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SMALL SCALE MINING POSSIBILITIES IN SOUTHEAST MISSOURI
6273

by
William Walbridge Weigel

A

T H E S I S

submitted to the faculty of the
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI
in partial fulfillment of the work required for the

D E G R E E O F
ENGINEER OF MINES

Rolla, Mo.

1936.

Approved by

C. R. Forbes

Professor of Mining.

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SMALL SCALE MINING POSSIBILITIES IN SOUTHEAST MISSOURI

I N T R O D U C T I O N

The disseminated lead ore bodies of St. Francois County in southeast Missouri are known for their enormous size and even grade over large areas. Several of these ore bodies are over a mile long by a quarter mile wide. They have been worked on a commensurate scale. The smallest mill in the district, at Bonne Terre, now treats 2,500 tons of ore daily. The other mills range up to 6,000 tons daily capacity. Each of these mills is supplied by a single ore hoisting shaft.

The disseminated ore district of St. Francois County is bounded by the Big River-Bonne Terre fault on the north and west, by the Simms Mountain fault to the west and south, and by the Farmington anticline to the east. Each side of this triangle is about twelve miles long. This district is commonly spoken of as the "Lead Belt". About twenty five miles to the south, at Mine La Motte is a district several miles square of somewhat similar characteristics. This has not been a producer since 1930, but has produced a very large amount of ore in the past.

The large size of the St. Francois County disseminated ore bodies and mills has served to distract attention from the fact that they occupy only a compara-

tively small portion of a much larger mineralized area. This larger area covers all or the greater portion of St. Francois, Madison, Jefferson, Washington, and Franklin Counties, and small parts of other counties in the neighborhood. This outside area has been the scene of mining since 1720 and has a considerable aggregate production, but it sank into obscurity on the opening of the Lead Belt. During the years after the Civil War, up till 1890, this district was one of the main sources of supply for lead and zinc in the United States. Since that date the outlying area has practically ceased mining except for the surface barite deposits. It is believed, however, that there is still a good possibility to develop mines in this outer area. Of course, these would probably not be of the Lead Belt size, but on a smaller scale.

Geology

The general geology of the Southeast Missouri district is simple. At the base are the Pre-Cambrian granites and rhyolite porphyries. Unconformably over these are the Cambrian sediments. The lowest is the La Motte sandstone, up to 300 feet or more thick. Over this, with a transition zone often 50 feet thick, occurs the Bonne Terre dolomite, the ore formation of the Lead Belt and the Mine La Motte areas. The lower part of the Bonne Terre is characterized by being very shaly and oft-

en glauconitic. The upper part is practically pure gray dolomite. The total thickness is about 350 to 400 feet. Although mineralized in some places throughout almost the full thickness, 75% of the ore is found in the lower shaly horizons.

Conformable over the Bonne Terre is the Davis Shale, This is actually only about half shale, the rest being very sandy limestone and dolomites. This formation is consistently about 150 feet thick. Over the Davis, the Derby formation shows about forty feet of massive thick bedded dolomite. Usually mapped with the Derby as a single formation, the Doe Run consists of thin bedded slightly shaly dolomite. Its thickness is about 50 to 60 feet, but is somewhat variable due to an unconformity with the overlying formations. No important ore bodies have been found in the Davis or the Derby - Doe Run.

Above the Derby-Doe Run, the Potosi has a thickness up to 400 feet. It is a dark gray to brown crystalline dolomite. It is characterized by a large amount of quartz-chalcedony druses, particularly near the surface. These accumulate as a residuum, often to a hundred feet or more in thickness. The presence of these "Mineral Blossom" boulders up to several feet in diameter scattered through the soil and in the rock

itself have complicated the prospecting. Diamond drilling through such material is almost prohibitive due to the expense of broken diamonds. It has been customary to use a churn drill either entirely or to set sleeves through to the underlying Derby-Doe Run.

Overlying the Potosi and formerly mapped with it is about 200 feet of similar gray dolomite, but characterized by a solid rusty colored chert residuum instead of the crystalline druses. This is known as the Eminence. These two formations, and particularly the Potosi, have been favorable ore horizons. Most of the production outside the Lead Belt has been from them. The Potosi-Eminence contact is particularly favorable for barite deposits although this material occurs associated with nearly all the Potosi ore bodies. The thickness of these two formations is variable, due to a marked unconformity at the top of the Eminence.

Over the Eminence are the Van Buren and Gasconade cherty dolomite. Over these are the Roubidoux sandstone and Jefferson City Dolomite. The last two are present north of the St. Genevieve fault zone and along the divides to the west. Some ore has been found in all of these.

The regional dip is to the west and only a few marked structures are evident. A few miles east of Bonne

Terre and Flat River, the Farmington anticline brings the La Motte sandstone to the surface. This structure strikes north and south and forms the east boundary of the Lead Belt. It has no direct effect on the ore bodies, however. Slight doming from the irregularities of the underlying Pre-Cambrian is common throughout the area, but is usually extremely difficult to recognize above the Davis. It has been found that the reflected doming has been one of the major factors in the localization of the Bonne Terre formation ore bodies. Many of the domes can be detected only by drilling. It is doubtful if this doming has any effect upon the location of the Potosi formation ore bodies.

Several fault zones cross the area and, as shown below, have strongly influenced the larger ore bodies in the Potosi formation and have certainly effected the Bonne Terre formation ore bodies also. The St. Genevieve fault zone occurs about ten miles north of Bonne Terre and strikes northwest to near Vineland. It continues to the northwest from here but becomes somewhat indistinct. A general disturbed area has been traced through Fletcher and Virginia Mines to the Pennsylvania formation outcrop in north Franklin County. This zone is from a mile to five miles wide, with the general downthrow to the north.

The Big River fault branches off this fault near French Village and strikes southwest past Bonne Terre to Irondale. Then the strike is about due west through Palmer to the dome near Wesco in Dent County. At Palmer this zone is six miles wide and very complex. East of Irondale it is usually about a half mile wide or less. The north side is the downthrown.

To the southeast from Irondale, through Loughboro and into Madison County is the Simms Mountain fault. The upthrown side on the south is mainly Pre-Cambrian outcrop and largely cuts out the Lead Belt formations. Paralleling this fault a few miles to the south of Doe Run is another fault. These two continue to the southeast into the Mine La Motte area. There are numerous branches of all of these main zones and some smaller independent fault zones. The fact that the general vicinity of these zones has been found to be very favorable to ore localization leads to the conclusion that they are probably pre-mineral.

The publications of the Missouri Geological Survey give details of the stratigraphy and structural geology of the region. The Bonne Terre quadrangle, mapped in 1903, has quite a few errors and is not fully dependable for surface geology. The others are probably quite accurate, except in the case of some of the rather poorly

defined faults in the Potosi-Eminence outcrop area. Outcrops are few over much of this, and no doubt some minor faults have been missed. Due to the small scale of the mapping other fault zones such as the Palmer area and the Shirley fault zone west of Potosi have been simplified for mapping purposes.

Individual Deposits.

Lead ore deposits were discovered by the early French explorers about 1720. Mining was started shortly thereafter at Mine La Motte, at Old Mines in Washington County at about 1725, and at other places at various dates up to about 1800. This early mining was largely merely in the surface clay or very shallow surface channels. The deeper mines in solid formation were not opened up generally until about 1840 and thereafter. These old surface diggings are important at present chiefly as an indication of possible deeper ore, especially if they are in a zone of faulting or deep channels.

About 1824, the Valles Mine area, about ten miles north of Bonne Terre, was first mined. This later developed into mines at about 100 to 170 feet depth. Total production up to 1893 was about 25,000 tons of lead and 30,000 tons of zinc. These were largely

oxidized ores and from above water level. The zinc ore was smithsonite, sphalerite being comparatively rare. But little attempt has been made to either prospect or mine this area below water level. As the presence of such a large quantity of so easily soluble a mineral as zinc ore would indicate considerable ore below the zone of oxidation, this area is certainly favorable for investigation. It lies directly in the St. Genevieve fault zone.

To the northwest along this fault zone around Vineland, Frumet, Kingston, and Fletcher is an area of several square miles of extensive mineralization. There has been much shallow lead mining in this area above water. These old dumps and the dumps of a few deeper shafts show considerable sphalerite and other zinc minerals. Certain parts of this area may be considered as a possible low grade large scale mine without ore selection. Other parts might be selectively mined for higher grade ore. Winslow gives a good detailed description of this area.

About fifteen miles to the northwest along the fault zone is the Virginia Mines - Mt. Hope area. This group produced about 30,000 tons of lead, mostly before 1890. But little zinc was associated with these ores. North of the Frisco Railroad, some small deposits are associated with another fault running to the northeast.

The production from these has been comparatively small, totaling about 5,000 tons of lead.

The Big River fault and the Simms Mountain fault meet a few miles west of Irondale. This general area contains several formerly worked deposits. One mile west of Irondale, the Federal Lead Company worked a lead mine in the Bonne Terre formation. Although the ore was good and drilling had shown more ore, this mine was closed in 1907. The cause was probably the general economic conditions and difficulty of supervision from Flat River at that time. Marked variations in elevation of the ore due to the faulting complicated the mining somewhat.

Several miles to the southwest considerable ore has been found by drilling in the Bonne Terre dolomite. This was done before 1920 but the land was not bought, owing to the high price at which it was held. These two deposits are in areas on the upthrown side of the faults and the Bonne Terre dolomite is at the surface. They show the effect of doming, as they are on the flanks of large porphyry knobs. The La Motte Sandstone is missing.

About two miles to the north of the Federal Irondale mine on the downthrown side of the Big River fault is a formerly worked zinc deposit. This has produced about 100,000 tons of oxidized zinc ore, or about 25,000 tons

of zinc. This was largely from a surface pit. A 130 foot shaft from the bottom of the pit, below water level, is said to have cut two or three layers of sphalerite. The dump shows some evidence of this. No drilling has been done on this side of the fault in the neighborhood as the Potosi outcrops.

To the west along the fault zone are many small old mines, especially around Palmer in the southwest part of Washington County. The total Palmer production was about 50,000 tons of lead. Little has been done since 1885. The fault zone is very wide and complex in this vicinity but only four or five drill holes have ever been put down near here. As these were drilled for lead ore and only one was cored, it is doubtful if any zinc ore would have been noticed. Some of the shafts in this area went slightly below water level, but mining ceased if much water was encountered. Old miners say that good ore was often quit on this account. The old dumps in the district show some oxidized zinc ore and some has been shipped from here.

West of Potosi about six miles is the Shirley fault, striking NW-SE. The geologic map of the area shows a simple fault but in reality a complex zone a quarter mile to a mile wide is present. At the point

where it crosses Highway No. 8, Dake in his report on the Geology of the Potosi Quadrangle refers to the Big Eye Mine. Since the publication of this report, churn drill prospecting at this point has developed a fair sized zinc ore body with some lead. A shaft sunk near one of these holes shows about forty feet of high grade sphalerite mixed with marcasite, unaltered rock, barite, and galena in the form of a cemented breccia. This is just below the water level. Along this fault in both directions are small hand worked lead mines, that show evidence of zinc ores.

Over the whole outlying Washington-Jefferson County area there has been much shallow lead recovered. Much of this, however, has been simply scattered through the clay as accessory to barite deposits. The larger ore bodies as shown have been as a rule concentrated along the fault zones. Particularly is this true of the zinc ores. Based on the assumption that the best place to find ore is where there has been ore already mined, in the vicinity of the above old mines would be the best location to search for other ore bodies. After this, any other area along these major faults, the St. Genevieve, the Big River, Palmer, and the Shirley, would be favorable. Other areas would require some special indications to justify close examination. It

must be remembered, however, that there may be undiscovered faults of magnitude up to 200 feet or so wholly within the surface area of the Potosi or Eminence formations. There are few distinctive beds in these formations and outcrops have been traced largely thru chert float. For instance, the Shirley fault may possibly continue six miles to the southeast from where it is shown as ending on the Potosi Quadrangle map. This would make it a part of the Doe-Run - Mine La Motte fault zone. West of DeSoto, there has been only reconnaissance geologic mapping done. This has indicated that faulting is widespread and probably complex in detail.

Causes of Slow Development.

About 1885, the mines in the Lead Belt region began to completely outclass the mines of the Washington - Jefferson County area. The Lead Belt Mines, although occurring at some depth, up to 350 feet, were easily prospected with the diamond drills. First prospecting was restricted to the area of Bonne Terre formation surface outcrop. It was thought that the ore did not occur where the Bonne Terre was covered by later formations. This has since been entirely disproved. The area of Potosi outcrop to the west and north with its heavy mantle of residual chert and quartz druse

pockets in the solid rock was both difficult and expensive to drill. The Bonne Terre formation was at such depths, 600 to 900 feet, that special drills were required to reach it.

Nevertheless a little scattered drilling has been done throughout the area but nothing of importance except near Irondale has been developed. It must be remembered, however, that even in the Lead Belt itself, holes drilled before 1915 are practically disregarded. The practice at that time was to drill with a solid bit, taking no core until lead ore was struck. Then the driller was to pull out and go back with a core bit. Many of the old drill operators say that considerable lead ore was missed this way. Later check holes verify this. This was partly due to actual inability to notice low grade ore in the sludge, especially if part of the return water was lost, and partly due to the driller not wanting to lose an hour or so changing bits. In the case of outlying areas under option, where perhaps a half dozen holes would be drilled on several hundred acres, the drillers would sometimes not report lead ore even if noticed and would actually throw away lead cores. This was because most of them lived in the Lead Belt and with the poor transportation of those days did not want to do much further drilling at such a

distance. Of course, any zinc ore cut by the solid bit would not be noticed at all. As the zinc ores tend to occur higher than the lead ores, it is possible that much was passed over in this way. One factor was that the mining companies actually stayed away from the fault zones to avoid the difficult drilling in broken ground.

Later drilling practice was to use the solid bit to a certain point in the formation and to core from there to the top of the La Motte. This is the present practice. However, these core bits were, of course, set with carbons and at first were set very dull. The effort of the bit setter was to cut carbon costs. Consequently core recovery was very poor, probably under 75%. In addition, it must be remembered that in all drilling, lead ore was what was being sought. Zinc ore was not even wanted and consequently unless extremely rich/^{neither}the driller nor the core estimator made any note of its occurrence. Old cores upon examination often show more zinc than lead, but no record was kept of this. The zinc ore is not conspicuous and was probably missed altogether in many holes even by conscientious core drillers.

The Lead Belt had a large area and the mining companies bought large amounts of land. Much of this was

totally unprospected land and as a result of gradual consolidation very large holdings were brought together. This gradually cut out the competitive urge to buy more land and since 1920 but little land has been bought in Southeast Missouri for mining purposes from private individuals. These huge reserve land holdings will require many years to prospect and develop and, in the meantime, the tax burden is heavy. One company alone has local taxes in St. Francois County alone of approximately \$500,000 a year. Due to the gradual more intensive prospecting, (more holes per acre) the speed of development is actually slowing down.

During this period of active land buying, the land owners even in the outlying areas preferred a possible distant future sale of their holdings to the expense and risk of trying to drill and develop it themselves. Untested, they were hopeful to get a good price for their land. If proven worthless, they would lose any chance of sale. In addition, the gradually developing large scale of operations in the Lead Belt, brought on by the comparatively low grade ore and the water problems encountered gave the district the name of requiring large capital.

Future Development.

Several attempts by outside companies to enter the field in recent years have met with poor results. This may have been largely because of poor management and lack of experience with the local problems and technique. One well financed campaign in the 1920's failed largely because it was on the leavings in the Lead Belt itself, land that had been already proved worthless by the older operators. Any attempt without close control from somebody of local experience is under considerable handicap. The geology is apparently simple but in detail is vague and but little understood except by those in close contact. The prospecting by diamond drills has many features peculiar to this field.

The St. Francois County field has been worked almost entirely under fee title. Neither the mining companies nor the land owners wished to work under leases. This large outlay of capital for land has kept out the small operator as much as anything else. With the cessation of active land buying and the wide publicity given the Joplin type of operating royalty lease, this attitude on the part of the landowners has changed. Operating leases for most prospects outside the Lead Belt could be readily obtained at reasonable prices.

The working of the barite areas on a semi-royalty basis has been carried on for a long period.

Judged by past experience, the character of the ore associations is such as to facilitate both selective mining and ease in milling. The mineralization is coarse and usually in distinct bands. The galena ore bodies at Palmer usually occurred as horizontal layers a few inches to a foot or more thick of pure galena. These would be ten to twenty feet wide and up to several hundred feet long. Associated would be several feet of clay readily separable. In fact, the gangue was mined off first to leave the galena layer free to be mined in a practically pure state. Several such runs or "channels" were usually parallel to one another at twenty to thirty feet centers. The hard rock gangue has some scattered lead through it, particularly in small seams and cavities. The zinc ore bodies, while as a rule not occurring in such pure layers, were coarsely mineralized. Much of it was found as interlacing seams and heavy incrustations. Other zinc ore bodies were largely cemented breccias. The Shirley shaft shows ore of this type. The original rock shows but little mineralization, the sphalerite acting as the cementing material. Both of these types would concentrate readily. The chief difficulty in separation would occur from the as-

sociated clay in the channel types and the barite from the hard ores. The clay is very sticky and difficult to wash, not emulsifying readily. The barite, due to its specific gravity, being so close to sphalerite, would make coarse gravity separation difficult. In some cases, this might make flotation essential.

Potosi and De Soto both have buyers that will buy any quantity, however small, of galena. Barite, also bought by them, has been left out of consideration, as it brings a comparatively low price and its market is glutted. If considerable quantities of concentrates were made, truck shipments direct to the smelters, or in case of still larger amounts, direct rail shipments would be advisable. Trucking charges direct from the mine to the East St. Louis smelting district would be less than the trucking to Potosi plus the railroad freight unless the mine were close to a shipping point. Zinc ores might have to be shipped to further smelting districts.

Prospecting in the Lead Belt is carried on by diamond drilling holes at regular intervals of 100 to 400 feet. To cover any large area by this means would require a very large initial expense. Holes from the top of the Potosi formation to the top of the La Motte sandstone would be approximately 950 feet deep.

Except for the small area west of Irondale of Bonne Terre formation outcrop, most of the area would have about this depth of drilling. The small operator would be restricted to prospecting the Potosi formation, with perhaps an occasional deep test hole. Such an operator should in addition confine his work to those areas most favorable geologically, that is, in the neighborhood of the faulted zones.

The Potosi-Eminence outcrop area has few outcrops at best, and at the fault zones such outcrops are practically absent. To accurately locate such zones with their intricate branching faults is very difficult. It is possible that for such work, geo-physical instruments would be very helpful. Magnetometers, due to their simplicity and ease of operation, would probably be best for such work. Tests made with them near Potosi have indicated good results on fault structures. Due to the comparatively shallow depths of the porphyry in the area, readings are large and even small faults show marked differences upon crossing them.

The lead ore bodies of the Palmer type have direct mineral continuous contact. Hence they make excellent conductors and they are usually much longer than wide. Such ore bodies should give good results with electrical geo-physical instruments of the resistivity type.

Sphalerite, of course, due to its electro-negative nature, would not show on such tests. Work of this nature, though, in locating faults and water channels, would help in finding zinc ore bodies.

The miners of the area are skilled in cheaply sinking small shafts by hand to depths of about fifty to one hundred feet. After finding good structure and indications by other means, such shafts for testing out the mineral possibilities might be advisable. Drill holes in a Palmer type ore body might go through the barren strips without showing any ore. Shaft testing would avoid such risk. If ore were found, a larger shaft should be sunk for production. For testing below water level and through hard rock, of course, such shafts would not be suitable, and drill hole, preferably churn drill, prospecting should be used. Throughout practically all of the area there is a supply of labor, much of it semi-skilled, plentiful for all except large operations. Wage rates are moderate, as most of the labor would be drawn from a rural element, partly self-sustaining. Local taxes are correspondingly moderate. Rough timber can be obtained over all the Washington-Jefferson area. If extra water is required for milling operations, wells or small streams would give ample supply. Unlike Joplin, however, there are no supply houses for mining machinery

within the district. Such material would have to be obtained direct from the factory, or from St. Louis to avoid maintaining a large warehouse supply.

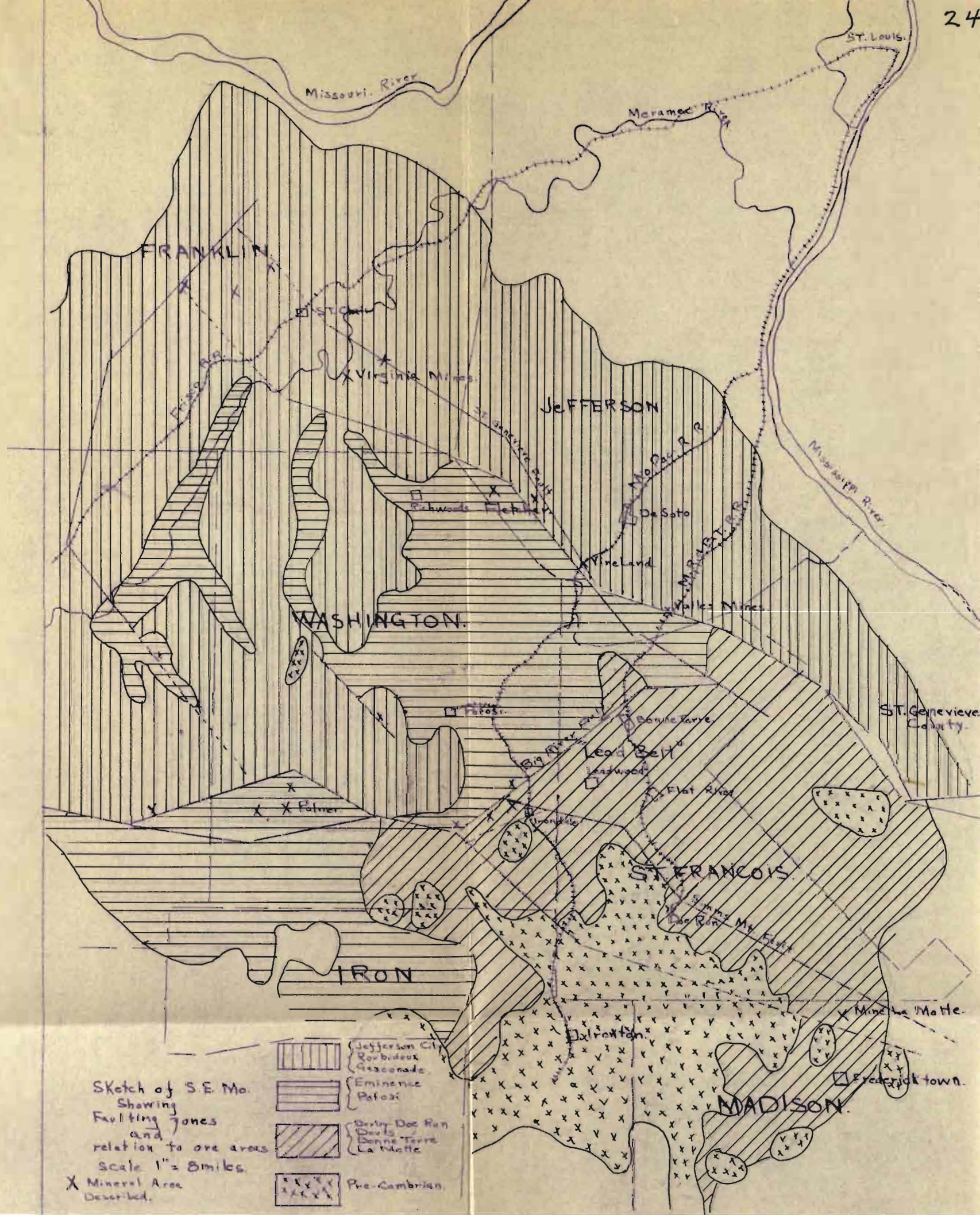
Although fair sized ore bodies may be discovered in this outlying area, past history indicates that the individual ore bodies, at least of the shallow zone, are of small tonnage as compared to the Lead Belt ore zones. The Valles Mines area produced the largest of any single group, about 25,000 tons of lead and 30,000 tons of zinc. It is therefore essential that the development be done very cheaply and that as the life of the mines may be very short that the equipment be of semi-portable type to increase its salvage value. Actual operating costs will be raised, but the total cost per ton lowered. The use of gasoline driven equipment to the fullest possible extent would probably be advantageous in some situations. In other cases, if second hand steam boilers could be bought, steam would be a good major source of power, particularly for pumping. The use of gasoline for major power would necessitate a generator and motors which, while convenient to operate, require highly skilled labor to repair. High tension electric transmission lines cross part of the district and would be available for the development stages of a mine of fair size.

S U M M A R Y

It has been shown that there is a large area in Southeast Missouri outside of the Lead Belt that shows considerable mineralization. This is demonstrated by the operation of mines of considerable production in the past over a widespread area. These mines tended to be along certain major fault zones and, due to the extent of the faulting, the area involved is very large. Owing to lack of capital and the state of engineering knowledge at that time, these mines were worked only for the shallow ores above heavy ground water level and only such deposits as were amenable to hand picking or very coarse concentration. Such deeper prospecting as was done by drilling throughout this area can be largely discounted, particularly if it showed negative results. It is probable that with the advance in engineering technique and the increased knowledge of the geology of the region, that mines of moderate tonnage can be profitably developed in this area at the present time. On account of better market conditions at present and in the near future, the zinc prospects would probably be the more favorable for investigation. History of the older mines indicates that such zinc deposits are actually more probable than lead in the near-shallow zone, that is, in the formations just under the major ground water level.

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Sketch of S.E. Mo. Showing Faulting zones and relation to ore areas. Scale 1" = 8 miles.

X Mineral Area Described.

-  Jefferson City, Roebideux, Gasconade
-  Eminence, Potosi
-  Grassy-Doe Run, Devils-Terrace, La Motte
-  Pre-Cambrian