been actively studied in and around the Old Lead Belt (Ohle and Brown, 1954; Snyder and Odell, 1958; Snyder and Gerdemann, 1968). The apparent close association of ore with stratigraphic traps, structural 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 depositional 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-



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

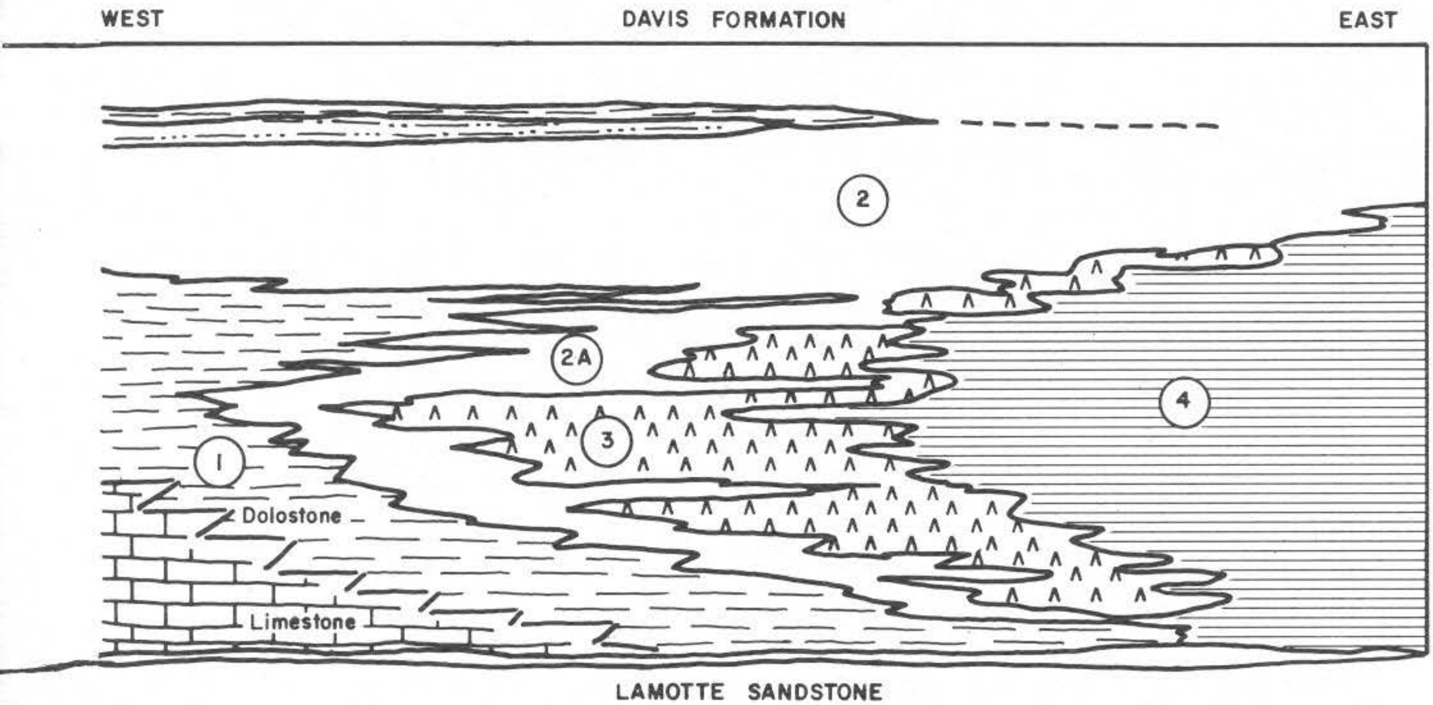


Figure 1

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

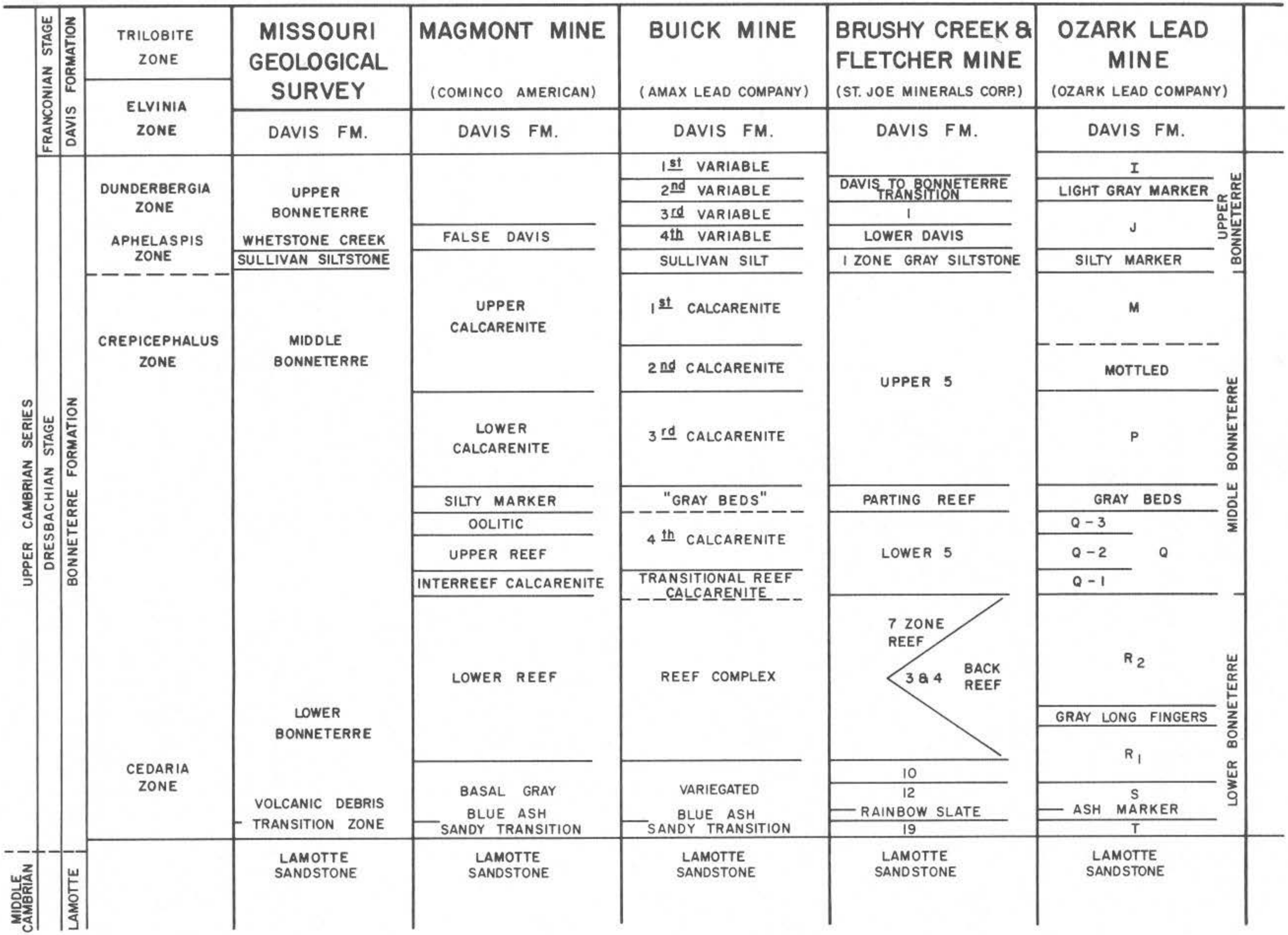


Figure 2

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 Bonneterre, as well as the trilobite zonation, are also shown for reference.

Agreement as to the Lamotte-Bonneterre contact appears to be generally consistent, but differences in the definition of the Bonneterre-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 Bonneterre 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.

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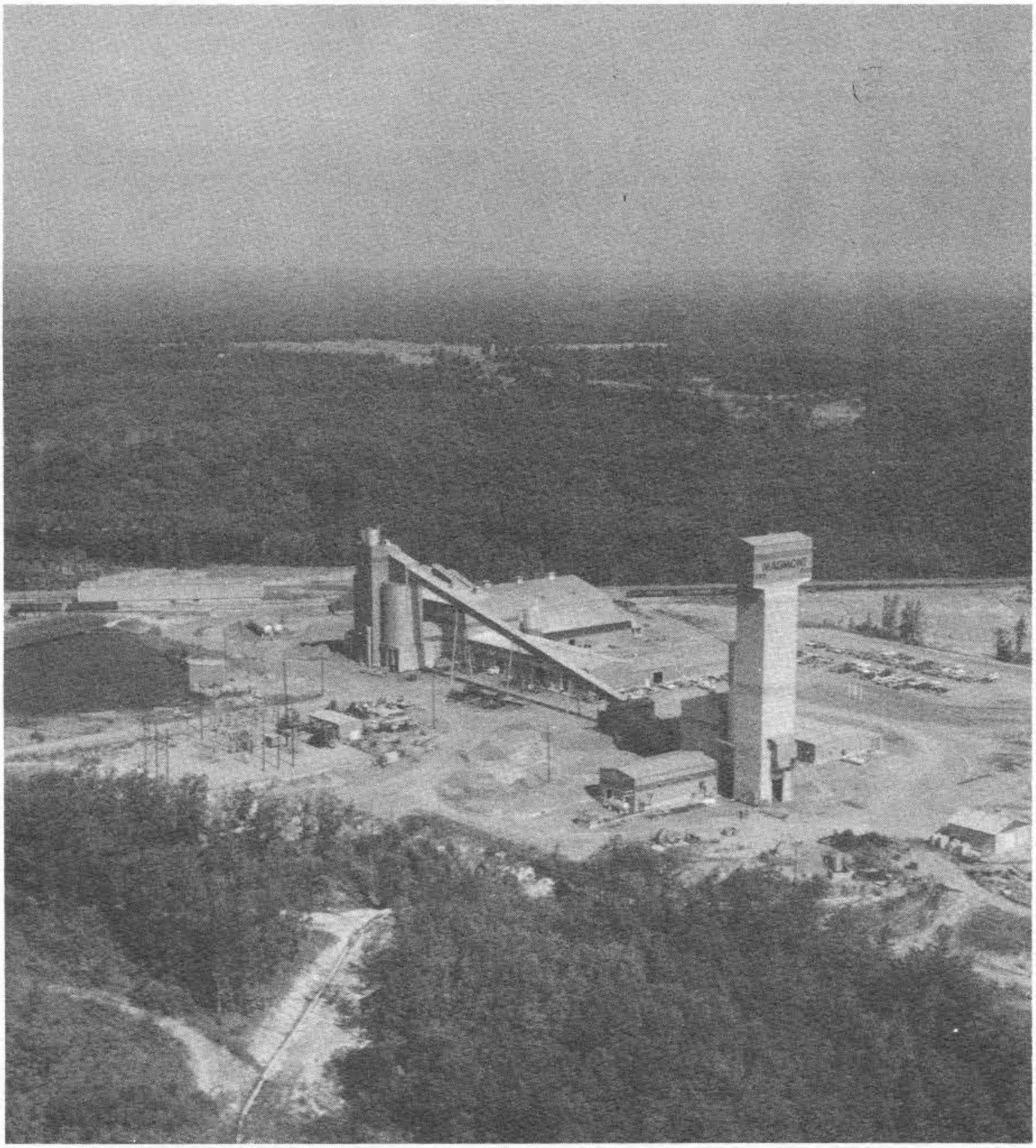


MAGMONT MINE

(Cominco American Inc. & Dresser Industries Inc.)

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

By Peter H. Sweeney
Ed Harrison
Milton Bradley
Mine Geologists
Magmont Mine, Bixby, MO 65439

INTRODUCTION

The first discovery of a lead deposit in the Viburnum Trend was made 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. 34 N., R. 2 W. 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 smelter located ¼ mile southwest of the mine. Zinc concentrate goes to the AMAX electrolytic zinc plant at Sauget, Illinois, 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 Formation averages about 285 feet in the Magmont mine area.

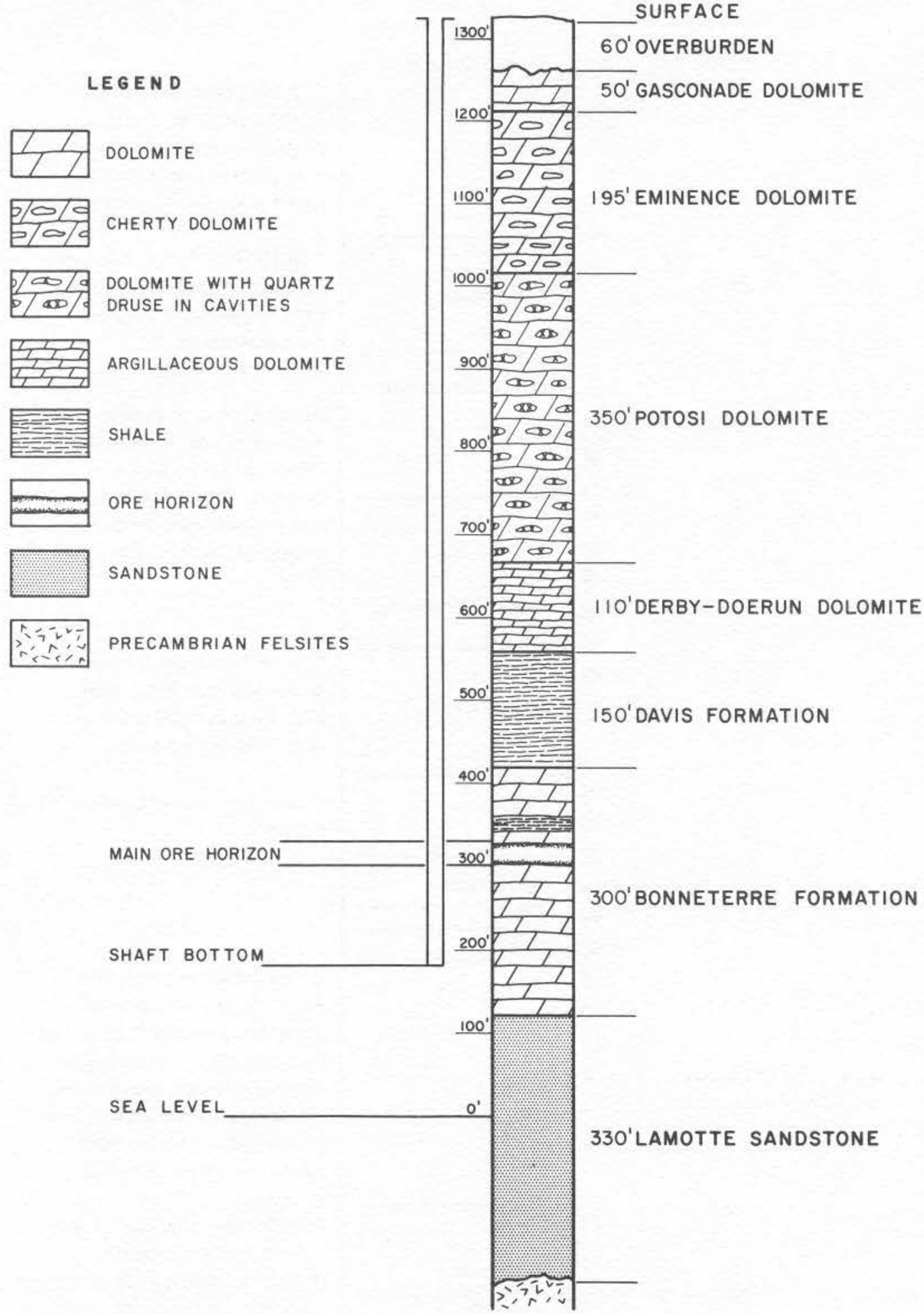


Figure 1

Typical stratigraphic section, Magmont mine.

Formation	Unit	Description
	Davis Formation	Grayish brown, medium to finely crystalline, moderately porous dolomite. Small dolomite pebbles and thin shale partings are characteristic.
BONNETERRE FORMATION	False Davis	8 to 10 feet of grayish-brown, medium crystalline dolomite with 30 percent gray-green shale interbands.
	Upper Calcarenite Lower 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.
	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 Interreef Calcarenite Lower 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.
	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 penecontemporaneous 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 interbedded 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 area of induced open space. Ore thickness within this area is commonly about 35 feet.

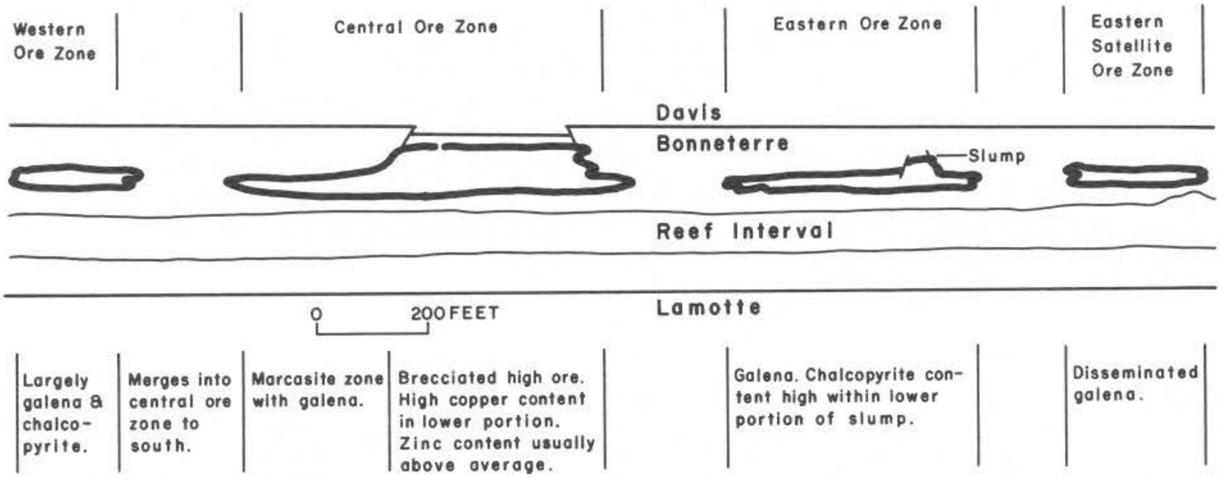


Figure 3

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).

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 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 these horizons within the Magmont mine is known mostly by drilling. Initial efforts to mine "C" horizon ore have been disappointing due to the low tenor and irregular distribution of mineralization. To date mineable ore at this 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 cannot be traced into 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

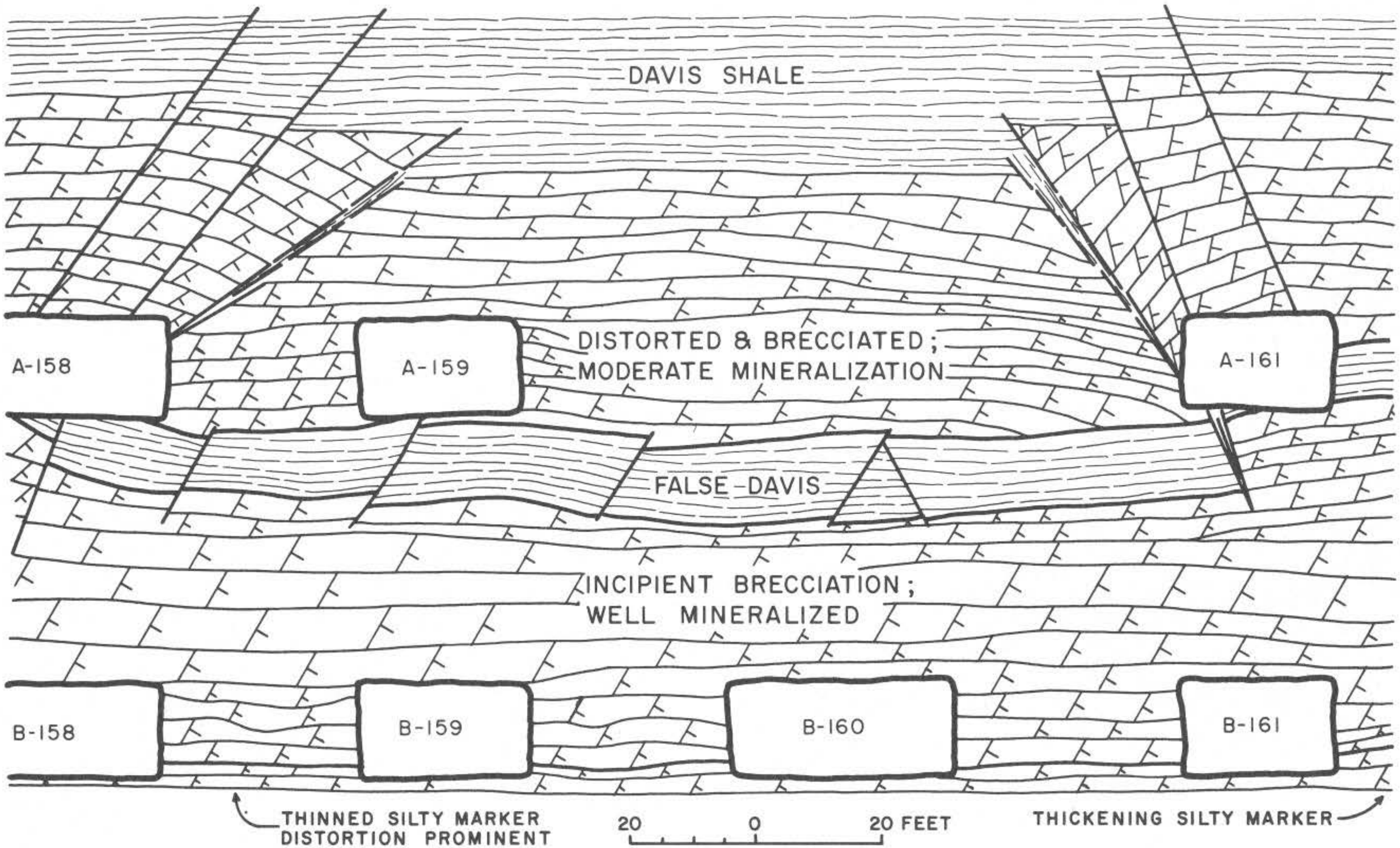


Figure 4

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

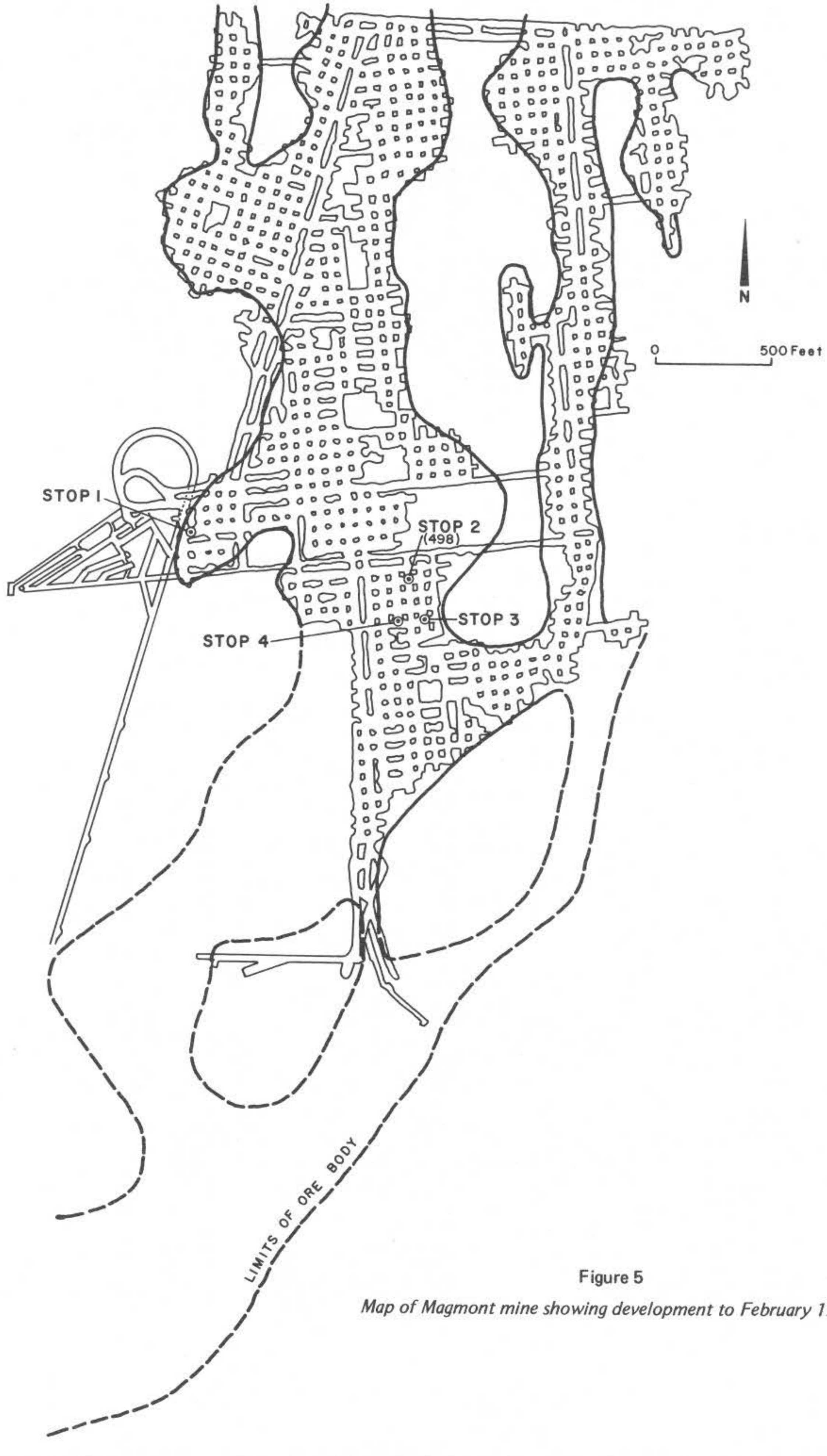


Figure 5

Map of Magmont mine showing development to February 1975.

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

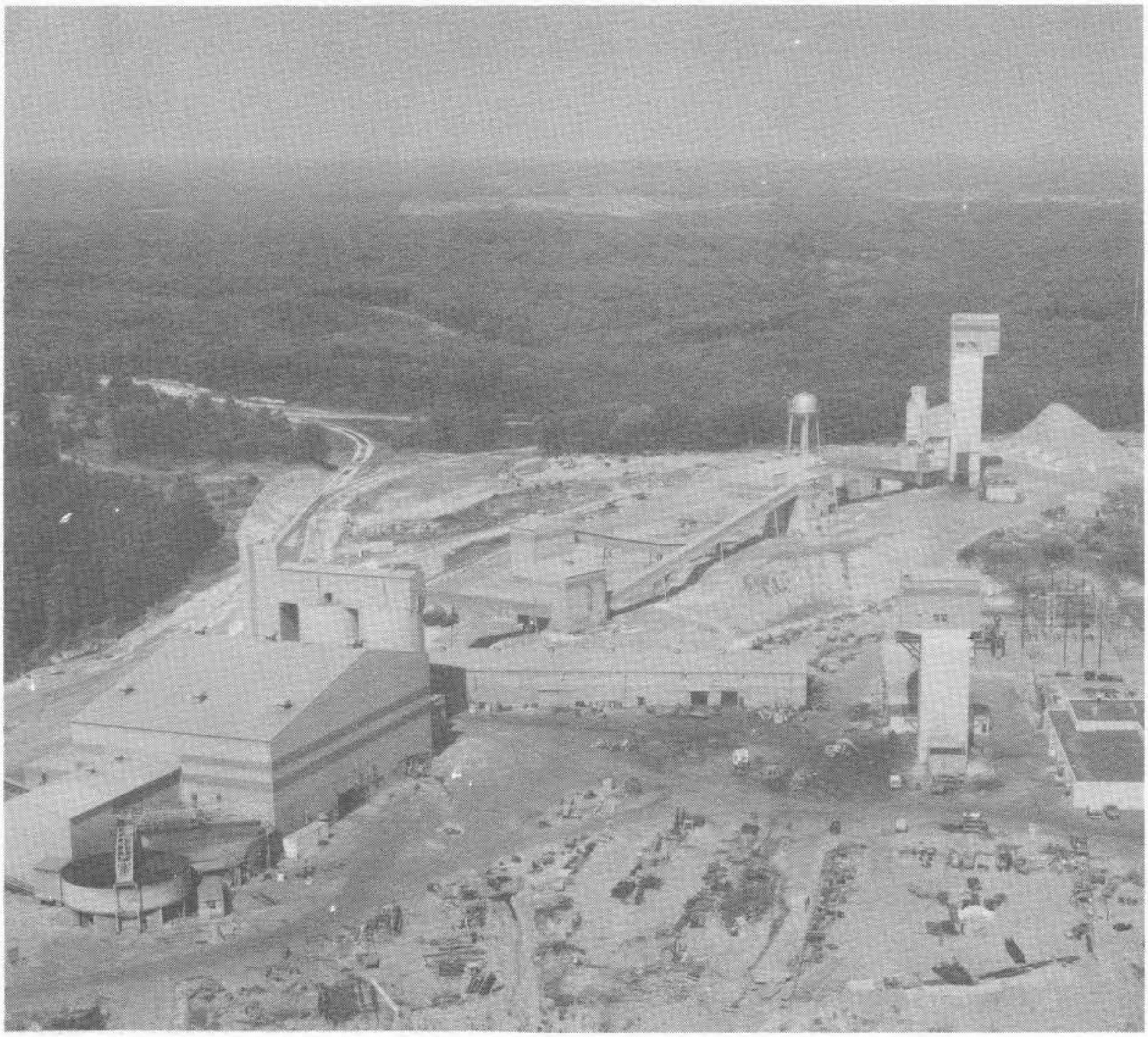
The tour of the Magmont mine may be revised as conditions warrant (fig. 5).

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.



BUICK MINE

(AMAX Inc. & Homestake Mining Co.)

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

By James H. Davis, *Chief Geologist*
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INTRODUCTION

The Buick mine, a 50-50 joint venture of AMAX, Inc. and Homestake Mining Company, is operated by AMAX. The ore body was discovered in 1960 and the mine was put into production in 1969. More than 7.5 million tons of ore, averaging about 9 percent lead and 3½ percent zinc, were mined during the first 6 years (to March 1975). In both 1973 and 1974 Buick accounted for 28 percent of the lead and 12 percent of the zinc mined in the United States. Ore grade was originally underestimated because small amounts of galena were lost by "grinding" during core drilling. An effective grade control program, developed and operated with full participation of the mine geology staff, also contributes significantly to the high mill feed grades. Ore reserves are estimated to be about 50 million tons, at approximately 8 percent lead and 2 percent zinc.

GEOLOGIC SETTING

Most of the ore occurs in solution-induced collapse breccias in the upper 130 feet of the Bonneterre Formation (which is 305 feet thick in the mine area). The lower two-thirds of the Bonneterre comprises three major facies, which are (from west to east):

a) the fore-reef, b) the reef and c) the back reef, sometimes called the "white rock" zone. The upper third of the Bonneterre is shelf facies (Lyle, 1973; Gerdemann and Myers, 1972).

The reef facies consists of 40 to 140 feet of digitate algal stromatolite interbedded with oolite and burrowed and mottled calcarenite. It wedges out 1½ miles west of the ore bodies. A few bleached horizons suggest periods of exposure to wave base or complete emergence. Thin rubble zones on top of the reef are locally ore-bearing.

The fore-reef facies, which is 200 feet thick west of the reef, is laterally equivalent to the prograding phase of reef development and underlies the reef in the vertical section of the mine. It is thinly bedded, poorly sorted calcarenite, with shaly partings.

A tongue of limestone, as much as 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. It thickens westward, crossing facies boundaries; at a point 1 mile west of the ore zone, the Bonneterre is 65 percent limestone, including fore-reef, reef, and shelf lithologies.

The edge of the back-reef facies is approximately 1 mile east of the ore zone; it thickens rapidly to the east. This "white rock" zone is composed of bleached, dolomitized and recrystallized planar algal stromatolites and burrowed lime sands and muds with irregularly distributed patches of soft green clay (Howe, 1968).

The shelf facies overlies the reef and, in the zone which includes the ore bodies, is in part an off-reef sand bar (time equivalent to the thicker parts of the reef a short distance to the east). Many original sedimentary textures and structures are preserved; intraclasts, oolites, fossil fragments and oncolites can be clearly seen, especially on polished surfaces. The upper 30 feet of this unit is transitional with the Davis (shale) Formation and contains several thin green shale beds.

ORE BODIES

The ore exposed in the Buick mine occurs as narrow, continuous bodies in the shelf sand and at the top of the reef. A thin, blanketlike ore body at the southern end of the property occurs at the reef-calcarenite contact and is associated with a buried Precambrian knob. It has not yet been exposed by the mine workings.

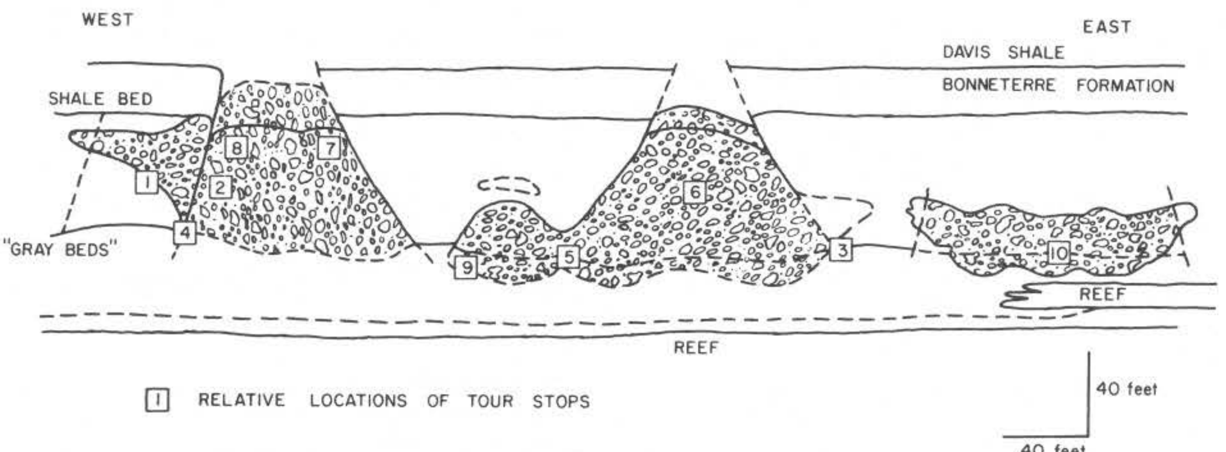


Figure 1

Generalized cross section of breccia bodies, Buick mine.

The most important ore controls are complex, solution-induced collapse breccias in the upper 100 feet of the Bonneterre Formation (fig. 1). Individual ore bodies of this kind are as wide as 250 feet and range from 30 to more than 85 feet in thickness. In plan they are sinuous and subparallel, with remarkable north-south continuity (fig. 3). The main structural elements of the breccias are the basin-shaped bottom and the outward-dipping boundary fractures along the flanks. Well mineralized, inward-dipping slump breccias are present along the boundary in some areas, but undisturbed, unmineralized beds are present at the fracture boundary elsewhere (fig. 1). Locally the upper parts of some boundaries are occupied by downward-tapering wedges of mixed lithology, including shale from the Davis Formation. Downward displacement in the breccia piles is from 3 to 10 feet at their base but as much as 30 feet at the top. Fragments of early-lithified beds in a matrix of granular flowage material make up the lower parts, whereas the upper parts include larger fragments and are more open, with a brittle style of fracturing.

MINERAL DISTRIBUTION

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 in the ore zone are dolomite, calcite, quartz and the clay minerals dickite and kaolinite. Each breccia body has a characteristic structural configuration and ore mineralogy. Zoning with respect to mineral distribution is pronounced across the breccias (fig. 2) and these distribution patterns tend to persist along the trend. Where two ore bodies merge, the mineral assemblage commonly includes identifiable characteristics of each.

The west ore body typically has two dominant ore shoots, one associated with each of its boundary fractures, and a weakly mineralized core. The west side grades, west to east, from galena to galena-sphalerite through a narrow interval. The eastern shoot contains galena, sphalerite, chalcopyrite, pyrite and cobalt-nickel minerals, but grades upward into a galena-pyrite zone.

The central ore body is generally thicker than the others; locally ore-grade mineralization extends from the base of the Davis Formation through the breccia and to the top of the reef. Mineral zoning is less complex than in the west ore body. The upper part of the pile is characterized by galena and pyrite, most of which is open-space filling. Pervasive replacement of breccia matrix by galena and, to a lesser extent, sphalerite is typical of the lower part. Higher concentrations of sphalerite lie along the margins. In the best-known part of the mine, a small body of very rich zinc ore is present along the western side of the central breccia (but may not be a part of it). It contains a distinctive, light-colored replacement sphalerite. Large fragments of this material have been found in a matrix of replacement galena and pyrite (and unreplaced dolomite). Sparse sphalerite in the breccia matrix, with the galena and pyrite, is of a different color. Exposures at the base of this zinc ore body suggest that it may be a filled scour channel, the coarse clastics of which were first replaced by sphalerite, then brecciated, and finally replaced (largely the breccia matrix) by galena, pyrite, and minor sphalerite.

The east ore zone is the thinnest, ranging from 30 to 40 feet in thickness. It has a tight mineral-zoning pattern, the most distinctive feature of which is a chalcopyrite zone in its lower central part. Within and surrounding this copper zone are zones of galena and sphalerite in varying proportions. The west flank is generally zinc-free, but has abundant pyrite. Massive botryoidal pyrite, up to 20 feet thick, caps the east ore body at the north end of the mine. Long segments of this ore body average more than 20 percent combined metals (Pb-Zn-Cu).

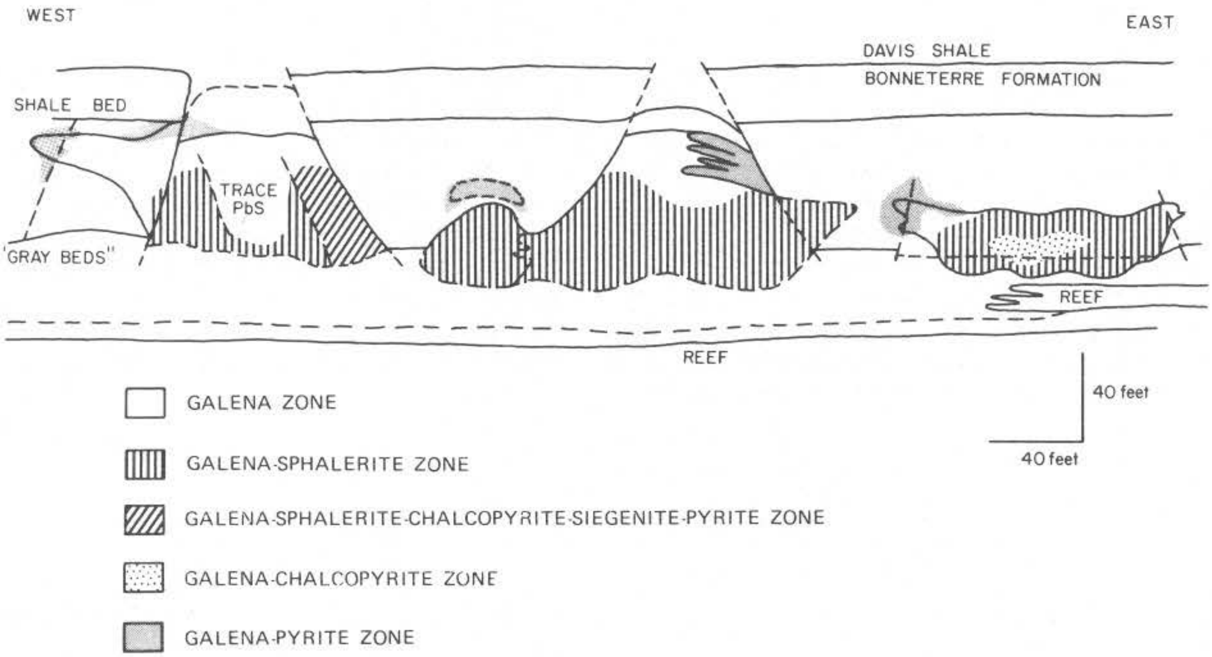


Figure 2

Generalized mineral zoning, Buick mine.

Along the north-south trend of the Buick ores there are gradual, but very significant changes in metal ratios. North from the shaft, lead content remains relatively constant as zinc decreases and copper increases. To the south, in a 5,000 foot interval, lead and copper content decrease, but zinc remains nearly constant. Farther south, the lead content increases slightly, and zinc and copper decrease. Paragenesis of the ore at Buick has not been determined. Numerous overgrowths of different minerals in vugs, leached and etched crystals, pre-breccia ore in a matrix of postbreccia ore, and complex zoning suggest more than one mineralizing pulse.

ORIGIN OF BRECCIAS

The geology staff at Buick currently considers the origin of the breccia bodies to be an open question, but prefers the hypothesis, which follows:

Shortly before deposition of the "gray beds", an off-reef lime sand bar occupied a position just west of the west ore body. 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 accumulations 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.

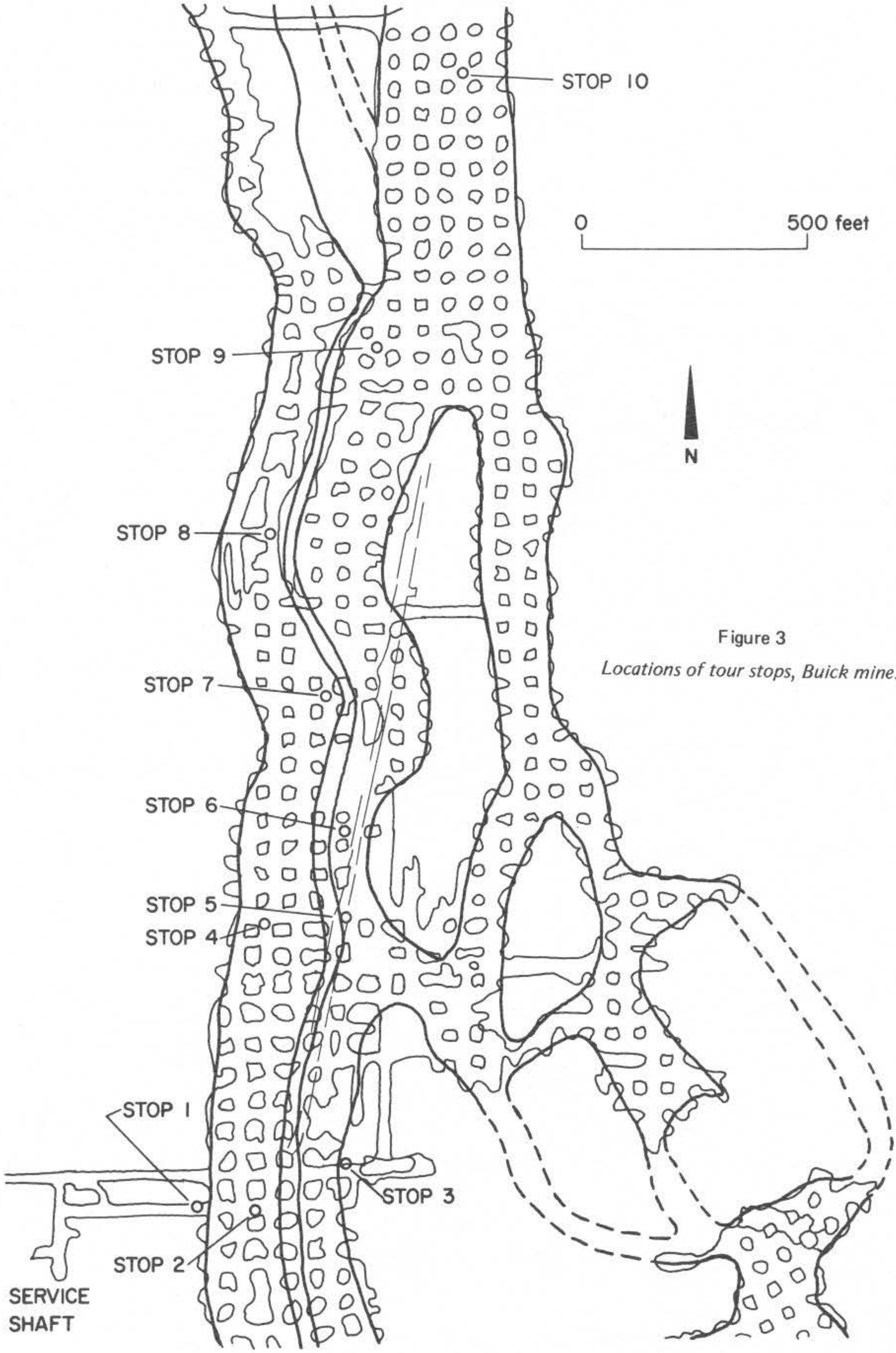


Figure 3

Locations of tour stops, Buick mine.

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 the mining-level landing elevation is 270 feet. Electrical power, at 4160 volts, and compressed air input is here. Ventilation air, at the rate of 270,000 cubic feet per minute, is pulled into the mine through this shaft, flows through the mine workings, returns along the haulage level (below the ore body), and is exhausted through the production shaft. (New exhaust shafts are being installed near the northern and southern extremities of the mine workings.) Mine water, almost 6,000,000 gallons per day, is pumped out through the service shaft. Ore is hoisted at the production shaft, 800 feet to the west, in two counter-balanced 12 ton skips. 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.

The locations of the stops of the mine tour are contingent on accessibility at the time, but are expected to be as indicated on the cross section (fig. 1) and plan map (fig. 3).

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 calcarenite; 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 body. 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 body (fig. 4)*

This stop is at the east side of the central ore body 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 two 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.

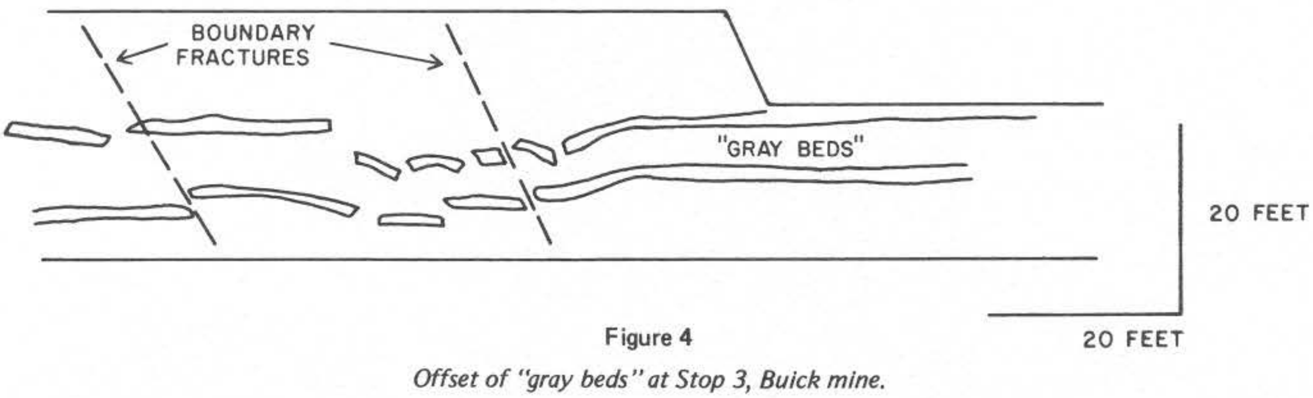


Figure 4

Offset of "gray beds" at Stop 3, Buick mine.

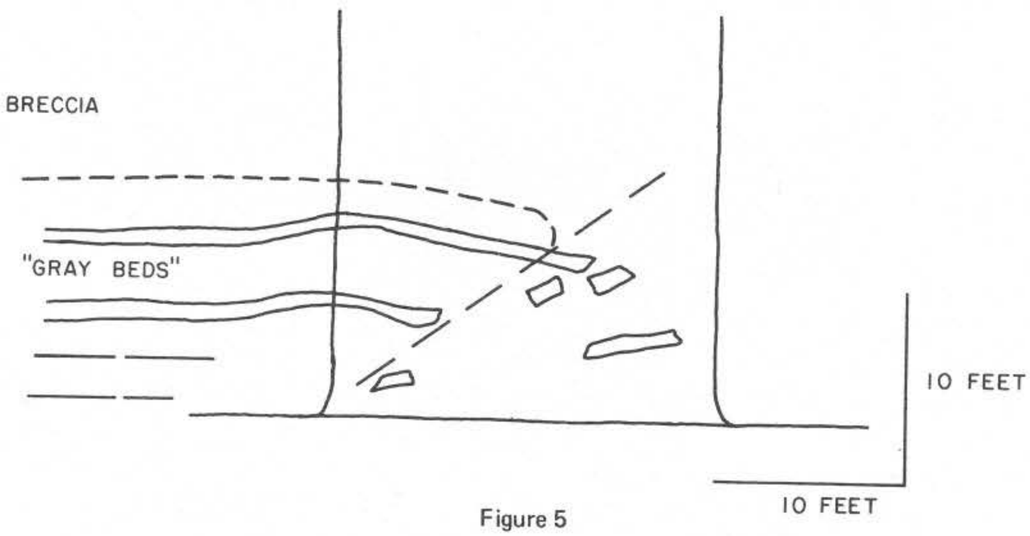


Figure 5

Offset of "gray beds" at Stop 4, Buick mine.

STOP 4 *West side of west ore body (fig. 5)*

This exposure shows offset "gray beds" at the lower west side of the west ore body. 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 body was 75 feet thick here and has been mined out.

STOP 5 *West side of central ore body*

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 6 *Pillar in west-central part of central ore body (fig. 6)*

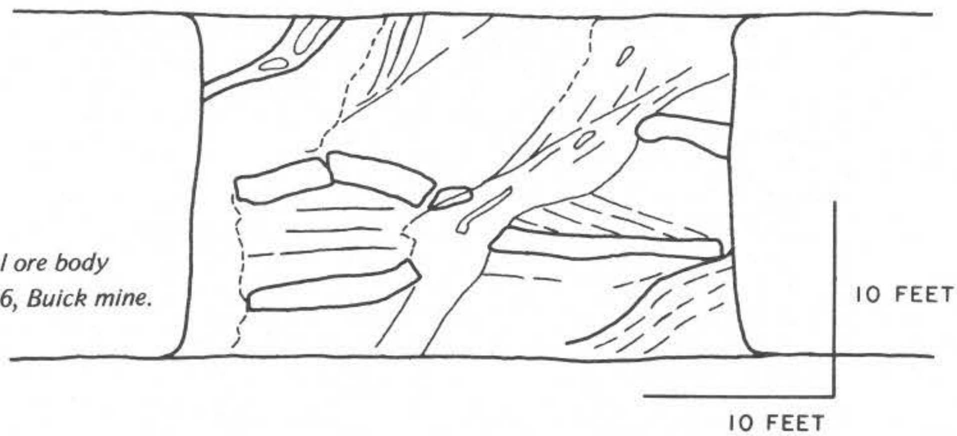
The complex nature of the interior of these breccias can be seen in this pillar. Galena outlines some blocks at the upper right side of the pillar.

STOP 7 *Upper east edge of west ore body*

This is a good example of brittle-style brecciation. Coarse galena occurs in thin, vein-like boundary fractures and irregular openings. Angular, early-lithified fragments, varying widely in size, are outlined by the white magnesium salts deposited by the evaporation of water seeping out of the permeable breccia matrix. The flat-bedded, undisturbed calcarenite wedge separating the west and central orebodies is exposed on the east side of the drift. At the top of the pillars is the shale unit which overlies the "calcarenite" of the Buick logging system. North of the shale exposure, the narrow top of the breccia pile can be seen (fig. 7).

Figure 6

Complex central ore body breccia at Stop 6, Buick mine.



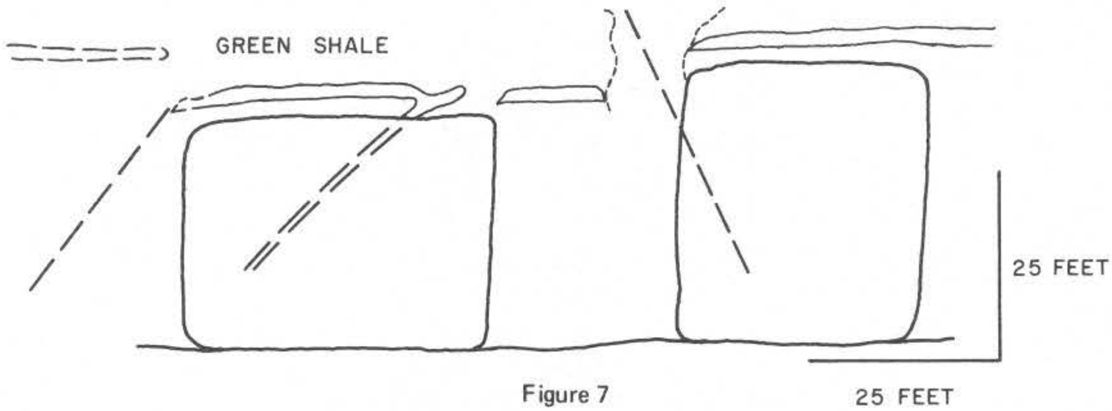


Figure 7

Offset of green shale at Stop 7, Buick mine.

STOP 8 ***Barren core of the west breccia body***

Porosity is as good as anywhere in the mine, but mineralization is limited to pyrite, late dolomite, and scant traces of galena.

STOP 9 ***West side of central ore body (fig. 8)***

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

STOP 10 ***Central part of east ore body***

These pillars contain the richest ore in the mine; many of them average more than 30 percent combined Pb-Zn-Cu through a vertical interval of 65 feet. The copper core, so characteristic of the east ore body zoning, is also exposed here. Sphalerite is dark, fine-grained and inconspicuous.

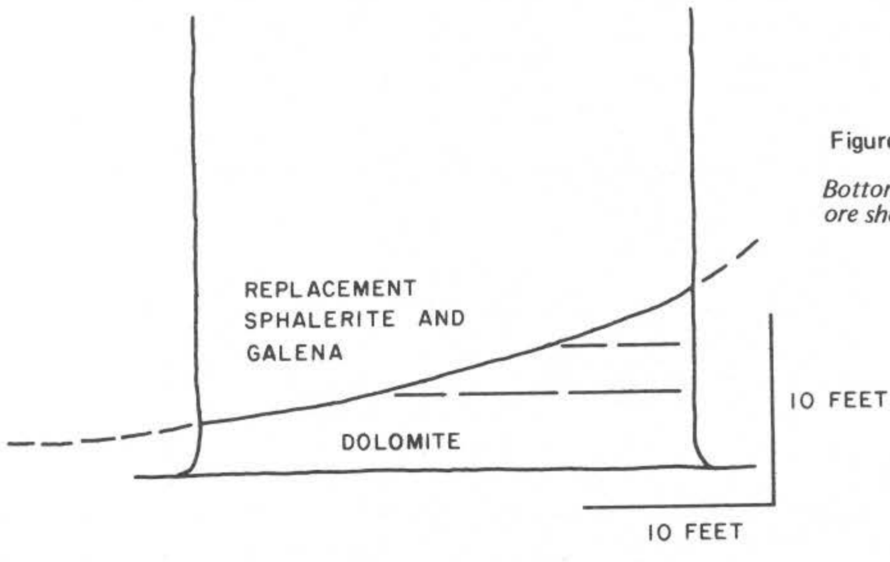


Figure 8

Bottom contact of high grade Zn-Pb ore shoot at Stop 9, Buick mine.

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ACKNOWLEDGMENTS

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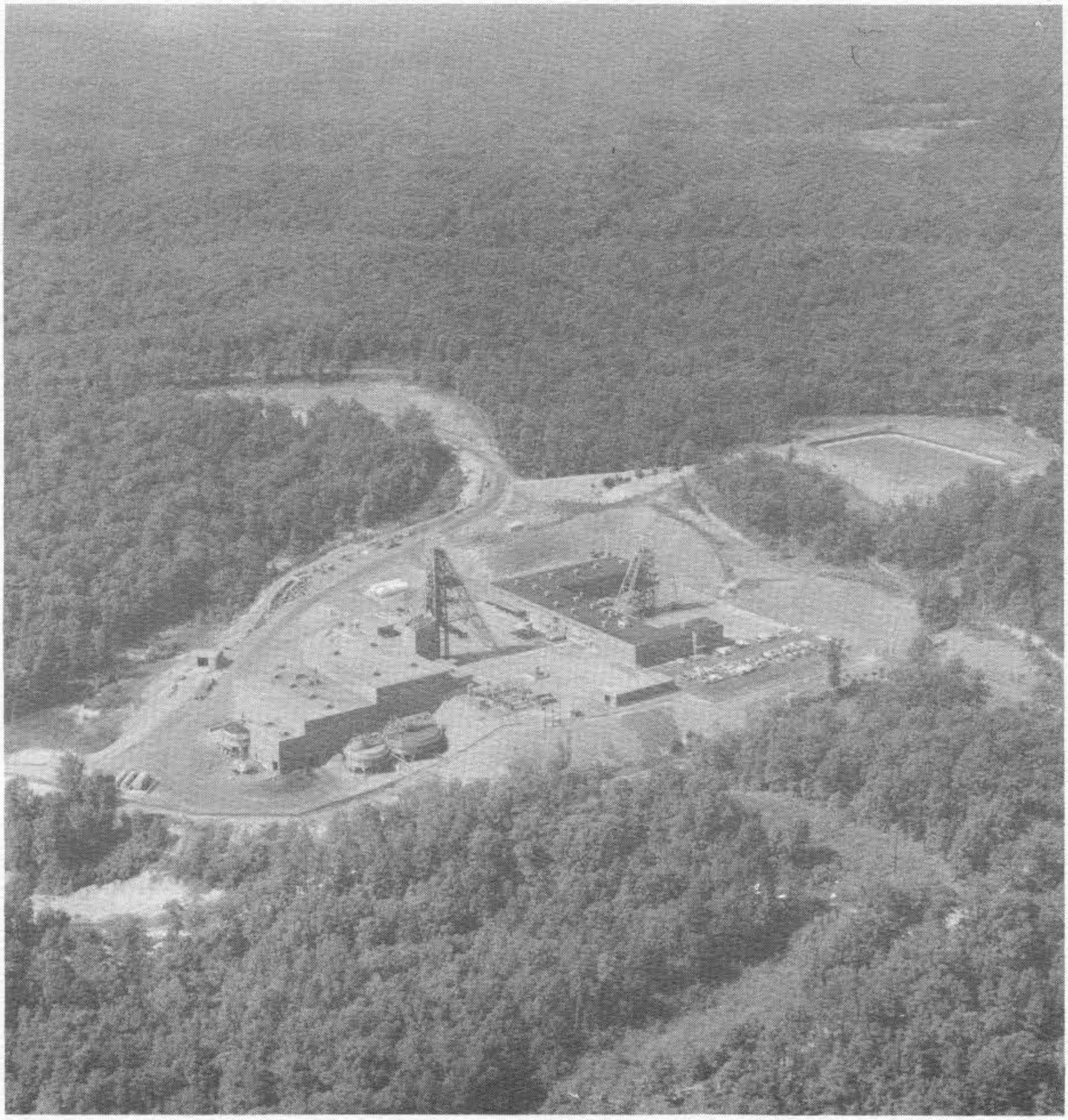
C.G. Hagegeorge and J.W. Odell, both with experience in Tennessee zinc mines, studied and mapped geology in the Buick mine during its early production phase. Their contributions to our understanding of the breccias is hereby acknowledged, although we accept full responsibility for the interpretations presented.

Association with John Lyle, during his study of the petrology of the Bonneterre Formation, improved our understanding of local facies relationships and made us more comfortable with the terminology of modern carbonate petrology.



FLETCHER MINE

(St. Joe Minerals Corporation)

FLETCHER MINE (ST. JOE MINERALS CORPORATION) VIBURNUM TREND, SOUTHEAST MISSOURI

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INTRODUCTION

Following the discovery of lead in the Viburnum area, exploration spread southward during 1957. Encouraging results were immediately forthcoming as the first pay hole in the Fletcher area was cut in the summer of 1958. In June 1963, St. Joe Minerals Corporation authorized the development of a $14 million, 5,000 tons-per-day facility in Reynolds County, 6 miles east of Bunker, Mo. Shaft sinking started during the week of July 14, 1964. The 1,344-foot, 12½-foot diameter shaft bottomed on November 23, 1965; the mill began operation on February 28, 1967.

This trackless mine, one of the most modern mining operations in the world, was designed by St. Joe engineers, and is one of the largest individual producers of lead in the United States. Lead, zinc and copper concentrates are produced at Fletcher. All concentrates are placed in 10-ton containers which are trucked 12 miles north to Buick, Mo., and are dumped into Frisco railroad cars for shipment to smelters. The mine employs about 70 men, who produce approximately 60 tons of ore per mine man shift.

STRUCTURAL SETTING

The Viburnum Trend is in the stable interior region of the central United States. The structure is simple, consisting of essentially flat-lying sedimentary carbonates, shales and sandstones overlapping Precambrian igneous intrusive and extrusive rocks. The St. Francois Mountain complex, the dominant structural feature of the region, lies about 40 miles east of Fletcher. This complex, as well as smaller outlying igneous knobs, were positive areas during late Cambrian deposition, and were controlling factors in facies patterns and sedimentary features in the Bonneterre Formation. These have an important influence on the distribution of base metal mineralization.

The Fletcher mine is on the axis of a buried, north-south trending ridge composed of several individual knobs that extend through the main reef horizon of the Bonneterre Formation. The Lamotte Sandstone laps up on and pinches out against this ridge complex. Bonneterre beds dip peripherally away from the knobs. This is illustrated by the structure contours shown in figure 3. Although present mining is taking place over the Precambrian knobs, future mining will progress away from the knobs, where the Bonneterre overlies the Lamotte Sandstone. Fracturing is common, particularly around the flanks of the knobs, but no major faults are present in the Fletcher area.

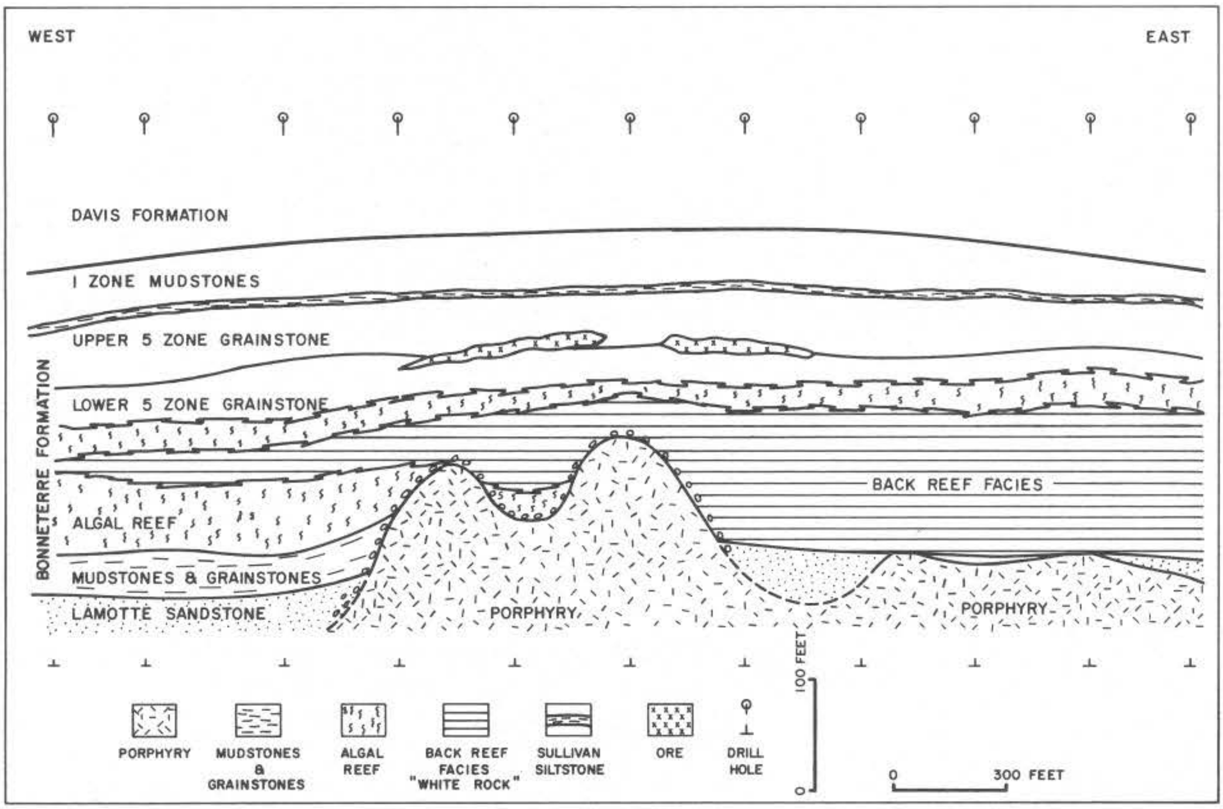

Figure 1

Idealized cross section of Bonneterre facies across shaft area, Fletcher mine.

STRATIGRAPHY

Late Cambrian sedimentation began with the deposition of the Lamotte Sandstone, a clean orthoquartzite sandstone that is fine-grained, friable, porous, permeable and commonly cross-bedded. The Lamotte was deposited on the stable platform, and pinches out against the igneous knobs. Conglomerates are present near the flanks of the igneous knobs.

The Bonneterre Formation conformably overlies the Lamotte Sandstone and is the host rock for the base metal mineralization in the Fletcher area. It initially was deposited as a limestone, but was dolomitized during lithification or shortly thereafter.

The Bonneterre consists of algal boundstones and burrowed lime mudstones which form much of a reef-backreef environment. Interbedded, shaly lime mudstones predominate in an offshore facies and lime wackestones and grainstones blanket the entire area. A description of these is given in a paper by Gerdemann and Myers (1972). Figure 1 illustrates the stratigraphy of the Bonneterre Formation in the Fletcher mine area.

The impermeable Davis Formation overlies the Bonneterre. It is composed of interbedded shales, carbonates, and glauconitic siltstones and sandstones, along with flat pebble and edgewise conglomerates.

Other Cambrian formations present in the mining region in ascending order are: Derby-Doerun Dolomite, Potosi Dolomite and Eminence Dolomite.

MINERALIZATION

The mineralization in the Fletcher area follows a pronounced north-south trend. It is continuous throughout the 5-mile extent of the Fletcher area; however, the grade of ore varies to a great degree (fig. 2). The mineralized zone in the north is 1,000 feet wide and averages 20 feet thick. The ore zone reaches its maximum width of about 2,000 feet in the middle of the area where an arc-shaped porphyry knob protrudes into the Bonneterre Formation. The grade of mineralization drops significantly as the ore zone continues south over the Lamotte Sandstone and narrows to less than 200 feet.

The structure influences the location of the ore. The ore bodies tend to follow the changing strike of the beds as they drape over the knob. The mineralized belt divides south of the shaft within the porphyry arc. A narrow elongated area of trace mineralization is surrounded by high-grade mineralization. One belt overlies the axis of the Precambrian high and the second belt lies to the west over the Lamotte pinchout. The two belts unite along the south flank of the porphyry knob. At this point the mineralized zone thickens to include the brecciated lower Davis Formation.

The sulfide ore minerals present at Fletcher are galena, sphalerite and chalcopyrite. The lead-zinc-copper ratios are approximately 40:4:1. Associated gangue minerals are calcite, dolomite, pyrite and marcasite.

Principal sulfide mineralization occurs as anhedral and euhedral crystals in disseminated and banded stratabound deposits within the upper 5 zone. Most of the mining to date has encountered the better

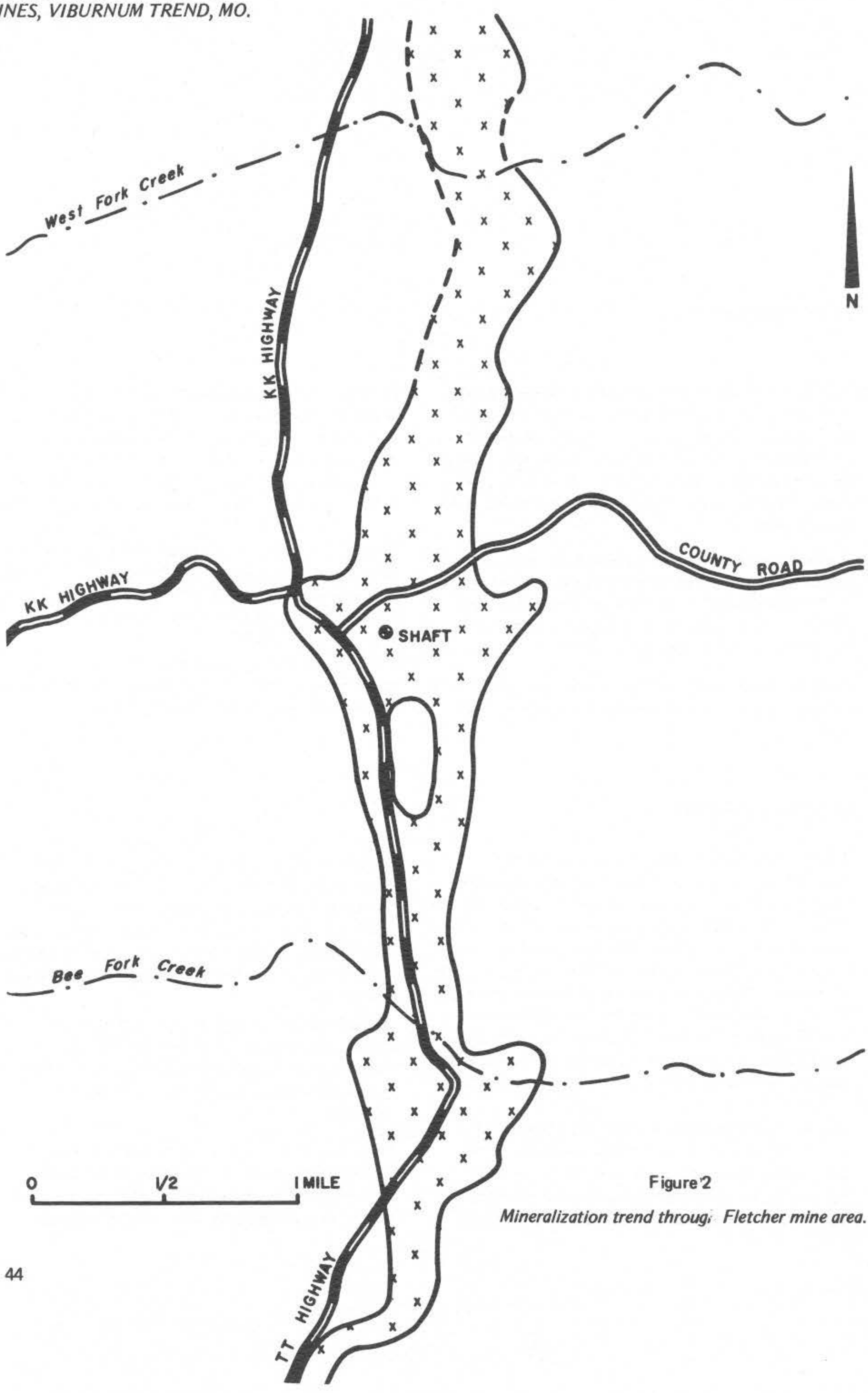

Figure 2

Mineralization trend throug; Fletcher mine area.

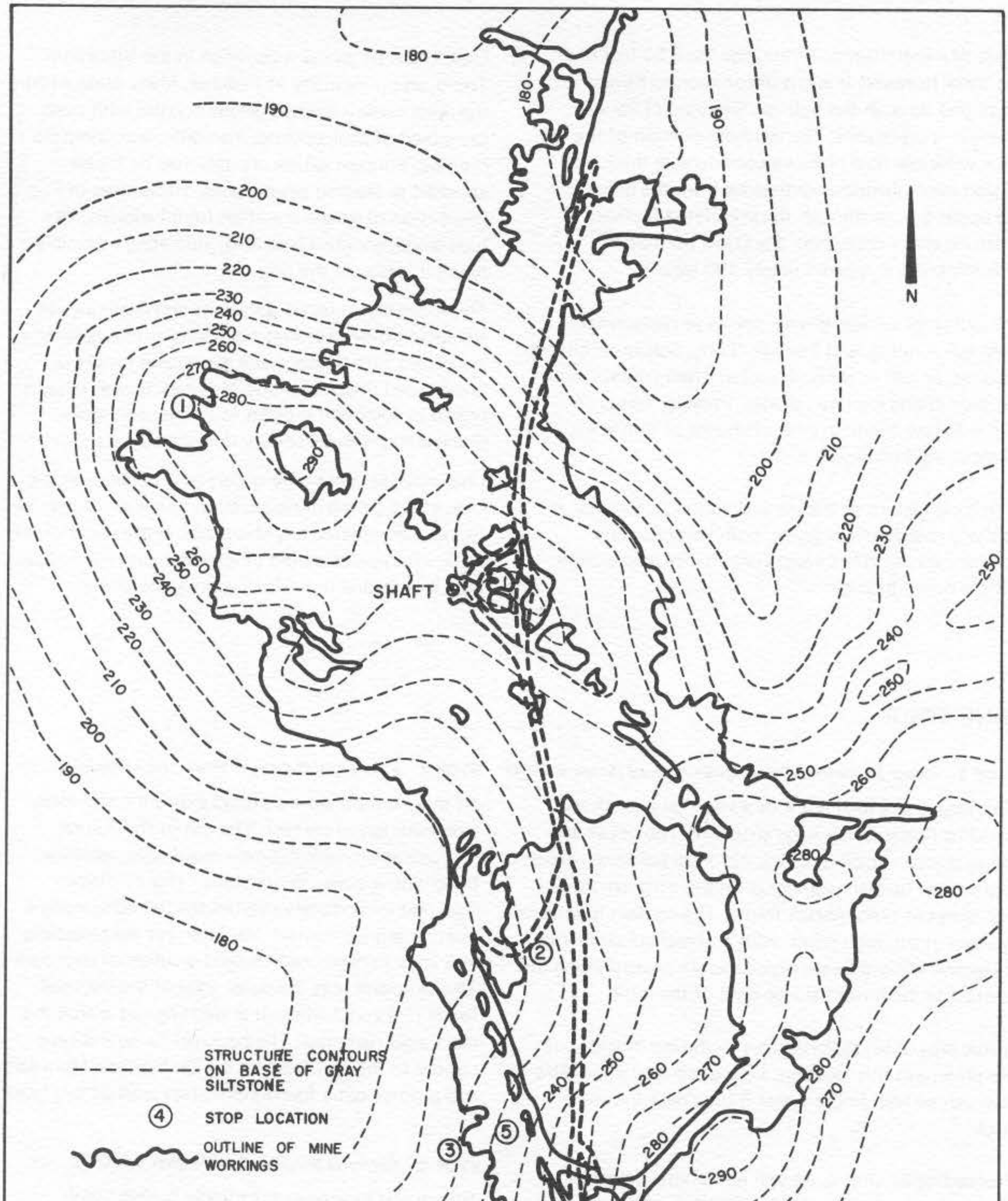

Figure 3

Locations of tour stops, Fletcher mine.

grade of mineralization within the basal 20 feet of the zone; however, it is not uncommon to have ore up to and through the Sullivan Siltstone (1 zone) where it is brecciated. The southern portion of the mine workings now reveals a considerable thickness of lead mineralization continuous from the base of the upper 5 zone through the brecciated Sullivan Siltstone and 1 zone, into the Davis Formation. This thickness is approximately 100 feet.

The principal sulfide, galena, occurs as replacement, open space filling, and fracture filling. Solution collapse breccias, as well as slump breccias, often contain mineralization filling the open spaces. Irregular bands of galena follow bedding, with offshoots of thin veins crosscutting bedding.

A striking feature of the mineralization at Fletcher is its sharp change in ore grade, both vertically and horizontally, with little apparent change in structure or host rock lithology.

Dissolution of galena is common in the Viburnum Trend, and principally at Fletcher. Many areas within the mine exhibit leached galena crystals with casts composed of chalcopyrite, marcasite, and dolomite rhombs. Younger galena crystals may be found attached to leached galena faces. These areas of dissolution of galena are often found adjacent to a high grade, enriched lead area, indicating a possible remobilization of the ore.

The accessory minerals sphalerite and chalcopyrite are also recovered at Fletcher. Sphalerite is generally associated with higher grade galena and occurs as fine-grained disseminations. It is dark brown to light brown in color and is often found in open space filling along with secondary dolomite crystals.

Chalcopyrite commonly occurs as thin bands at the base of the galena mineralization; however, it may be found disseminated anywhere within the mineralized zone, often independent of lead and zinc mineralization, as euhedral crystals in open space filling.

MINE TOUR

STOP 1 ***Upper Bonneterre/Precambrian Igneous (Stope 63W14)***

This area is at a high point of a knob on a northwest-trending Precambrian ridge structure. The upper and lower 5 zone clastic unit (fig. 4) of the Bonneterre Formation can be seen lapping up on the irregular-shaped exposures of Precambrian felsite. The contact is extremely clean at this high point, with no basal conglomerate. Extensive conglomerate exposures are present along this contact in the lower haulage level of the mine.

Initial dips of up to 25 degrees to the north and south are present at this location. Low grade lead mineralization can be seen in the upper 5 zone near the stope back.

Proceeding to Stop 2, we will be walking downhill. This is due to the dip of the formation away from the Precambrian knob (fig. 3). We will remain at the same stratigraphic position in the Bonneterre until entering the decline. Here we progress down through the lower section of the 5 zone clastic unit into the 7 zone algal reef.

STOP 2 ***7 zone reef/3-4 zone "White Rock" features***

At this location we see a good exposure of 3 zone, bleached, tan-white reef. The top of the 3 zone contains small, well defined depressions, which are filled with 4 zone "White Rock" (fig. 5). Brown algal reef immediately overlies the 3-4 zone along a sharply defined contact. We interpret the bleaching in 3 zone to have been caused by subaerial exposure. This exposure is at the outer edge of the backreef facies (3-4 zone) where it is wedging out within the main algal reef mass. The backreef facies thickens rapidly to the east (toward the St. Francois Mountains) and pinches out a few hundred feet west of this location.

STOP 3 ***Dolomite Solution Breccia (Stope 67C42)***

This stop is located in the middle 5 zone clastic unit, near the brown spotted marker bed. Galena was the principal sulfide in this area. It has been dissolved and transported, leaving secondary dolomite casts. Note also that the chalcopyrite crystals have not been affected.

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.

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BONNETERRE FORMATION AVERAGE THICKNESS 300'

ORE	ZONE	LITHOLOGY
		Davis Shale
	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.

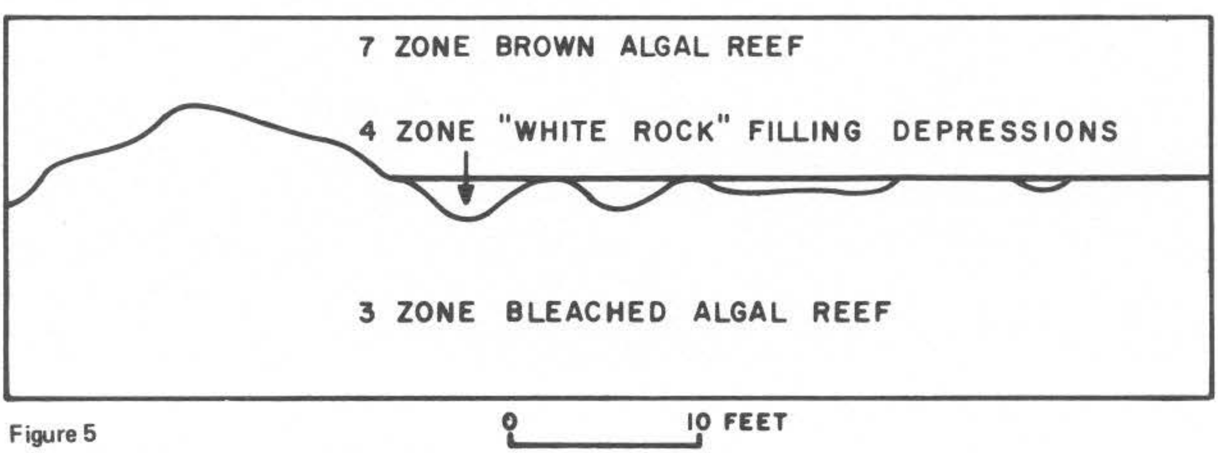
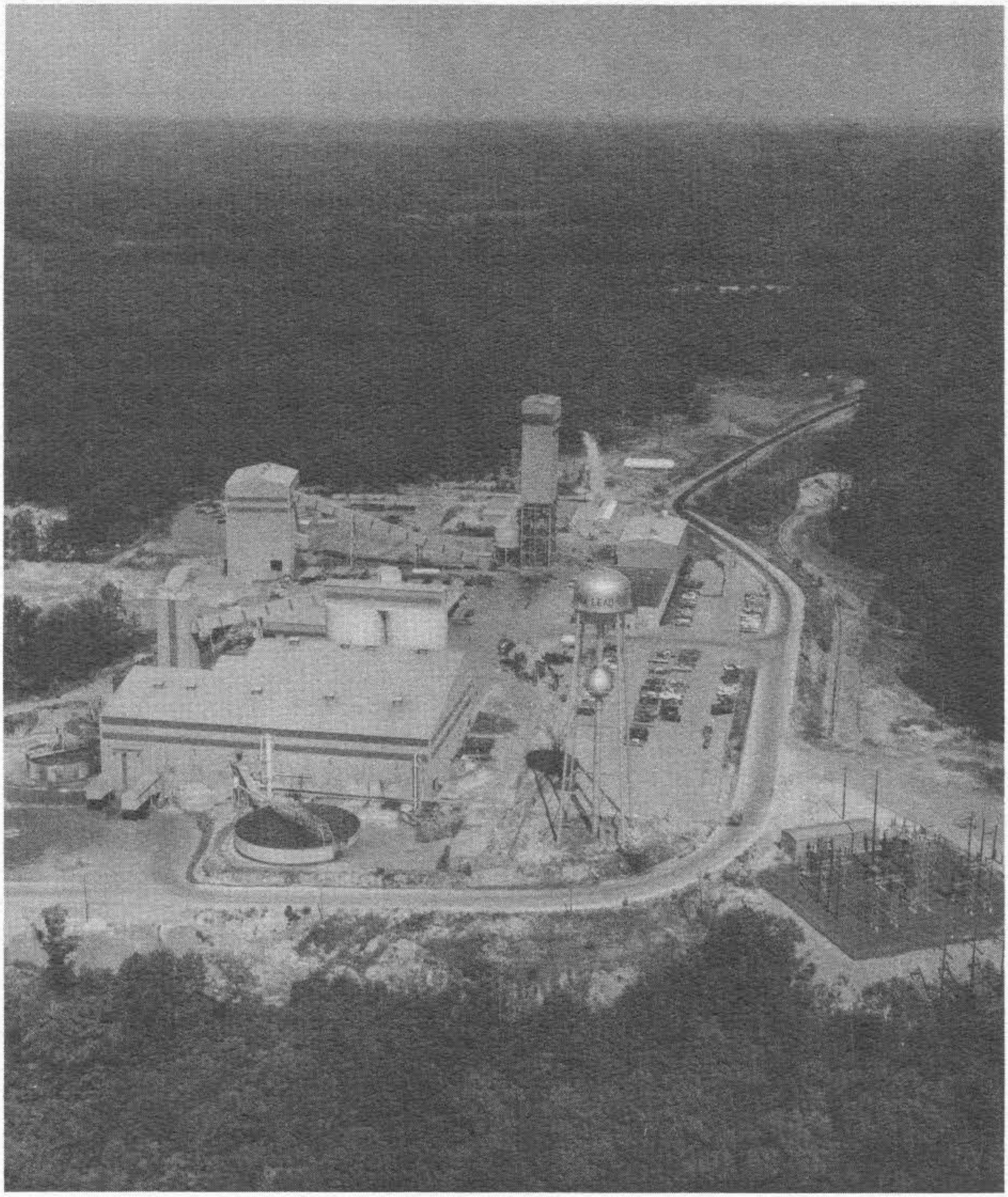


Figure 5

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



OZARK LEAD COMPANY MINE

OZARK LEAD COMPANY MINE
VIBURNUM TREND, SOUTHEAST MISSOURI

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INTRODUCTION

The Ozark Lead Company mine, the southernmost mine of the Viburnum Trend (New Lead Belt), is 7.4 miles southeast of Bunker and 12.7 miles northwest of Ellington, Mo.

The ore body was discovered in January 1962. Underground development of the mine began in May 1964 with the drilling by oil-field equipment of a 7-foot diameter, 1250-foot deep development shaft. Two levels of the mine were developed from this shaft. Subsequently, a 20-foot diameter, three compartment, concrete-lined production shaft was sunk by conventional methods and, in April 1967, this shaft intersected the underground development headings that had been completed. The mine began production in June 1968 with a designed capacity of 6,000 tons of ore per day.

The open stope, room-and-pillar method is used to mine the multilevel ore body. Ore moved by load-haul units is passed through raises between levels to a diesel rail-haulage system on a sublevel. This mine design was influenced by the characteristics of the ore body. Ore is transported by rail to ore pockets feeding directly to an underground primary jaw crusher. Ore is hoisted automatically in two balanced 18-ton skips from the loading pocket by the largest friction hoist in the area.

Lead and zinc concentrates from the mill are trucked approximately 40 miles to Glover, Mo. The lead concentrates are treated by the American Smelting and Refining Company, Glover plant. Minor amounts of copper, silver and cadmium are recovered from the lead and zinc concentrates.

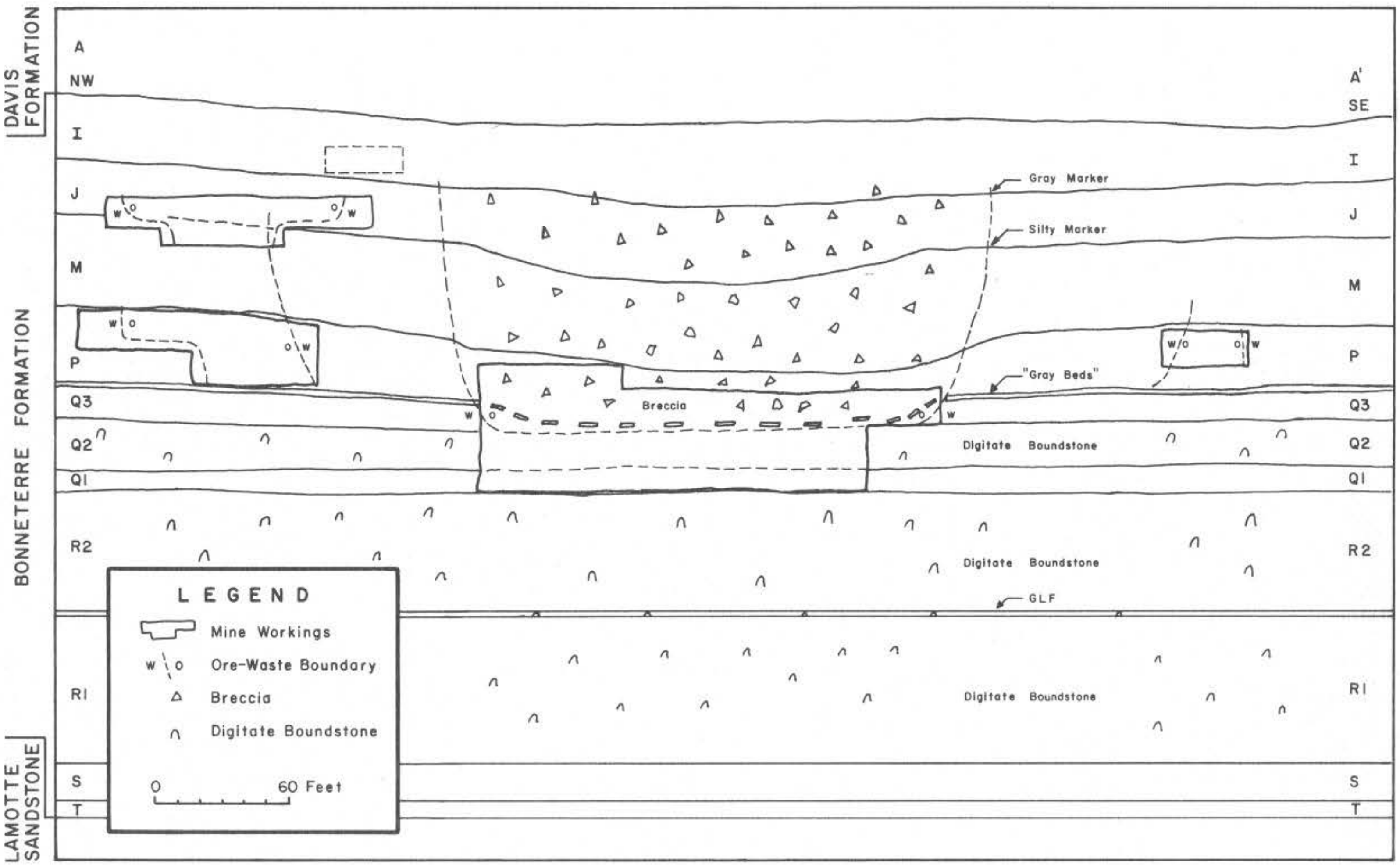


Figure 1

Schematic cross section across main ore zone, Ozark Lead Company mine.

STRUCTURE

The regional depositional strike of the Bonneterre Formation in the mine area is north-northeast. However, the ore body is unique compared with others in the area because it lies at right angles to the regional depositional strike of the sediments (fig. 3). This is due to a series of buried Precambrian "highs" that trend northwest and grossly control the location of the ore body. A northwest-trending, high-angle reverse fault with approximately 100 feet of vertical displacement lies immediately south of the "highs" and parallels them.

Within the ore body several features have been recognized that have relationships to the ore. The most important of these are:

a. *Structural highs*
These structures are characterized by either a system of gently rolling anticlines and synclines or a mounding of strata related to some sedimentary or Precambrian feature. Commonly, a system of fractures is closely associated with these structures. The flanks of the structural highs are usually good hosts for bedded or disseminated mineralization.

b. *Breccia*
A breccia body upwards of 120 feet thick and 200 to 300 feet wide extends, more or less continuously, for thousands of feet parallel to the Precambrian "highs". (figs. 1 and 3). The breccia is interpreted as due to solution collapse. Gray beds, normally lying 10 to 12 feet above the base of the breccia, have been broken and downdropped. An isopach of the breccia body indicates thinning of as much as 20 to 30 feet.

c. *Faults*
These are most commonly developed in conjunction with the breccia and attendant solution collapse.

SEDIMENTATION AND STRATIGRAPHY

The Bonneterre Formation can be subdivided into four facies formed in response to varying energy conditions at the time of deposition of the sediments. These are (a) a shaly lime-mudstone facies, (b) a clastic-carbonate facies, (c) a digitate-boundstone facies, and (d) a planar-boundstone and burrowed-lime-mudstone facies (Larsen, 1973). The shaly lime-mudstone facies lies west of the mine and the planar-boundstone and burrowed-lime-mudstone to the east. Within the mine area, the clastic-carbonate and digitate-boundstone facies predominate.

The initial Bonneterre transgression resulted in deposition of the basal sandy transition zone, followed by a 20- to 30-foot thick zone of lime mudstone and wackestone (fig. 2).

These zones were, in turn, followed by a period of maximum digitate boundstone development. The stratigraphic relationships record a prograding or regression during lower Bonneterre time which culminated in an uncomformity at the end of lower Bonneterre time. Above the unconformity the Bonneterre becomes dominantly transgressive. The zone of digitate boundstone shifted approximately 6,000 feet to the east. A well developed oolitic grainstone and packstone formed immediately west of the upper zone of

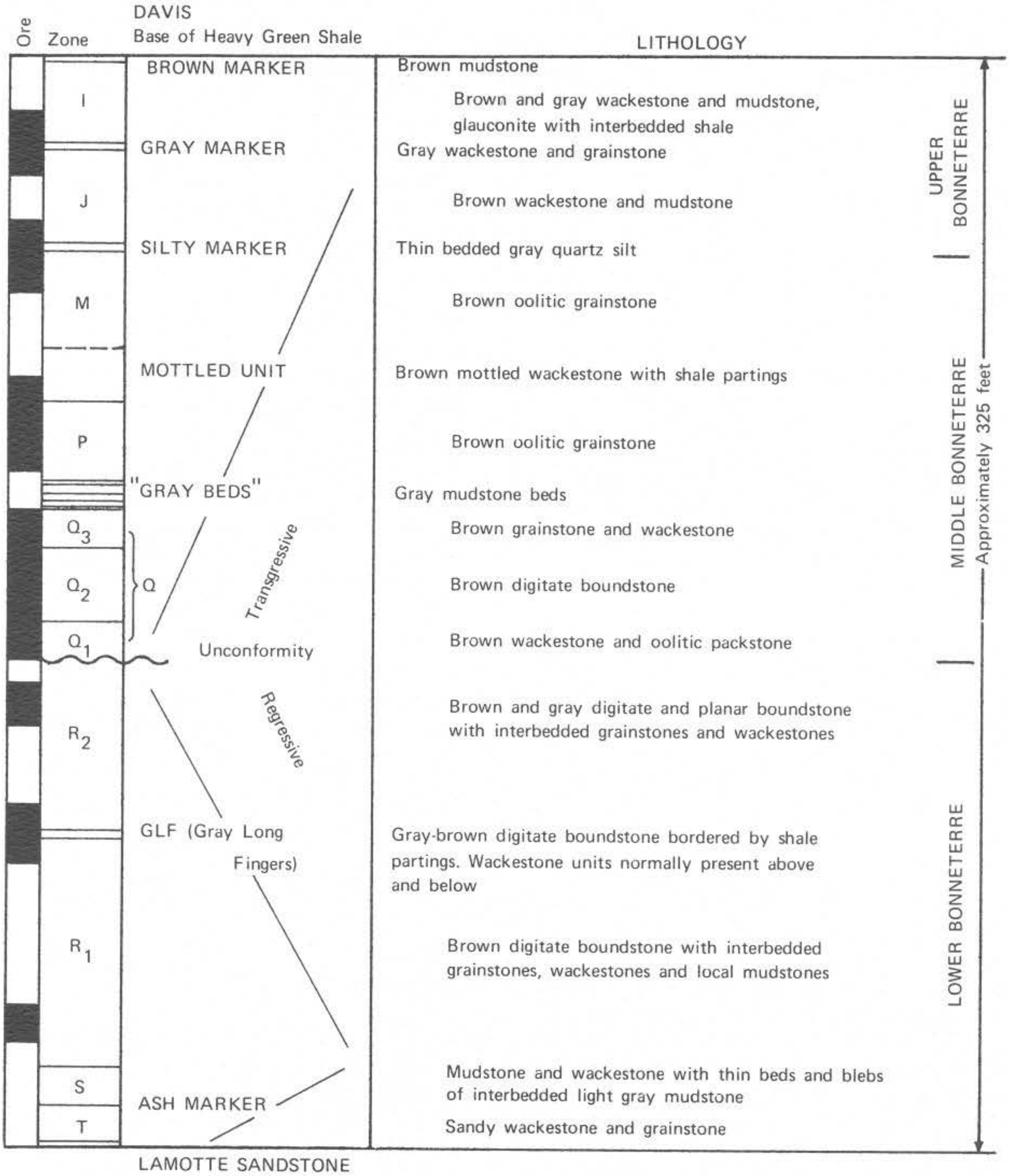


Figure 2

Generalized divisions of the Bonneterre Formation, Ozark Lead Company mine.

stromatolite growth. Within the mine area, digitate boundstone development ended with the expansion of the clastic-carbonate facies. This facies is dominantly grainstone but with packstone and wackestone beds. The packstones and wackestones represent lower-energy periods. Gray beds and the silty marker (Sullivan Siltstone) of middle and upper Bonneterre time both thicken to the west and mark transgressive pulses.

MINERALOGY

Galena and sphalerite are the dominant ore minerals. They occur in approximately a 5:1 ratio. Galena occurs as both octahedrons and cubes. Leaching and removal of galena occurs locally, but does not appear restricted to any particular ore horizon. A typical mineralogical relationship shows early chalcopyrite overgrown by galena octahedrons; these octahedrons are then leached and etched and overgrown by later cubes.

Sphalerite is generally very finely crystalline and shows a wide range of colors: yellow, orange, black and brown. Sphalerite crystals are rare; but two forms, the tetrahedron and dodecahedron, have been noted. Chalcopyrite is quantitatively minor, but in addition to being noted on the perimeter of ore zones, it also occurs in rather unusual discrete bodies. These bodies have virtually no galena and attain several thousands of tons in size. Copper bodies are restricted to the lower mining units. In one of these copper areas, chalcopyrite locally contains bands or seams of bornite. Covellite and djurleite have been seen megascopically in the bornite areas. Digenite, enargite and possibly tennantite have been noted microscopically.

Other sulfides in the mine include siegenite, millerite and polydimite. Calcite is common in vugs and openings and some samples exhibit as many as two or three ghost crystals. Dickite is also commonly seen in minor amounts.

ORE OCCURRENCE

A distinctive feature of the ore body is that ore occurs throughout the Bonneterre. The ore is both structurally and stratigraphically controlled. It can be broadly divided into four categories based on its mode of occurrence:

a. fracture ore

b. bedded or disseminated ore

c. breccia ore

d. marginal break (fault) ore

FRACTURE ORE

Ore minerals are restricted to veinlets that exhibit crosscutting relationships with the strata and may have a stockwork appearance. Some veinlets exhibit zoning. Veinlet or fracture mineralization is generally not of economic importance unless favorable hosts are encountered. This type of mineralization is common within the Bonneterre below the breccia units.

BEDDED OR DISSEMINATED ORE

This category encompasses mineralization that has spread laterally within a host horizon which permitted such movement. Lateral spread of mineralization occurred along bedding planes and broken boundstone units, but it was generally restricted to wackestones and packstones. Mineralization of this type is one of the most important in the mine.

BRECCIA ORE

This type of mineralization is generally disseminated or concentrated in vugs within the white, secondary-carbonate matrix of the breccia. Mineralization may also line watercourses in the breccia and surround breccia blocks. See figures 1 and 3.

MARGINAL BREAK (FAULT) ORE

A complex system of through-going faults or breaks parallels the breccia margin. This system served as channelways for mineralizing solutions and channeled the solutions into favorable hosts. Relatively impermeable units encountered along this system caused ponding of mineralized solutions.

Regardless of category, the ore exhibits two habits – replacement and open-space filling – both indications of an epigenetic origin.

MINE TOUR

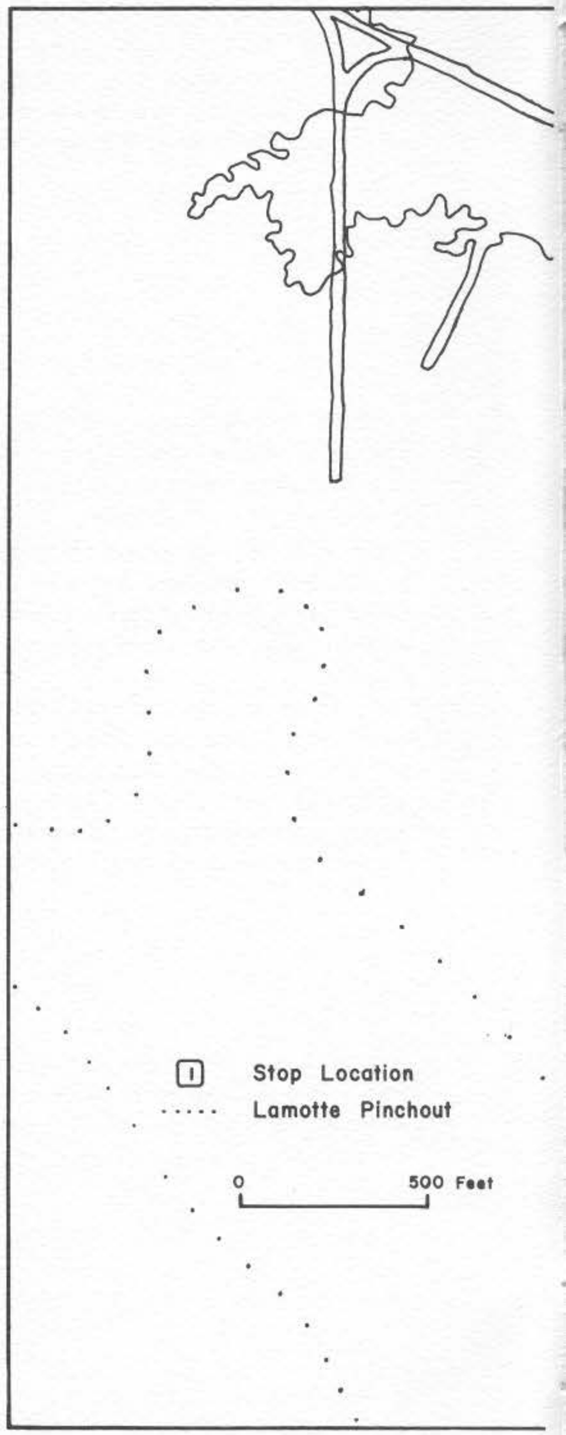
Stops listed below are tentative. In the event that mining conditions require a change, other locations will be selected to show comparable features, insofar as possible. See figure 3.

STOP 1 ***G-1 area***

This area shows an example of typical bedded mineralization. Galena is disseminated throughout; sphalerite is also present. Digitate algal boundstone is exposed near the back. Note the typical vug- and fracture-filling type of mineralization.

STOP 2 ***F-1 area***

This stop shows the relationship between breccia ore and non-brecciated rock. Note that the "gray bed" has been fractured and dropped in the breccia zone.



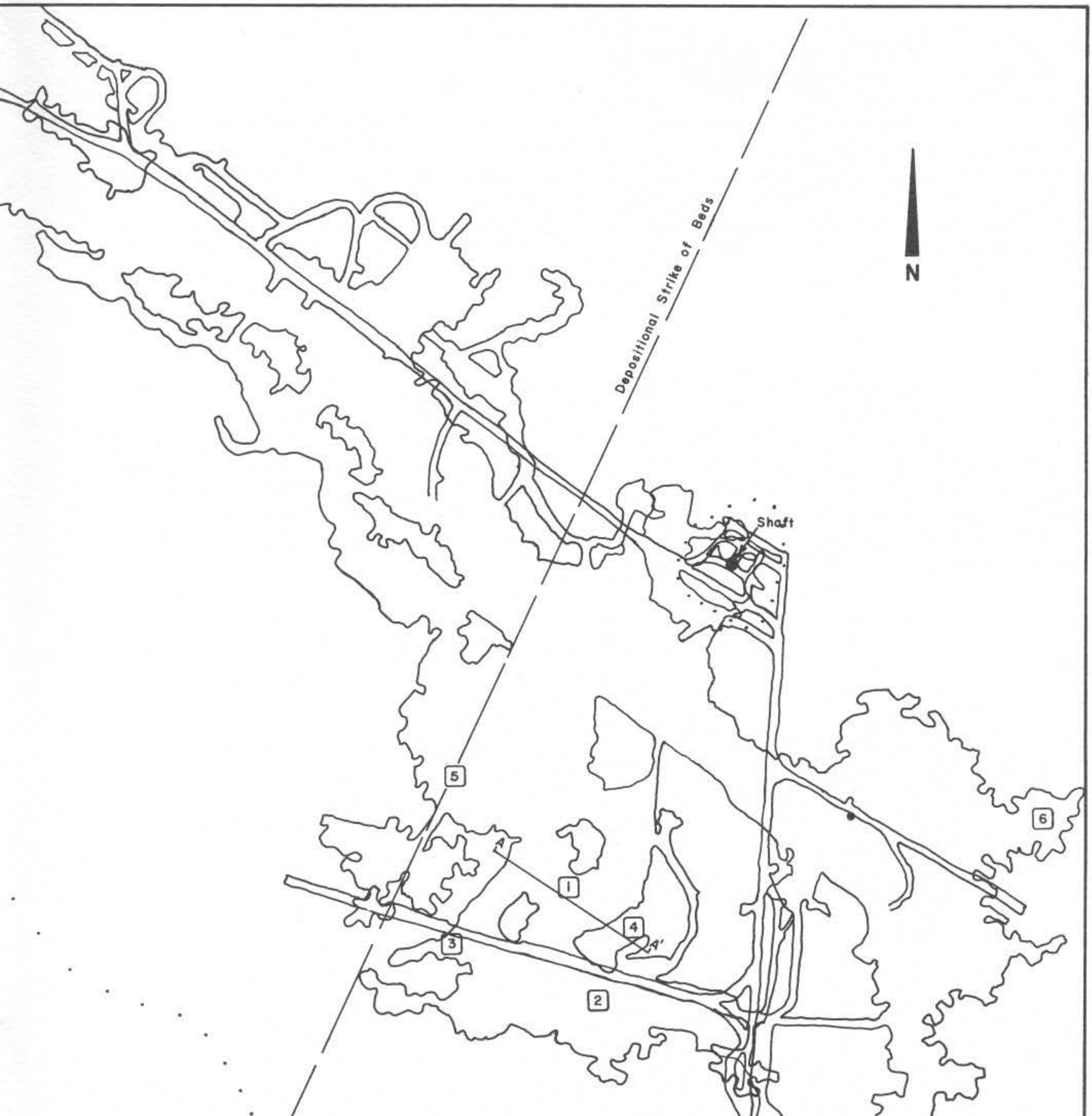


Figure 3

Locations of tour stops, Ozark Lead Company mine.

STOP 3 *D-2 area*

Here, typical marginal-break mineralization of good grade has been mined along one side of the breccia. Possibly a fault or marginal break may be visible. White secondary dolomite characteristically is present and is especially prominent on the side of the ore zone away from the breccia. Upon entering or exiting from the area, the relationship of breccia to marginal-break mineralization may be visible in a short ramp between the two zones.

STOP 4 *D-6 area*

This stop shows an example of the marginal-break mineralization on the other side of the breccia zone. If possible, reversal of the boundary fault or break with dip toward the breccia will be seen. Note abundant white dolomite on the side away from the breccia. In places, the rock, where abundant white dolomite occurs, takes on a vuggy, vermicular, almost brecciated appearance. Indication of dissolution of galena has been noted in this heading. Upon exiting, note the right-angle turn this narrow ore zone makes to parallel the turn in the breccia to the west.

STOP 5 *T-1 area*

Good grade upper-level mineralization has been mined from this area. Much of the mineralization has ponded up against the bottom of the silty marker. Marginal breaks or faults and mineralization that stairstep and/or narrow downward indicate a similar control to that of the marginal-break mineralization. Considerable sphalerite is commonly present.

STOP 6 *K-2 area*

In this area the unconformity underlying the Q-1 bed may be seen. Humps and mounds of the underlying rock are in many cases bleached, probably due to subaerial exposure. A thin, brown, oolitic grainstone is prominent in the Q-1 bed and may be traced over a considerable distance in the mine area. Light colored remnants of the planar boundstone and burrowed lime-mud facies may be seen at the top and bottom of the Q-1 bed locally.

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