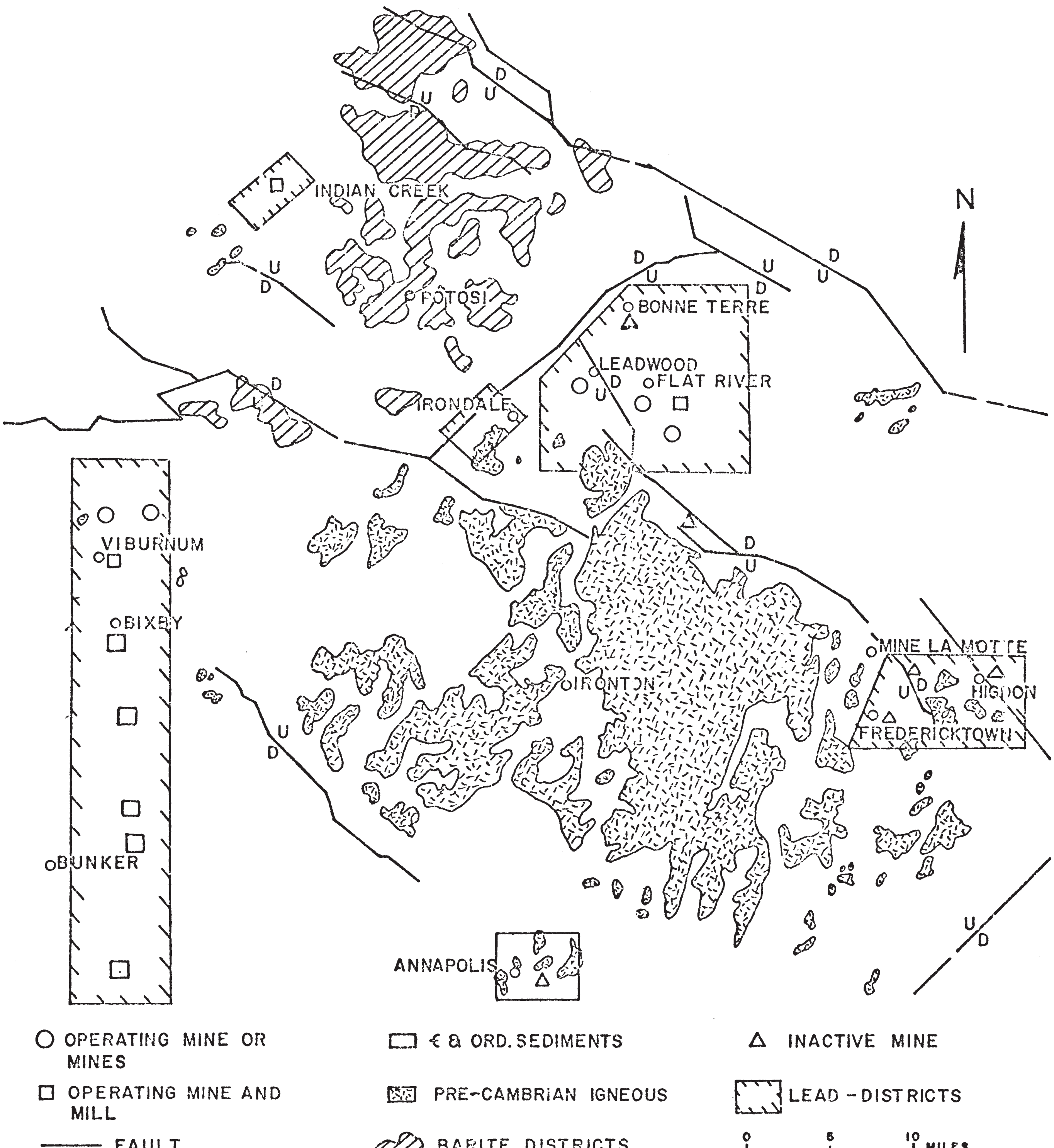
ASSOCIATION OF MISSOURI GEOLOGISTS

15TH ANNUAL FIELD TRIP

BONNE TERRE, MISSOURI

OCTOBER 3-4, 1969



MAJOR GEOLOGIC FEATURES OF LEAD AND BARITE DISTRICTS OF SOUTHEAST MISSOURI

ASSOCIATION OF MISSOURI GEOLOGISTS FIELD TRIP

October 3, 1969

For the Friday afternoon trip we have been invited to visit Milchem's Settle barite pit and washer near Potosi, Mr. Olin Whaley, Manager, and Baroid's Fountain Farm barite grinding plant at Mineral Point, Mr. C. Houk, Manager. These arrangements were made by Mr. Russell Dessieux of Chas. Pfizer & Co., Inc. who has provided the following information about the barite industry and flowsheets of these plants (Figure 1).

In Washington County, all barite mining operations are similar with only variations in the kind and size of equipment used. The only production of barite currently is from the Potosi and Eminence formations.

The barite mined occurs in the residual clays of the Potosi and Eminence formations. Only minor amounts of barite are produced from bedrock. The clay containing the barite is loaded using power shovels or front-end loaders into large off-the-road dump trucks and hauled to the washer where it is dumped into a truck hopper. From here the material is fed into a large rotary breaker using high pressure water. Some selectivity occurs in the breaker as the softer barite more readily breaks than the gangue rock. The oversize is hauled off as waste.

From the breaker the material falls into the logs which separate the clay from the gravel and barite. The log tails, containing mostly clay, flow by gravity to the tailings pond.

The washed material from the logs is fed into a secondary rotary breaker or trommel screen. The oversize material from the trommel is a by-product but is used for road building material.

The material that passes through the trommel screen is conveyed to the rougher jigs which separate the barite from the gravel by gravity. The jig tails or gravel is a by-product used for road building material.

The barite is then ready for fürther grinding or processing, depending on ultimate uses.

The amount of material washed per hour through a barite washer ranges from 70 to 120 cubic yards, depending on size of the loading equipment and capacity of the washer. The yields range from 100 to 150 pounds of barite per cubic yard of material mined.

Barite production in Missouri in 1968 was 314,000 short tons, valued at $6,800,000, much of which came from Washington County.[1]

1. Missouri Mineral Industry News, July, 1969.

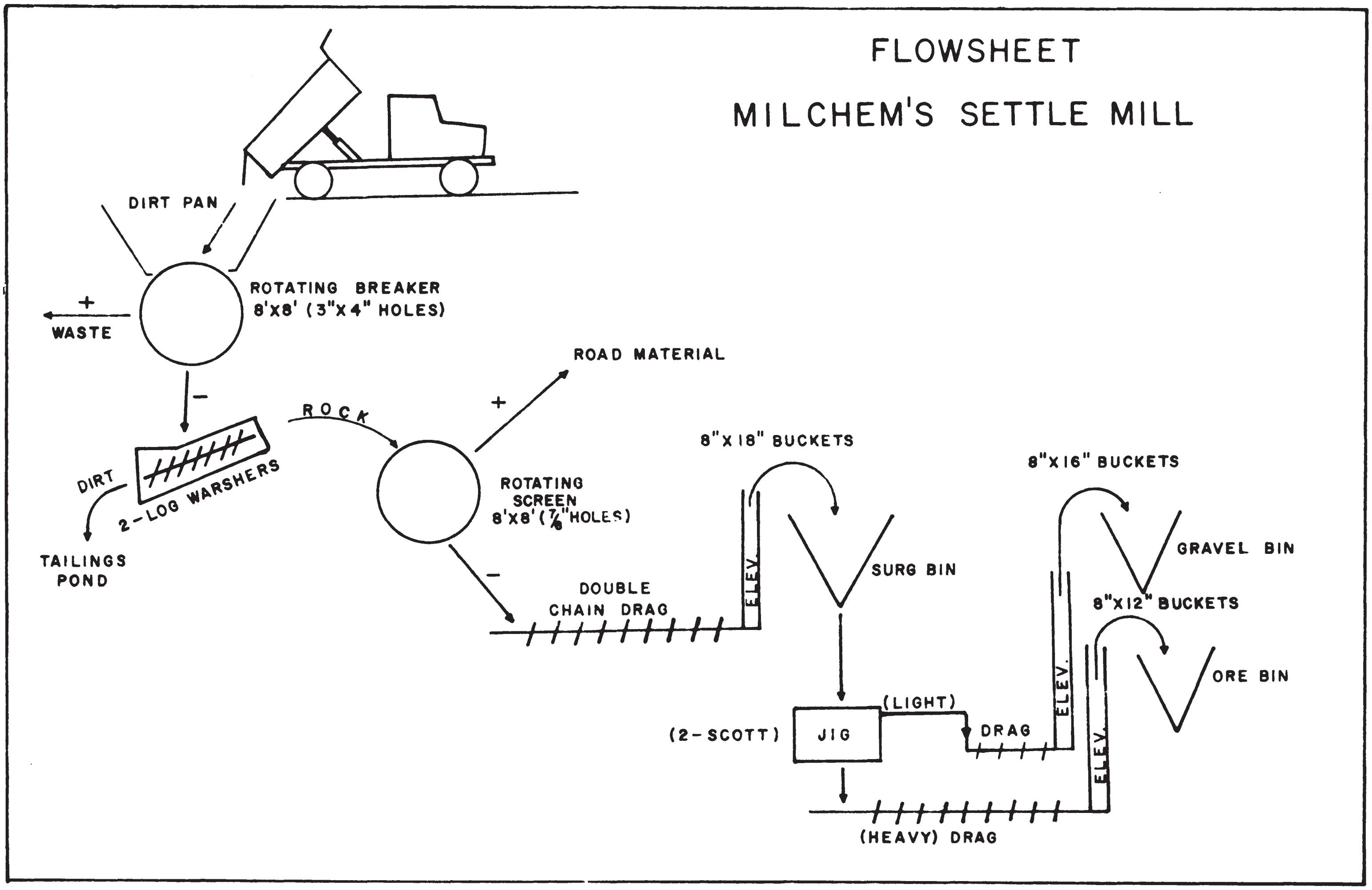
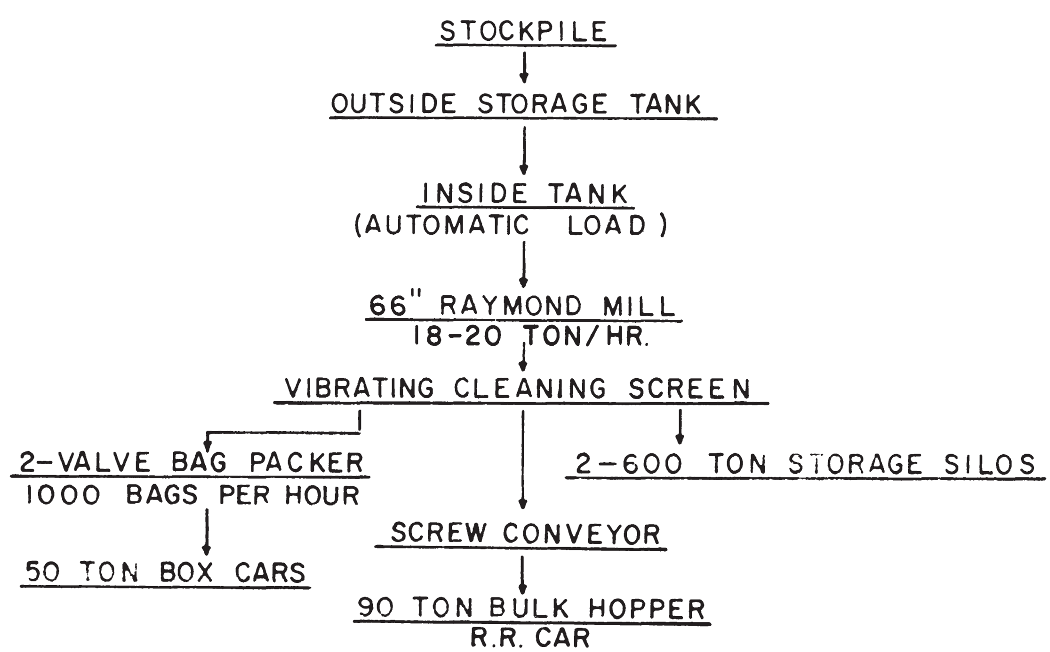


FIGURE 1



FLOWSHEET

BAROID DIV. OF NAT'L. LEAD

FOUNTAIN FARM GRINDING PLANT

ASSOCIATION OF MISSOURI GEOLOGISTS FIELD TRIP

October 4, 1969

Harold E. Myers

INTRODUCTION

We are primarily interested in the Bonneterre formation which is about 400 feet thick in this area. To a lesser degree the underlying Lamotte sandstone and Precambrian surface are important. Local usage breaks these formations into numbered units (Figure 3). These divisions were evolved in core logging and are a mixture of lithologic and stratigraphic units. All the units are not present in all places and may change laterally into another unit (Figure 3). This breakdown of the Bonneterre is very useful in interpreting the sedimentary structures and environments which localize ore controls in the district. These units will be referred to by number throughout the guidebook and by the trip leaders.

The major ore controls in the Lead Belt are sedimentary ridge complexes. The northeast grain of the mining is immediately apparent on examination of the district map (Figure 2). This is due to and parallel to a series of northeast-trending ridges. Ridges were developed as irregularities on the sea floor similar to a sand bar, which were caused by the thickening of calcarenite units. The tops of the ridges were above wave base at least part of the time and reworking of sediments left a well-sorted carbonate sand. Away from the ridges, the sediments were finer grained carbonate muds and exhibit little evidence of reworking. Along the flanks of these bars, changing conditions resulted in a number of minor structures and intertongueing of sedimentary units (Figures 6 & 7). Later the bars were the sites of extensive algal reefs. The size of the ridges vary widely but most are several thousand feet long (Figure 2) and the closure on structural contours is up to 50 feet. The minor features associated with and localized by sedimentary ridges are the final ore controls. Consequently, the examination of these smaller features is the purpose of this trip.

This trip will cover parts of Mine #8, one of seven mines presently operating in the Lead Belt. These mines all ship ore underground to Shaft #17 at Federal Mill. Present Lead Belt production is about 10,000 tons of ore a day, five days a week.

Figure 4 shows the area covered by this trip with the major structures and stops marked. An examination of the district workings (Figure 2) shows what a small part of the whole we will be able to cover. However, we feel this is a representative sample. While these exposures do not include the most striking in the district, we can see more geology per unit time than any other place in the district.

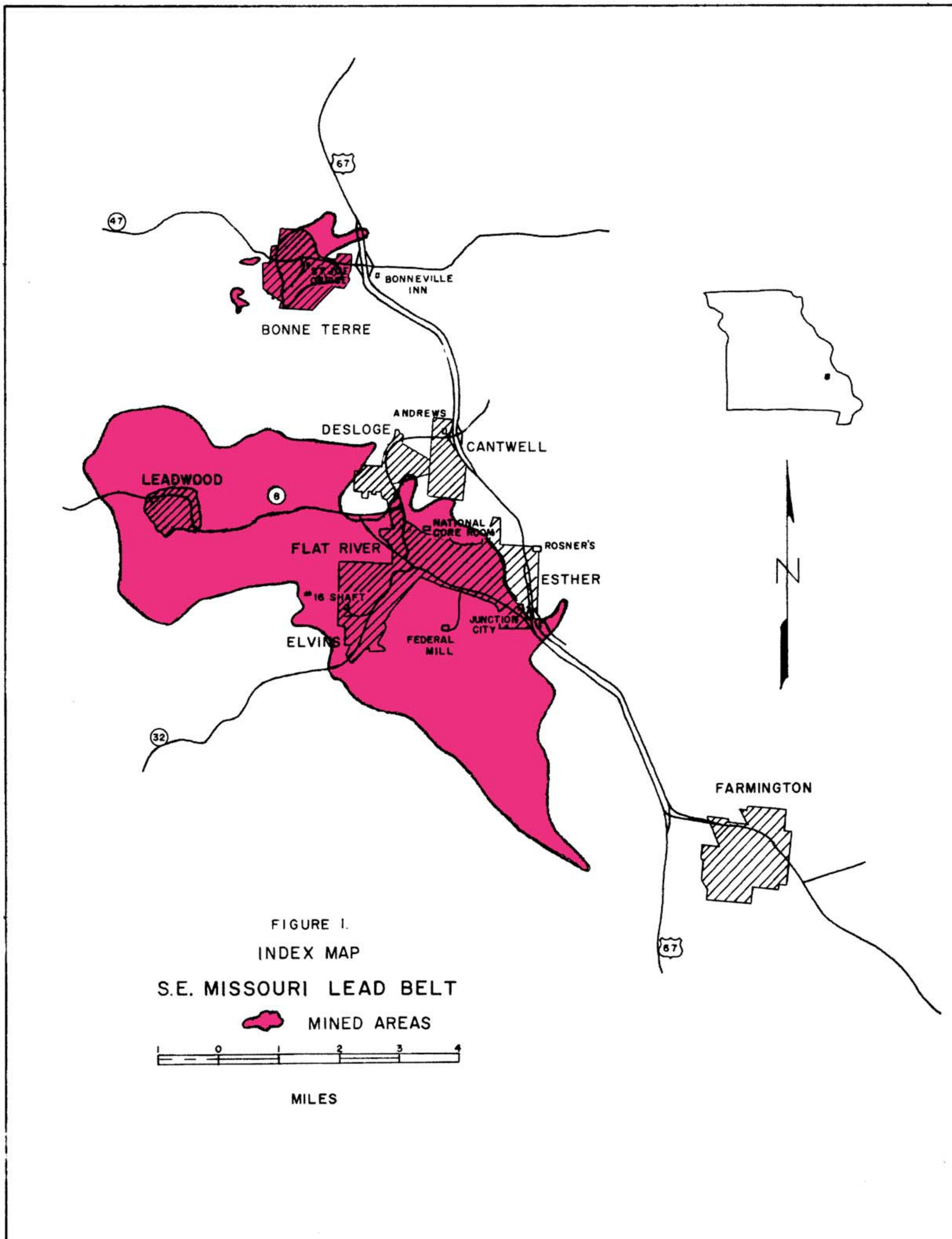


FIGURE 1.
INDEX MAP
S.E. MISSOURI LEAD BELT

Acknowledgment is given to the present and previous members of the St. Joseph Lead Company Geology Staff for developing much of the material in this guidebook.

Geology Staff - October, 1969

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SAFETY PRECAUTIONS

This may not be a conventional welcome but we want you to be sure to read the following:

1. The overhead trolley wire carries 275 volt D.C. power with the railroad track as the ground. Be especially cautious when entering or leaving the man-car.

2. Any other power lines carry 440 volt A.C. power. The insulation may be bad at places due to the age of some of these lines.

3. Avoid stepping on loose rock which might turn underfoot.

4. The trip route has been examined for loose rock and slabs, however, it pays to look up before hammering or prying on either walls or pillars.

5. Stay with the group - it's a big mine.

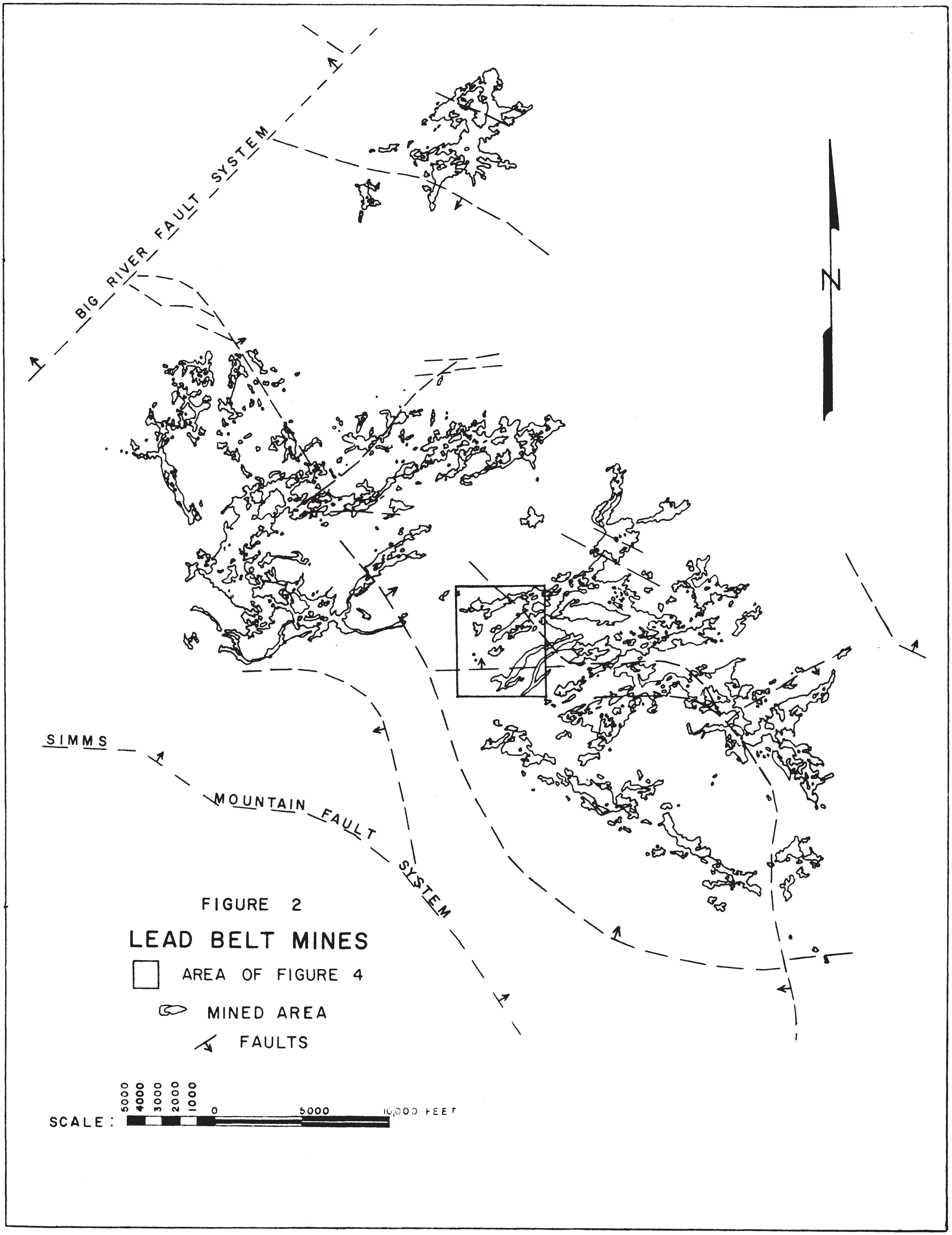
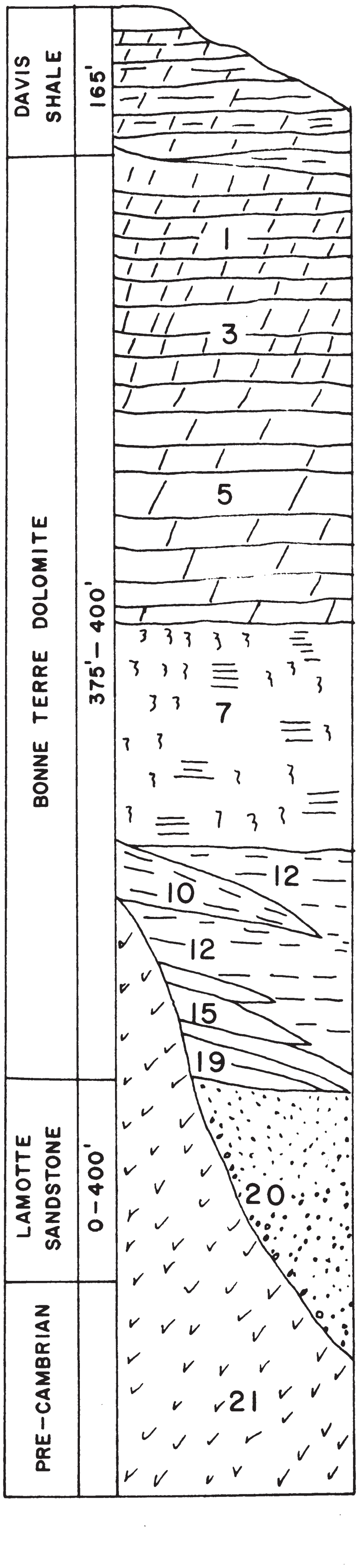


FIGURE 2

LEAD BELT MINES

FIGURE 3

GENERALIZED STRATIGRAPHIC SECTION



1. Dense, gray dolomite.

3. Mottled blue and white dolomite. Chocolate brown dolomite at Bonne Terre.

5. Thick-bedded tan and brown oolitic dolomite.

7. Main algal reef zone. Commonly thick massive reef throughout on ridge structures in Federal area. Thin and scattered reefs in Leadwood area. Non-reef rock is generally thin, wavy bedded, fine-grained, gray or tan dolomite. Contains black shale partings and gray spotting.

10. Thick, fine-grained, even-bedded tan dolomite on southwest side of district. Coarse-grained, lenticular tan dolomite over ridge structures. Thin or absent between ridges.

12. Thin, wavy bedded, fine-grained and spotted dolomite. contains black shale partings. "Marble" beds common at base. Thin over ridges.

15. Light colored, coarsely crystalline. Often glauconitic. Frequently thick over ridges.

16. Brown compact dolomite. Algal mat, sometimes with "fingers", locally called "marble". Usually found at 15/19 contact.

19. Tan or gray sandy dolomite. Thickens to form ridges.

20. Sandstone with occasional siltstone beds. Poorly cemented in upper part. Thin dolomitic sand beds in upper part. Residual igneous boulders at base.

21. Precambrian, granite and porphyry.

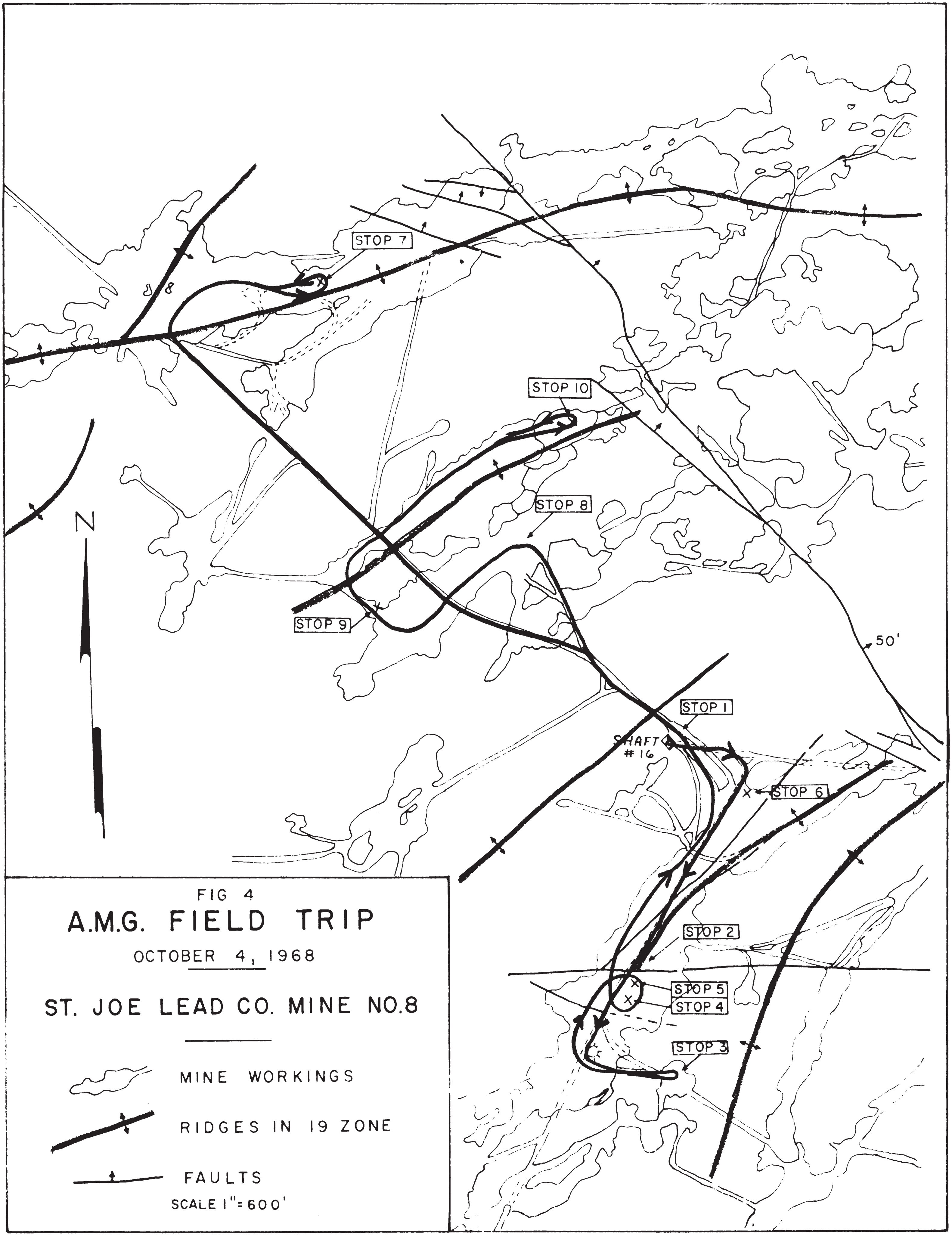


FIG 4

A.M.G. FIELD TRIP

OCTOBER 4, 1968

ST. JOE LEAD CO. MINE NO. 8

STOP NO. 1

Lower Level of Shaft No. 16. This is an exposure of typical Lamotte sandstone (Figure 3) which underlies the entire Lead Belt with exception of the few places where porphyry knobs extend into the Bonneterre formation. Note the Lamotte's purity, its fineness of grain, its crossbedded character, its poor cementation and its high porosity and permeability. Finally, note the traces of lead mineralization present at this locality.

Also exposed at this level is the contact of the Lamotte sandstone and the sandy transition or 19 zone of the lower Bonneterre (Figure 3). This will be seen up a short incline. Note the smoothness of this contact, the sharp change in the composition of the sediment, and the similarities of the sedimentary structures, i.e. crossbedding, etc.

At no time on this trip will you be more than 100 feet vertically above the Lamotte formation and most of the time this distance will be less than 50 feet.

Glauconite is present here in the 19 zone, therefore, a word about its occurrence is in order. Glauconite is found scattered throughout the lower Bonneterre formation in amounts varying from traces to 40-60% of the rock. It does not appear to be restricted to any one environment nor to influence mineralization in any way. Certain units of the 15 zone typically have a concentration of glauconite (Figure 3).

As we walk south through an old mainline drift you will have opportunity to observe the Bonneterre-Lamotte contact again. The contact is well marked as it comes out of the back of the drift. The southwest dip is the result of regional faulting and is the reverse of the original dip.

STOP NO. 2

Fault Exposed in Drift. A brief stop will be made here to look at a fault which will be seen again at a higher elevation at Stop No. 5. This is a persistent fault traceable for thousands of feet along strike. The vertical displacement, however, is small being on the order of ten feet; down on the north. One of the more interesting aspects of this fault is that wherever it crosses a sedimentary ridge complex there is mineralization.

Some characteristics of faults in the district might be of interest:

1. Vertical displacement varies from a maximum of 600 feet to a minimum of inches.

2. The dip is always near vertical.

3. They are mostly left-lateral wrench faults.

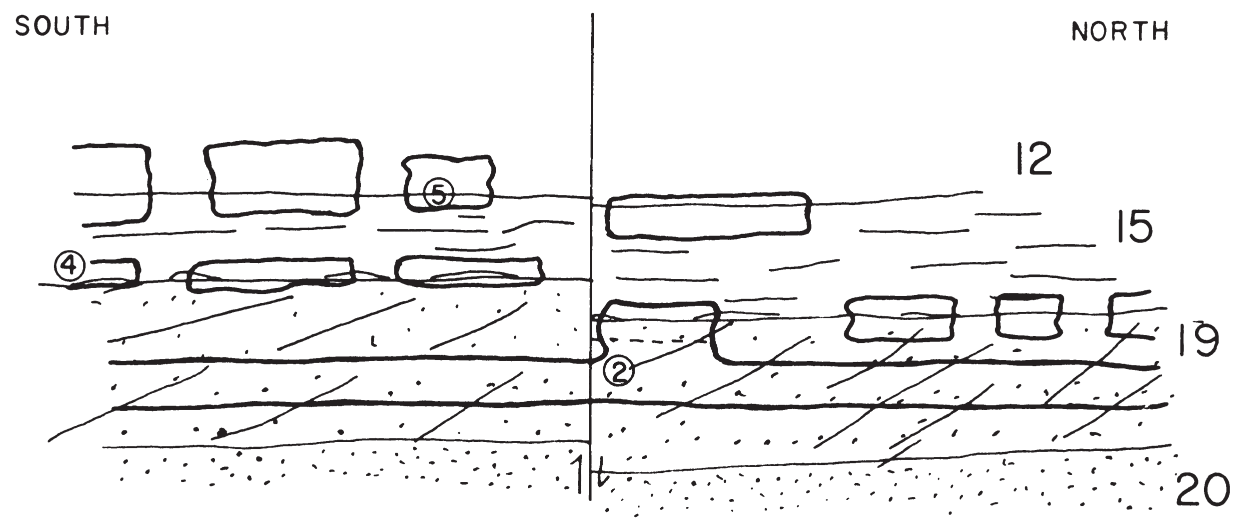


FIGURE 5

GENERALIZED SECTION ALONG DRIFT

SHOWING RELATION OF MINING TO FAULT

SCALE 1"= 50' STOPS ②

Stop No. 2 (Continued)

4. Horizontal movement is greater than vertical. Where displacements have been determined, this ratio is about 6:1.

5. Galena is found in fault gouge both as good crystals and as crushed and sheared masses. Often both are found in the same fault.

6. Faults are areas of leaching and oxidation by meteoric water and often carry water when cut by the mines.

The remainder of the drift is in the sandy transition (19) zone. The stoped area was mined on the 15/19 contact. This is on the southeast flank of a major ridge complex striking NE-SW (Figure 4). Some time will be spent examining sedimentary structures associated with this complex (Stops 3, 4, 5).

STOP NO. 3

Drift 49F103. As you walk through the drift to Stope 49F103, note particularly the top of the 19 zone. The drift is almost normal to the ridge axis (Figure 4) with the crest of the 19 ridge just east of Stope 49F103. At the entrance of the drift the contact is about waist high with channeling and patch reef development. It is climbing steeply and goes into the back before we reach the stope and in the stope the contact is 12-15 feet from the floor. There are good exposures of crossbedding within the 19 zone along the left side of the drift.

STOP NO. 3A

Stope 49F103. This area gives an opportunity to see the upper beds of the 19 zone in an area where these beds are extensively mineralized. This stope has been abandoned because it is too low grade to mine but one can see the nature of the mineralization with the best galena at the 15/19 contact and disseminated galena throughout the top of the 19 zone. Note the high sand content which is variable in different beds, the irregular bedding and cross bedding, and the erratic nature of the mineralization.

Also of interest here is the small vertical fault (vertical displacement 1') which cuts across the stope. Note the open spaces filled with calcite and some galena. Note especially the plan view of the fault as exposed in the back. Would you expect so much fracturing and brecciation on a fault of such minor displacement?

STOP NO. 4

Tarr Park. This area is popularly known as "Tarr Park", since here (and at Stop No. 7) many of the illustrations and deductions in W. A. Tarr's classic paper on Southeast Missouri geology were developed (see Economic Geology - 1936). Many of the stope exposures remain almost the same as 33 years ago, although there has been some extension of the area mined, some bottom taken out and extensive mining overhead at a higher level. The top of the sandy transition (19 zone) is exposed, clean and sharp, at all lower elevations in the stoped area. This is overlain at most places by a foot or two of brown compact algal dolomite* and numbered 16 in the section. Locally, a thin light colored, glauconitic bed (15 type) may be present between the transition and this unit. If present, it usually contains some sand and is included with the sandy transition. This brown dolomite bed is now regarded almost certainly as primarily an organic reef layer, essentially algal, with plentiful fossil remains and lime mud. The algal interpretation is based on the widespread, though scattered, presence of vertical, cross-cutting cylindrical growths (digitate stromatolites) called "fingers", which locally attain diameters up to 6 inches. (See discussion Stop No. 10).

The lower brown dolomite is overlain by a one-foot bed of light-colored glauconitic rock (15 type) and this, in turn, by a second brown dolomite zone normally 30 inches thick, which is the key unit in this stope. This second unit is likewise regarded as basically an algal zone, though with much other contributing sediment. Faint "fingers" and vertical growths and masses of brown mottled material, almost certainly algal, are present in most exposures.

This unit is very patchy in distribution, variable in thickness and partially or totally absent over broad areas. Wherever thinnest or absent, its stratigraphic position is usually occupied by a few inches of black shale. A rich streak of galena commonly is present in and immediately above this black shale. The marginal structures where shale fades out and the brown dolomite rapidly builds up to full 30-inch thickness are called "fan-structures" (Figure 6A) and mark very sharply the boundaries of mineralization or stope limits, although interior islands, bordered by fans, are not uncommon.

The significance of the shale bands and their relation to mineralization is one of the key Lead Belt problems. Tarr proposed that they were the result of solution of the brown dolomite bed, the shale being the insoluble residue. He found a number of plausible structural features to support this reasoning, and in his enthusiasm even suggested that the galena had been greatly concentrated or enriched by this process.

* The local term for this unit is "Marble", abbreviated "N".

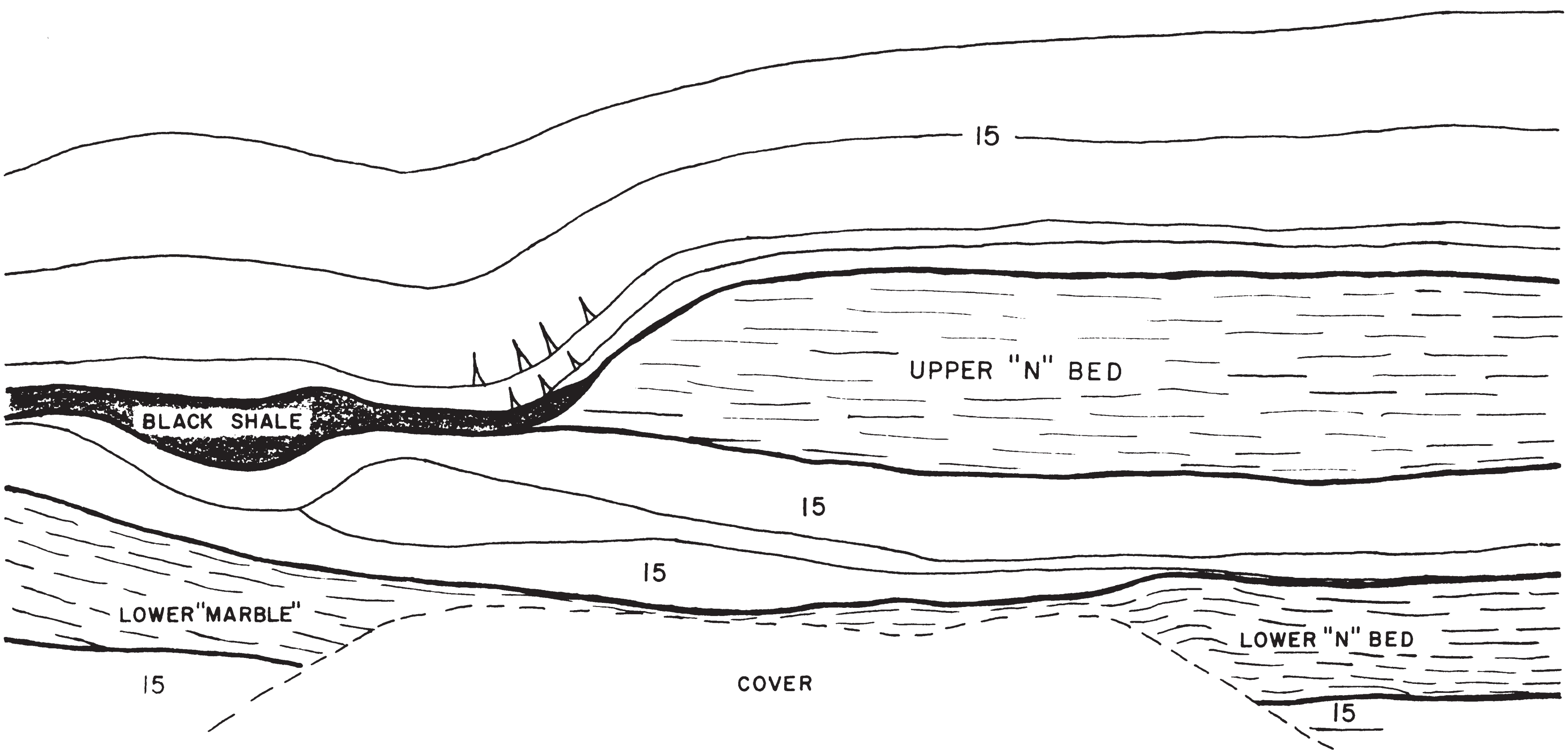


FIGURE 6A

"FAN—STRUCTURE"

SEEN AT STOP 4

SCALE: 1" = 2 FEET

Stop No. 4 (Continued)

Early in the present geological study of the area a project for the study of these shales was set up under Professor Kerr of Columbia University and carried out by Donald F. Beaumont. The essential conclusion of this study was that the black shales were the depositional equivalent of the brown algal dolomite and not a solution residue. The principal facts developed were:

1. The black shales are predominantly composed of illitic clay.

2. They contain substantial fractions of fine detrital quartz, feldspar and porphyry plus some dolomite.

3. They are full of finely divided iron sulphide, which is responsible for the black color.

4. There is no carbonaceous content as has been suggested because of the color.

5. The insoluble residue of the related brown dolomite pods (about 7%) is insufficient in amount and too dissimilar in nature to correspond to the shale layers.

At the time of Beaumont's work, in 1952-53, the algal and reef-like nature of many of the organic beds in the Bonneterre had not been recognized. It is now much easier to understand and interpret the black shales. Essentially, they are believed to be the muddy sediments of lagoons enclosed by fringing reefs, and interrupted in places by patch reefs. The thin "marble" layers or lumps within the shale areas are, therefore, imperfect reef growths within the lagoon that were stifled and submerged in clay-rich sediment. The sediment was initially very high in water content and underwent much compaction and squeezing upon burial. Considerable bending, warping and thickening occurred in the immediately overlying layers before consolidation. This bending was soon masked by later deposition - usually after deposition of 4 to 5 feet.

Ore on this horizon (at or near the upper surface of the 19 zone) usually is associated with well-defined ridges in the sandy transition (19 zone). These ridges, in the nature of sand spits, usually trend northeastward, evidently due to the prevailing ocean currents. Algal reefs flourished on, and especially along the flanks of the ridges at the end of sandy transition time. The result commonly was a set of fringing reefs with interior lagoons bounding a transitional ridge; the lagoons were quite irregular in outline, especially if the ridge slope was very gentle as here at Stop No. 4. Note the much narrower mined area in the southeastern or steep flank of this ridge (Figure 4).

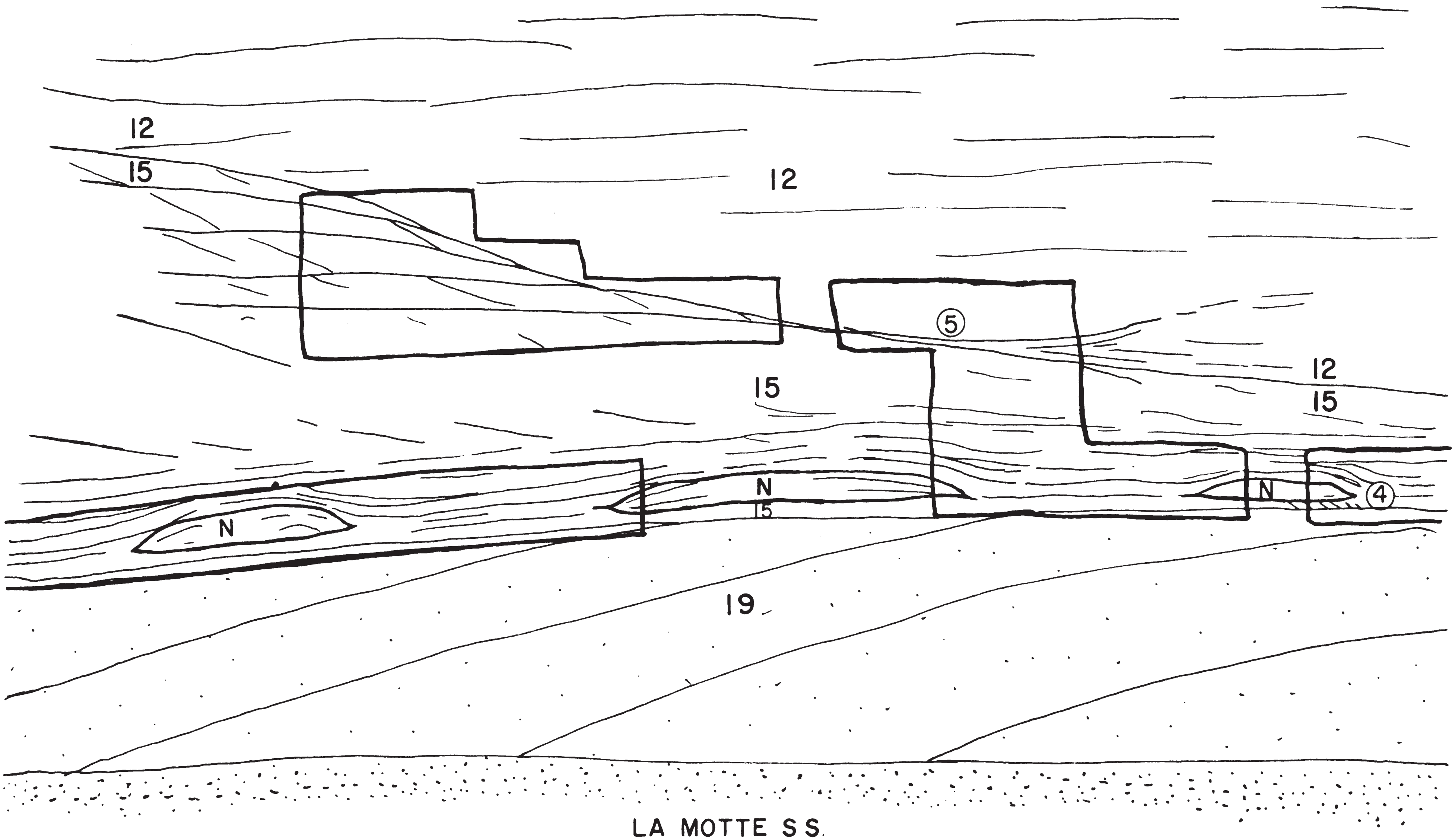


FIGURE 6—RIDGE FLANK STRUCTURE

NO. 8 MINE 1988 SHEET

④ STOPS

SCALE: 30 FT

STOP NO. 5

By way of a short incline, it will be possible to walk up to a stope directly overlying that of Stop No. 4 and 20 feet higher in elevation. The intervening beds, 10 to 15 feet in thickness, at places contain a few thin seams of lead ore but generally consist of tan crystalline dolomite, classed as 15 zone by its position but without much of the usual light color and common glauconite content. These tan beds are moderately coarsely crystalline, fairly dense and in places strongly crossbedded. They are believed to represent calcarenite sand. This lime sand, while lacking in quartz content, nevertheless, lent itself to the building of many ridges similar to those of the sandy transition. These upper 15 zone ridges are sometimes superimposed on but are often offset from or cross at a slight angle to the 19 zone ridges (Figure 6).

Reefy and organic rock again developed commonly over or along the flanks of these ridges, with minor lagoons and black shales over their surfaces.

Note here, as in the stope below, how galena so commonly forms a very rich seam just above a black shale band, and how it replaces the overlying dolomite far more than the dolomite below. As a general rule, it is common to find the overlying rock is mottled or gray whereas the underlying is likely to be a crystalline tan dolomite. It has been suggested that iron in the beds above was in the ferrous state and that below in the ferric. Was this a factor? Could a slight gradient in temperature, Eh, or Ph, have been a possible control? It will also be noted that the black shales usually are firmer and better laminated in the lower half of any given seam than in the upper portion. Was the upper surface more permeable? There is definite evidence from permeability studies that shaly bedding planes, even single stylolites, greatly increase permeability <u>along the bedding</u>.

STOP NO. 5A

Also to be seen in this stope is an example of how calcarenite ridges are built both by onlap and lithofacies relationships (Figure 6). Note the lead mineralization on the "crepe"* over tan crystalline dolomite contact; the change of the bed just above the marked bedding plane from a gray "crepe" rock to a tan crystalline rock in just a few feet; the onlap relations of the "crepe" beds to each other and to the tan crystalline beds; note also the persistence of mineralization on the marked bedding plane while the best mineralization remains at or near the "crepe" over tan crystalline dolomite contact.

The fault seen at Stop No. 2 is also exposed in this stope. Here the fault surface is exposed and shows strong slickensides and mullion structures. Note the narrow leached and oxidized zone and mineralization up to the fault plane. This ore is found again across the fault.

If time permits, we can see this fault again on the way back to the shaft.

* Local term for gray to gray-tan, fine-grained dolomite with many closely spaced wavy black shale partings.

STOP NO. 6

Lunch stop.

STOP NO. 7

Stope 4587. This is a famous stope known as 4587, one of the richest ever mined in the Lead Belt, largely mined out 35 years ago. It is at present regarded as an excellent example of a fringing algal reef enclosing an irregular lagoon where two very strong bands of black shale accompanied by intense lead mineralization and minor sphalerite developed over a wide area. The section is nearly identical with Stop No. 4. Clean sandy transition in the stope floor is overlain by a 1 to 2-foot basal reef, then by 1 or 2 thin light-colored 15-type beds commonly strongly spotted with oval brown spots (oncolites). These are formed by algal entrapment of carbonate particles. (See discussion Stop No. 10).

Excellent "fan structures" where black shale flared suddenly into a 3-foot thick "marble" bed once terminated this stope almost everywhere on the northwest (down slope) side. They have been almost entirely mined out though a few vestiges remain.

The basic structure of Stope 4587 is another strong sandy transition ridge 40 to 50 feet in maximum thickness. The algal patch reefs formed characteristically around the 30-foot isopach line. Farther southwest the lower stope fades and ore makes in a much higher overlying reef zone.

Some exposures at Stop No. 7 afford fair showings of zinc sulphide, usually fringing the galena bands both above and below. However, microscopic work rather clearly indicates that sphalerite preceded and is partially replaced by galena.

The main reason for visiting the stope is to view features which we feel could be caused by mineralization stoping. The first is bedding planes terminating against a thick band of galena. The other is blocks of rock which have been dropped and tilted and which are now encased in galena. We welcome your explanations.

STOP NO. 8

Ridge Cross-Section. Figure 7 illustrates this stop. These pillars have recently been slabbed providing cleaner faces in which the rock types stand out. The flank of this ridge complex has been mined from the top of the sandy transition up into the bottom of the reef (7 zone) some 50 feet higher. Note on the right that mining of the 12/19 contact was 8-10 feet high but as the center of the ridge complex is approached mining height is greatly increased where multiple contacts carry mineralization.

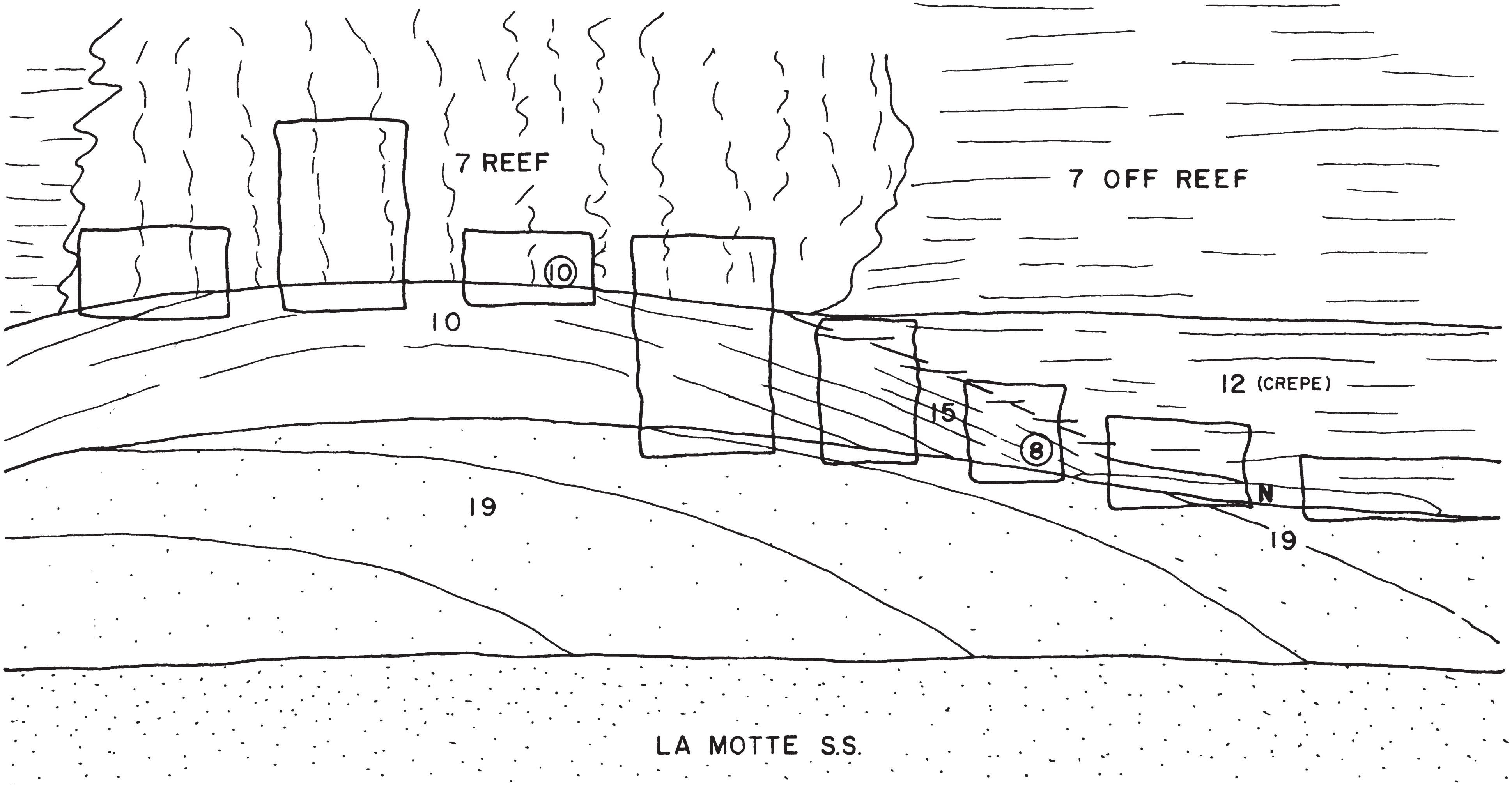


FIGURE 7—EXAMPLE OF RIDGE COMPLEX

NO. 8 MINE 1948 SHEET

(8) STOPS

SCALE: 50 FT.

Stop No. 8 (Continued)

A reef mass sits on top of this ridge just above the highest mining to be seen here. Stop No. 10 is in that area.

Other features of interest here are:

1. An interformational conglomerate.

2. 15 zone light-colored crystalline dolomite pinchout.

3. Galena veining the "marble" bed here.

4. A very sandy facies of the 19 zone.

STOP NO. 9

Cross-cutting veins. This is a brief stop to show galena that is cross-cutting bedding. The rock is 10 zone, tan coarsely crystalline dolomite with scattered oolites. While this type of mineralization is not too important in mining, it must be considered in any theory of the origin of mineralization.

Note the strong initial dip on the flank of this ridge complex.

STOP NO. 10

Reef stop. In this area, about 100 feet above the Lamotte sandstone and resting on a widespread tan crystalline dolomite phase (10 zone) is a broad thick area of 7 zone algal reef (Figures 7 & 8). The most characteristic features of 7 zone algal reef are seen in this stope and include fingers, rolls, roll edge, etc. A discussion of the types of structures follows:

Fingers (Digitate Algal Stromatolites) - Vertical cylindrical structures an inch or two - up to 6" - in diameter which cross thick layers of confused bedding. These fingers are believed to be collenia type algal growths and are characteristic of the 7 zone reef.

Spotting - Both gray and brown spots or balls are seen associated with the fingered reef structures. These are believed to include girvanella type algal growths and are found in reef rock and in bedded calcarenite in or near reef masses.

Reef - A major organic mass, in place, composed of algal deposits and entrapped and interbedded clastic sediment (Figure 8). These form elongate bodies along the crests of tan crystalline dolomite (10 zone) ridges and may be as much as 100 feet thick. These reefs, in mineralized areas, often provide excellent ore receptacles. The ore is found along the numerous irregular thin black shale partings that often separate successive thick layers and along roll edges. Of less importance is mineralization found occasionally following fingers, in vugs and

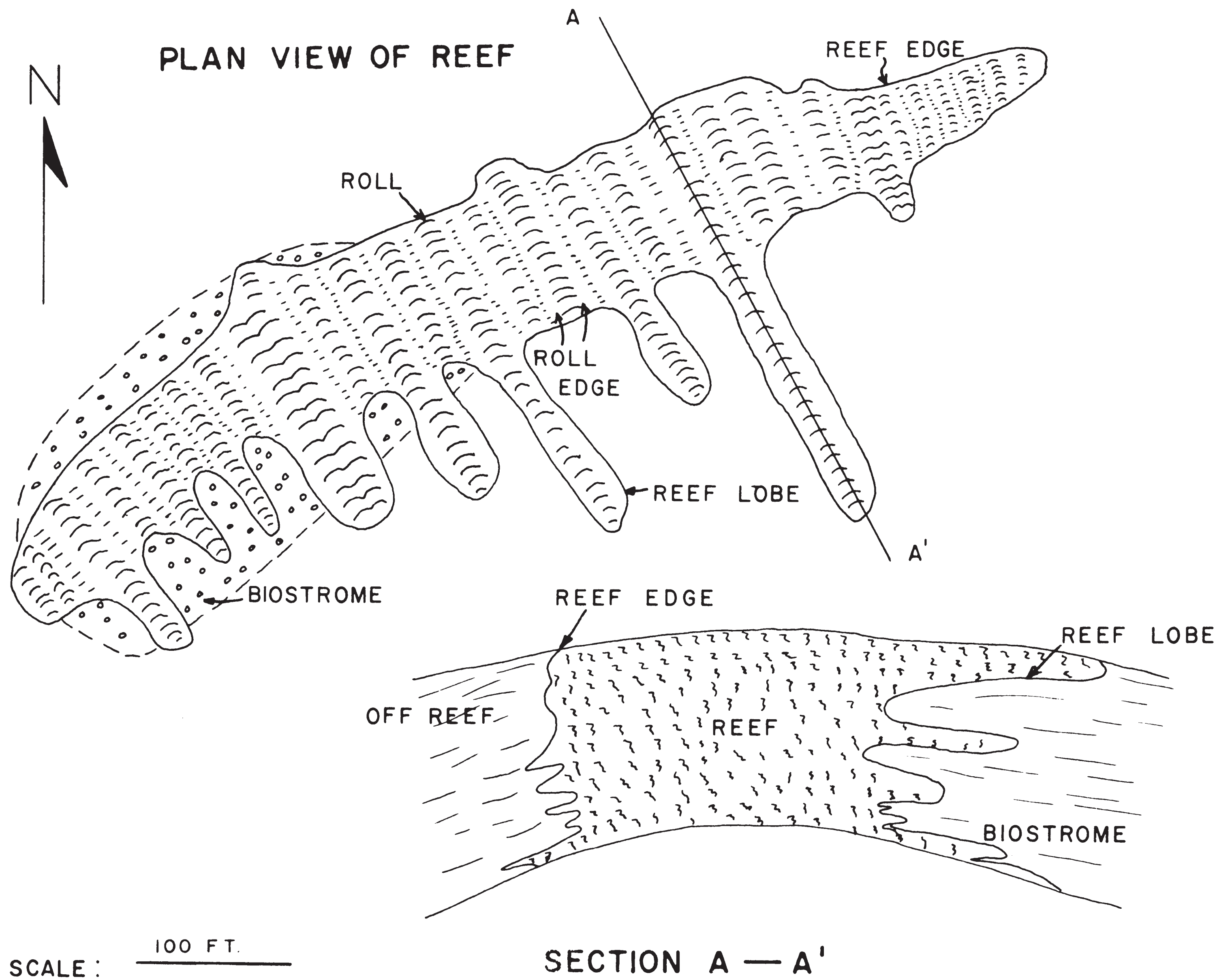


FIGURE 8 — REEF STRUCTURE

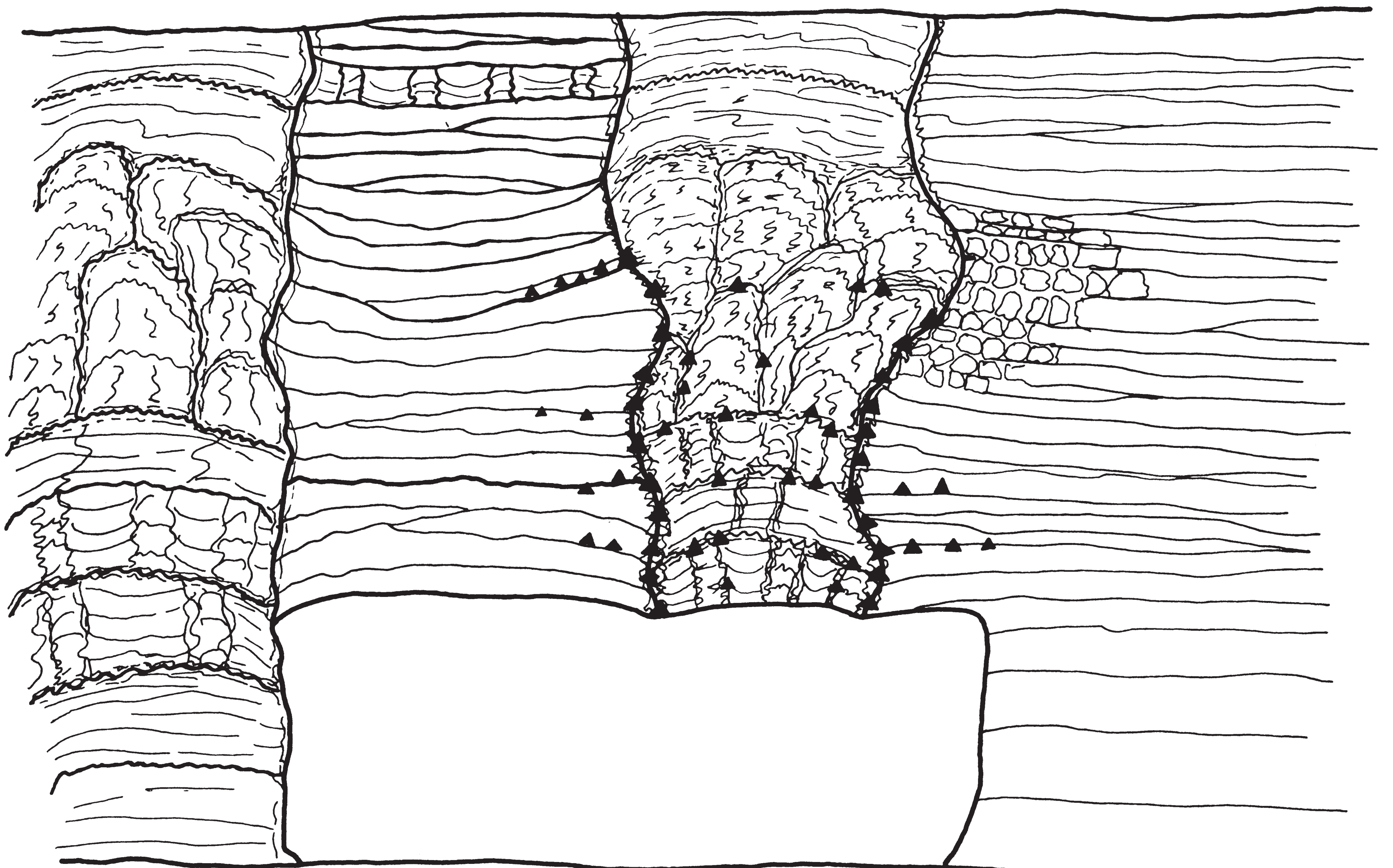


FIGURE 9

CROSS SECTION OF ROLL STRUCTURES

▲ MINERALIZATION

0 5 10 15 FEET

Stop No. 10 (Continued)

patches, and fracture filling.

Rolls - A rectilinear unit within a reef composed of a succession of superimposed colonial growths separated from similar units by clastic sediment or growth lines (Figure 9). These are parallel in a given area and are also believed to be parallel to the current direction.

Roll edge - A near vertical zone of black shale and interbedded reef and calcarenite found where a roll butts against another roll or calcarenite (Figure 9). These are important in localizing ore within the reef mass.

Roll width varies from about 4 feet to up to over 50 feet. The distance between adjacent rolls varies from 0 feet to over 50 feet also. This has a great influence on mining.

Ore is not found outside the reef at this level and much of the reef is only weakly mineralized or barren. Note that mining is at or near the reef-tan crystalline dolomite contact.

LEAD BELT REFERENCES

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Figure 10

Minerals Found in Lead Belt Ores

Country Rock

Adularia
Calcite
Clay Minerals
Dolomite
Glauconite
Hematite
Iron Sulfide (Marcasite?)
Quartz

Mineralization

(* Not universally agreed to belong in this group).

Bornite
* Bravoite
Calcite
* Chalcocite
Chalcopyrite
* Dickite
Dolomite
Galena
* Illite
Marcasite
Millerite
* Pyrite
Siegenite
Sphalerite

Secondary Minerals

Bieberite
Bornite
Calcite
Cerussite
Chalcocite
Covellite
Epsomite
Greenockite
Malachite
Pyrolusite (Wad)

Figure 10 (Continued)

Reported - Extremely Rare

Anglesite
Aragonite
Chalcanthite
Copper, Native
Quartz, Secondary
Tenorite
Manganocalcite