BARITE MINING AND PRODUCTION IN MISSOURI *

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INTRODUCTION

Barite mining in Missouri probably began about the middle of the 19th century, about 100 years ago, but there is no record of the exact date. Schoolcraft, in a report on the lead mines in Washington County published in 1819, mentions the occurrence of barytes with the lead mineral in Washington County but states that it was regarded as a nuisance by the miners and thrown away or left in the ground to be covered up again by succeeding operations.

Old records in the form of pages from ledgers and day books of several country store keepers indicate that the mining of barite or tiff as it was generally known was well established and fairly profitable industry as early as 1855. The price paid at that time in exchange for other commodities was around $7.00 per ton but a few years after the Civil War it had risen to $10.00 per ton. The first recorded data show that in 1872 a little over 5000 tons of barite was sold in St. Louis, a fact which indicates that the industry must have had a much earlier beginning. Since then there is a fairly complete and continuous record of production and prices.

In the central Missouri region mining of barite is also recorded at an early, though somewhat later, date. In Broadhead's report of 1873 mention is made of a barite grinding plant on Osage river which had been in operation for at least five years previously, and of shipment of ground and raw barite by boat down the river to St. Louis.

Barite is the only barium mineral that is produced commercially in sizeable quantity. Its chief value in industry is the result of a fortuitous combination of physical and chemical properties. Its high specific gravity, combined with relatively low cost, makes it an ideal substance for weighting drilling mud and its chemical stability prevents reactions with the drilling fluids and ground water. In paint manufacture where endurance as well as covering power is essential, barite likewise is a valuable compound.

LOCATION

The center of Missouri barite mining is in Washington County, about 50 miles southwest of St. Louis. This area for many years was the leading producer, not only in Missouri but in the United States. In

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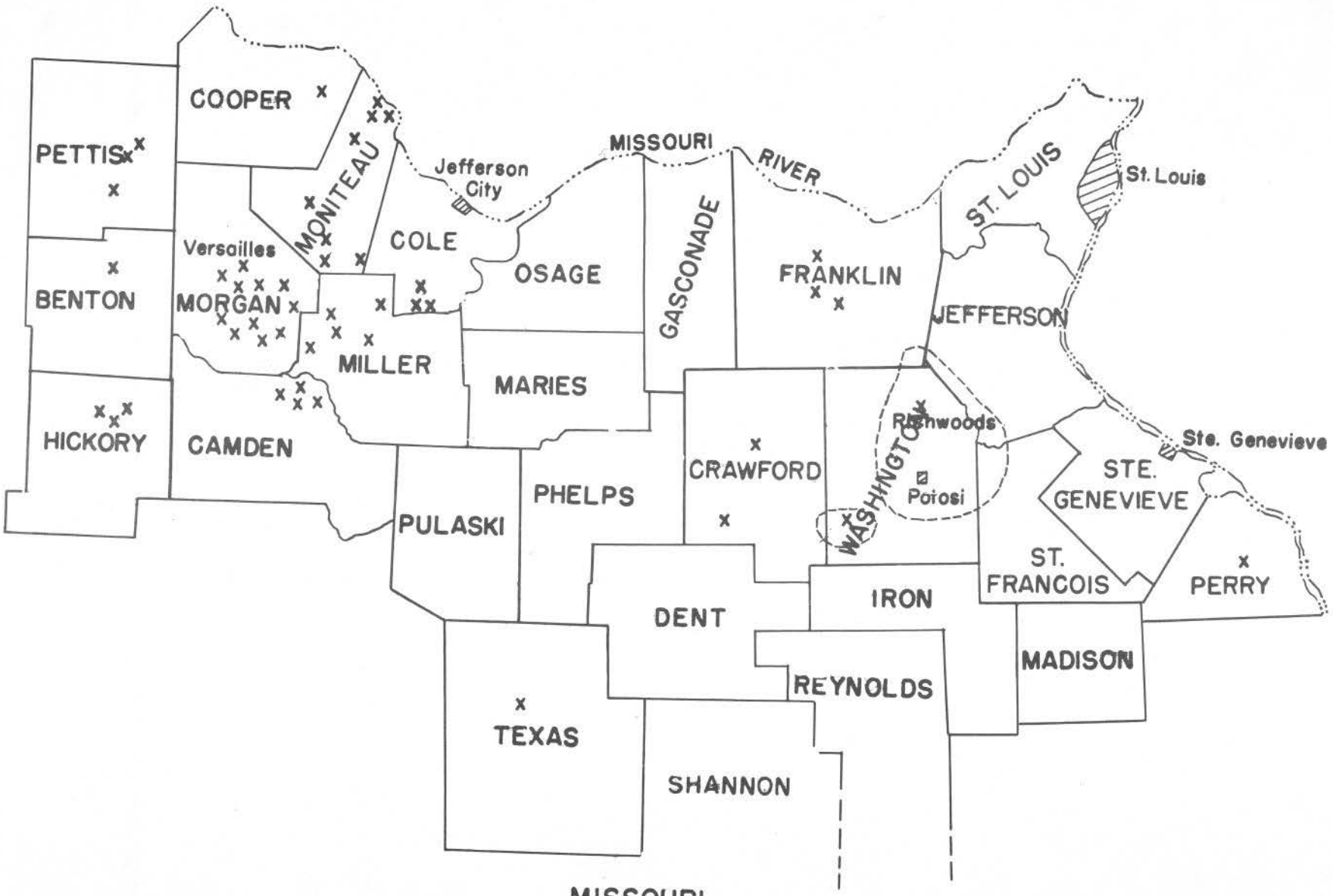


MISSOURI
Barite Producing Areas

addition to Washington County, St. Francois, Jefferson and Franklin counties have produced appreciable quantities and minor amounts have been mined in several other southeast Missouri counties.

In the central Missouri district production has been recorded at one time or another from at least twelve counties, but the principal mines were in Cole, Moniteau, Miller and Morgan counties. The output from these sources, while important, was only a small fraction of the annual production for the State.

GEOLOGY

Geologically, barite has been found throughout almost the entire section from the Cambrian to the Pennsylvanian, but commercial deposits are generally confined to a few favored horizons. The geologic section for Washington County and the surrounding area is shown on page 4. The principal producing horizons are the Potosi and Eminence formations, but the greatest concentration occurs near the contact between the two formations. It is generally assumed that the Potosi is the more important of the two but since no records are available, it is difficult to determine what percentage of the total is derived from each formation and the Eminence certainly contributes a large part. Relatively minor amounts have been produced from the Gasconade formation which crops out to the west and northwest of the town of Potosi and several small deposits have been worked in the Bonneterre, Davis, Derby-Doerun and Roubidoux formations.

In a study of the field relationships of the barite deposits it becomes apparent that although the greatest concentration occurs in the Potosi-Eminence zone, the deposits were formed in whatever formation was at the surface during the time of mineralization. This feature is even more noticeable when the central district is considered. Here the principal deposits are in the Gasconade, Jefferson City, and Mississippian formations and smaller ones in the Roubidoux and Pennsylvanian. There is an apparent connection between the two areas through scattered occurrences in Franklin and Gasconade counties and then west and into Cole, Moniteau, Miller, Morgan and other counties. In the south part of Franklin County barite is found in the Gasconade and Roubidoux, northward it is in the Jefferson City, and to the west in Cole County this is the important producer. Northwest from here it occurs in the Mississippian as at Lupus in Moniteau County and a small deposit was found in the Pennsylvanian in Cooper County. In Miller and Morgan Counties it is found chiefly in the Gasconade but farther west and southwest in Benton and Hickory counties, it occurs in the Jefferson City and in the Mississippian.

This geologic distribution is related to the physiographic development of the Ozark region accompanying the uplift of the Ozark Dome in post Pennsylvanian time. Since the uplift was greatest near the center, the oldest geologic formations are exposed there. Outward from this center, younger beds crop out more or less concentrically around the older core. Erosion reduced this slowly rising land mass to a more or less flat surface and barite was deposited in whatever rocks were at the surface where

DIAGRAMMATIC SECTION OF BARITE OCCURRENCE

GEOLOGIC COLUMN

WASHINGTON COUNTY	
ORDOVICIAN	ROUBIDOUX
	GASCONADE
	EMINENCE
	POTOSI
UPPER CAMBRIAN	DERBY-DOERUN
	DAVIS
	BONNETERRE
	LAMOTTE
	PRE CAMBRIAN

CENTRAL MISSOURI	
PENNSYLVANIAN	CHEROKEE
MISSISSIPPIAN	BURLINGTON, ETC.
ORDOVICIAN	JEFFERSON CITY
	ROUBIDOUX
	GASCONADE
UPPER CAMBRIAN	EMINENCE

the mineralizing solutions were concentrated.

MODE OF OCCURRENCE

Practically all of the workable barite deposits in the Washington County area lie in residual clay, derived by weathering from the Potosi and Eminence formations. The residual mantle varies from a few inches to forty or fifty feet in thickness, probably averaging between ten and fifteen feet. Barite is irregularly distributed throughout the red clay along with chert, quartz druse and limonite. In places there appears to be somewhat of a concentration near the bedrock surface and many of the richest deposits, worked in the days of hand mining were found here, but it is not uncommon to find barite fairly evenly distributed from top to bottom. Lateral distribution is quite erratic. Rich streaks or runs of irregular shape and extent alternate with practically barren ground, probably representing original concentrations in fractures and solution channels in the limestones. Removal of the limestone by erosion, chiefly solution, then left the insoluble barite in the residual clay in positions somewhat parallel to the original deposit. Hillside creep and slumping probably served to distribute it over an area somewhat wider than the original deposit. The contact between the residuum and the bed rock is very uneven. In many places the rock surface consists of irregular pinnacles alternating with depressions and solution channels. Locally the bed rock surface is soft and friable and is known as sand. This condition is the result of solution and recrystallization of the dolomite. The sand is actually a mass of loosely consolidated dolomite rhombohedrons.

Barite varies from minute particles and chips to large nodules and lumps. Some irregular masses weighing hundreds of pounds have been encountered and in the days of hand mining, in virgin ground, the average size of marketable material was probably from eight to ten or twelve inches. Smaller sizes were at first rejected but later, when the ground was reworked a second and perhaps even a third time, much smaller sized material was recovered.

Little if any barite was ever produced from bed rock in the Washington County area. In some places irregular veinlets and stringers can be seen at the outcrop, but rarely have any been noted that were more than an inch in width. Occasionally some fairly large masses were found in the sandy upper portion of the bed rock formation, probably representing the bottom or roots of vein deposits. Such material could be easily dug out of the "sand" in the same manner as it was dug from the clay, but mining in solid rock has not been attempted except where a considerable amount of galena accompanied the barite. From a study of the distribution of barite in the clay, it seems evident that it is largely the result of residual concentration through removal by solution of an overlying formation which originally contained it. The original occurrence was probably a filling of joints and solution openings related primarily to surface features. This relationship is suggested by a deposit in the Eminence dolomite in a bluff on the west side of Big River a short distance north of the village of Fletcher. Here, large massive barite may be seen in joints enlarged by solution, and also in solution openings along the bedding planes.

In the central district the mode of occurrence is somewhat different. Some deposits of the residual type have been found, but the larger and more productive ones are of a type known as "circles". A circle is a circular or nearly circular area of broken or fractured rock associated with solution or sink structure. Usually it is the result of collapse of the roof rock of a cave or of the slow settling of the upper strata over an area of active solution in the underlying rocks. In the first case a sink hole was produced which was partly filled with the broken fragments of the roof, lying in various positions in a confused mass, typical of collapse breccia. The walls of such deposits are usually overhanging and the diameter of the circle increases with depth. If the collapsed area extends to the surface, clay and other debris from the sides will be washed in and may more or less completely fill the space between the rock fragments. Mineralization after the collapse resulted in the deposition of barite and frequently some galena in the broken, fractured sink area.

Where there was no large underground cavity, the collapse was probably no more than a slow subsidence of the upper beds because of bedding plane solution, with accompanying radial fracturing and brecciation and only slight dislocation. More active circulation of ground water in such an area would result in further solution and subsequent mineralization produced a breccia consisting of fragments of dolomite cemented with barite accompanied by small quantities of galena, sphalerite and iron sulphides. Some of the sink structures antedate the deposition of Pennsylvanian sediments, as they are filled with undisturbed beds of shale, sandstone and coal, but others are later and show the Pennsylvanian sediments in confused masses of rubble filling the opening. Barite is more common in the latter.

Circle deposits are usually small, the largest ones being perhaps 200 to 250 feet in diameter. The depth is not definitely known as mining operations were suspended in nearly all cases before the bottom was reached, but at least one was worked to a depth of 125 feet.

In the Lupus area in the northeast part of Moniteau County, barite was found in the Mississippian limestone, in part as replacement deposits. In one of the mines a practically solid face of barite 45 feet high was exposed exhibiting all of the characteristics of the original limestone including bedding planes, stylolites and fossils. These deposits have now been worked out and the pits are filled with water.

Barite, generally known as tiff, a term that has been in use for 150 years, occurs in a variety of forms to which local names descriptive of its shape, form, and nature have been applied. Thus, ball tiff is a botryoidal more or less hemispherical form of barite, the balls varying from an inch to two or three inches and having a radiating, bladed structure. Other forms are known and described by such names as chalk tiff, dry bone sheep nose tiff, split tiff, and spar. The latter is used in Washington County to designate barite occurring in well formed crystals, a type which is known in the central district as "glass" or "glass tiff". The term glass tiff is used in Washington County to designate calcite. Names used locally to describe the mode of occurrence are: rock tiff, gravel tiff or clay tiff. Chalk tiff and dry bone are difficult to concentrate in the jigs because their apparent specific gravity is considerably less than that

of normal barite so that much is lost in the tailings.

Other minerals associated with barite are quartz in the form of large, heavy, drusy masses or thin shell-like druses known by the hand miner as "moory" quartz, chert, galena, pyrite, marcasite, sphalerite and limonite. The latter two are detrimental as it is difficult to separate them from barite in the jigs because their specific gravities are so near to that of barite.

MINING

Before 1937 practically all barite mined in Missouri was produced by primitive hand methods. Miners worked only when they felt like it. Each individual generally dug on land owned by some one else and paid a royalty of fifty cents a ton to the land owner and a fee of fifty cents a ton for handling. The output per man was small but because of the large number of people engaged in digging, the total production was fairly large. Several factors have combined to eliminate the hand miner and at present the industry is almost 100 percent mechanized.

All barite in Missouri is mined in open pits. In Washington County it is essentially a stripping operation, the material stripped off constituting the "ore". This consists of ferruginous clay containing fragments and boulders of chert, quartz druse and barite. In a few places barren surface soil is first removed but in most of the operations barite is found almost from the surface downward so that stripping waste overburden is not feasible. The depth of pay dirt varies considerably from a minimum of two or three feet to twenty or thirty feet or even more with an average of perhaps between ten and fifteen feet. Excavations are usually carried to bedrock but may be bottomed at any point if the barite content drops below a certain minimum. The bed rock surface is often very uneven with large pinnacles and intervening depressions. The tops of the rock pinnacles limit the depth of mechanical operation and much good ore may be left in the hollows between pinnacles unless these are removed by blasting which is seldom done. Ore thus left is lost because the large quantity of jig tailings used for building roads in the pits precludes any future mining operations.

In Washington County little or no exploratory work is necessary as most of the area has been worked over by hand miners and the hundreds of old pits which honeycomb the surface serve as a guide to the shovel operators. As soon as the barite recovery drops below a satisfactory minimum, the shovel is moved to a new location.

Deisel or gasoline engine-powered shovels or drag lines, with buckets of a cubic yard capacity are used for excavation. Haulage to the washing plant is by trucks. Some operators prefer to use light trucks with conventional rear dump bodies while others have gone over to heavier types with special dump bodies. Maintainance of roads for hauling is difficult, especially in wet weather. An adequate supply of gravel from jig tailings is available and it is a simple matter for truck drivers to bring in a load of gravel on the return trip, but every time the shovel is moved a new road has to be built.

In central Missouri mining methods are essentially similar where surface residual ores are found but in circle deposits the situation is somewhat different. Since much of the ore occurs as a cement in a rock breccia, drilling and blasting are necessary and add to the mining cost. Furthermore, these deposits are of relatively small diameter and considerable depth, hence access to the lower part presents a difficult problem. Most of the circle deposits are in areas of little relief and the cost of cutting an entrance through solid rock to the required depth is prohibitive. As an alternative many operators cut spiral ramps around the edge of the pit in the ore body but the steep grade, because of the small diameter of the deposit, limited the depth and much good ore was unrecoverable. One operator hoisted the ore with a clam shell bucket and a derrick on the rim of the pit. A small bulldozer was employed to move ore into a pocket within reach of the bucket. Another hoisted the ore in a box suspended from a trolley on an overhead cable. In these pits drainage presented another problem, especially in wet seasons. The water was used at the mill for wash water thus eliminating the necessity of having to provide a separate supply, but since it varied in quantity with the seasons, it was not entirely satisfactory.

MILLING

The term milling as applied to the recovery of barite is perhaps a misnomer. It is applied to all the operations involved in producing a marketable barite concentrate and includes washing to remove the clay, screening and breaking to remove coarse waste rock, and jigging to separate the barite from fine waste material. Galena is usually separated from the barite in the same operation.

In a typical mill the ore or "dirt" is dumped directly from trucks onto a grizzly built of 60 or 80 pound rails with four inch spacing and is washed through with a stream of water under high pressure. Large chunks of barite are sledged by hand and boulders of chert and waste rock are discarded. An improvement over the stationary grizzly in the form of a rotating type is now in common use in many washing plants. It consists of a steel cage four to six feet in diameter and seven to ten feet long with four inch spacing between the bars. It is mounted on rubber tired trunions, and rotated at about 10 r.p.m. Bars on the inside serve as lifters as it rotates carrying the load to the top and then dropping it. Trucks dump into a pan from which the unwashed ore is washed into the grizzly with a hose. Large boulders of barite are broken up by impact as they drop from the lifters. Waste rock, being hard and resistant aids in breaking the barite as the grizzly rotates and finally is discharged to the waste bin.

The grizzly feeds directly to twin steel logs which are from 20 to 30 feet long and three feet in diameter. The overflow at the lower end is rejected and goes to a settling pond and the discharge at the upper end goes to a rotating breaker screen, somewhat similar to the grizzly but running at higher speed. The steel shell of the breaker is punched with five-eights or three-quarter inch openings. Lifters on the inside carry the feed well up the side and when it drops the softer barite is broken and passes through the openings. Hard, waste rock is discharged to the waste conveyer.

The undersize from the breaker-screen goes to the jigs for separation. Any galena present is usually recovered in the first cell of the jig. Jigs of several kinds are in use, the most common being the plunger and diaphragm types. Variations in the flow sheet have been made in some plants involving the use of a jaw crusher instead of a breaker screen, vibrating or rotating screens to size jig feed, and in one installation in the central district a set of rolls for regrinding the hutch product and tables for recovering the finer sized barite and galena. Tailings and concentrates are carried to storage bins by chain drags which also dewater them.

Water requirements for washer operations are high. A plant with a capacity of 800 to 1000 cubic yards of dirt in a 24 hour day, producing around 100 tons barite concentrates, will use a minimum of 1000 to 1200 gallons of water per minute. Of this, probably in the neighborhood of 800 or 900 gallons can be recirculated, while the remainder is make-up water requiring a dependable source of supply. Where near-by permanent streams can be dammed, these furnish excellent supplies but where such sources are not available, water is pumped from wells drilled for the purpose.

The disposal of waste from a washing plant presents a serious problem. Stream pollution resulting from direct discharge of waste into the stream is frowned upon by the state conservation department. Consequently a mud pond or settling basin must be built and maintained to clarify the waste water. Usually a dike is built across a small valley and is increased in height and width as conditions demand utilizing waste from the washer and barren overburden from stripping operations. Where large volumes of ore are handled there is a correspondingly large volume of waste mud and in flat country, mud ponds soon spread over many acres of land. Old mud ponds constitute a hazard for live stock for many years after they are abandoned as the mud dries slowly beneath the surface crust. Jig tailings make good road surfacing material and are much used to maintain roads on the property and in highway maintainance.

RECOVERY

The per acre yield of barite recovered by modern methods varies greatly from place to place. The minimum of recoverable barite for profitable operation is generally considered to be about 150 pounds per cubic yard of dirt, equivalent to five or six percent. At this rate an acre foot of land would yield from 200 to 250 tons of concentrates. This has been exceeded in most operations. The hand miner is said to have recovered from 500 tons to over 15,000 tons per acre in rich ground, but no information is available as to the average depth of such workings. Hand mining methods, as a rule, yielded less than one half of the barite contained in the clay. The fines were necessarily left and these, together with patches of unworked ground between holes, now constitute the washing ore in previously mined areas.

Mechanization of the industry has served to keep production abreast with demand to a large extent. The introduction of power shovels, heavier

hauling equipment, the rotating grizzly, double log washers and other labor-saving devices has made it possible to operate with profit in those areas where hand miners had worked for generations and had left only the fines scattered through the waste dumps.

The use of decrepitation and screening has permitted the recovery of a marketable product from barite containing large quantities of limonite. Froth flotation methods while apparently feasible have not been introduced in Missouri operations. Experimental work in the recovery of barite from waste mud and sand from washing plants indicates that a satisfactory recovery may be made by tabling or by the use of centrifugal or spiral type separators and possibly by flotation. Present losses in the overflow from the log washers and in the fine jig tailings can probably be eliminated to a large extent by the installation of suitable equipment. The retreatment of mud from old settling ponds is already under consideration and gives considerable promise of success.

USES OF BARITE

The chief uses of barite from the standpoint of quantity consumed are: drilling mud, lithopone, chemicals, fillers, and glass. Certain physical and chemical properties combine to make it ideal for those uses where weight and durability are essential. The comparatively low cost makes its use attractive where large quantities are needed.

In oil well drilling by rotary methods it is customary to circulate water down the inside of the drill stem and upward between the drill stem and the walls of the hole to lubricate the bit and remove the cuttings. When gas and oil are encountered under pressure they tend to enter the hole and it is necessary to confine them within their formations to prevent blowing out. The weight of the column of drilling fluid acts to confine such gas pressure. Usually mud is added to the fluid to increase its specific gravity and plaster the walls, but the addition of large quantities of mud increases the viscosity beyond practical limits. Therefore, ground barite is used to give the necessary weight and small amounts of bentonite are added to act as a suspending agent without undue increase in viscosity. Such muds may be weighted up to eighteen or twenty pounds to the gallon. They also serve to support the walls of the hole thus helping to prevent caving. Iron oxide can be used instead of barite and serves equally well in most cases but meets with objections because it stains everything with which it comes in contact a red or yellowish brown. Cleanliness, therefore, as well as inertness and high specific gravity is a desirable property.

Lithopone, an intimate mixture of zinc sulphide and barium sulphate, is the second largest consumer of barite. Barite is crushed and mixed with pulverized coal or some other form of carbon and fired to produce barium sulphide or black ash. This is leached with hot water and the subsequent addition of zinc sulphate to the leach solution forms a precipitate of zinc sulphide and barium sulphate which is the essential constituent of lithopone. Further treatment involving a number of complex processes produces the finished pigment.

Barium chemicals possess widely varying properties which make them valuable in many industrial processes, but it is beyond the scope of this paper to undertake a discussion of the numerous uses of barium compounds.

As a filler, barite is widely used in paint, oil cloth, linoleum, rubber, x-ray shielding, paper, and textiles. In glass manufacture it is used as a flux, as an essential constituent in certain mixes, and as a decolorizer and deoxidizer. Barium metal has not yet come into extensive use. It can be used to deoxidize copper and when alloyed with lead, to make bearing metal. It has been used in alloys for spark plug electrodes and when alloyed with magnesium and aluminum, as a "getter" for the removal of gasses from various types of vacuum tubes. For more detailed discussion of the uses of barite and barium compounds the reader is referred to reports of the U. S. Bureau of Mines.

PRODUCTION

Missouri has produced more barite than any other state. Production has been continuous since about 1850 and fairly complete records are available beginning in 1880. Since that date, more than 28,000,000 tons valued at 68.9 million dollars has been mined. This is almost 35% of the United States' production for the same period. For many years Missouri was the leading producer and in some years accounted for two-thirds of the total. In the early years Georgia was the principal competitor, but in 1944, Arkansas surpassed Missouri and has been the largest domestic producer since then.

Until some time after the close of World War I the entire output was obtained by hand mining. In 1923 a single washing plant was in operation, but during the depression years this was closed and practically all barite was produced by hand labor. As conditions improved and demand increased, a number of operators installed small washing plants and power shovels. The decline in hand mining was further accentuated by certain provisions of the wage-hour law and decisions of the National Labor Relations Board as well as by the lure of higher wages paid in other branches of industry. With the beginning of World War II, the war industries offered unusually attractive wages and hand labor practically disappeared from the barite mining industry. Producers were able to maintain their production and keep pace with the demand only by fully mechanizing .

FUTURE

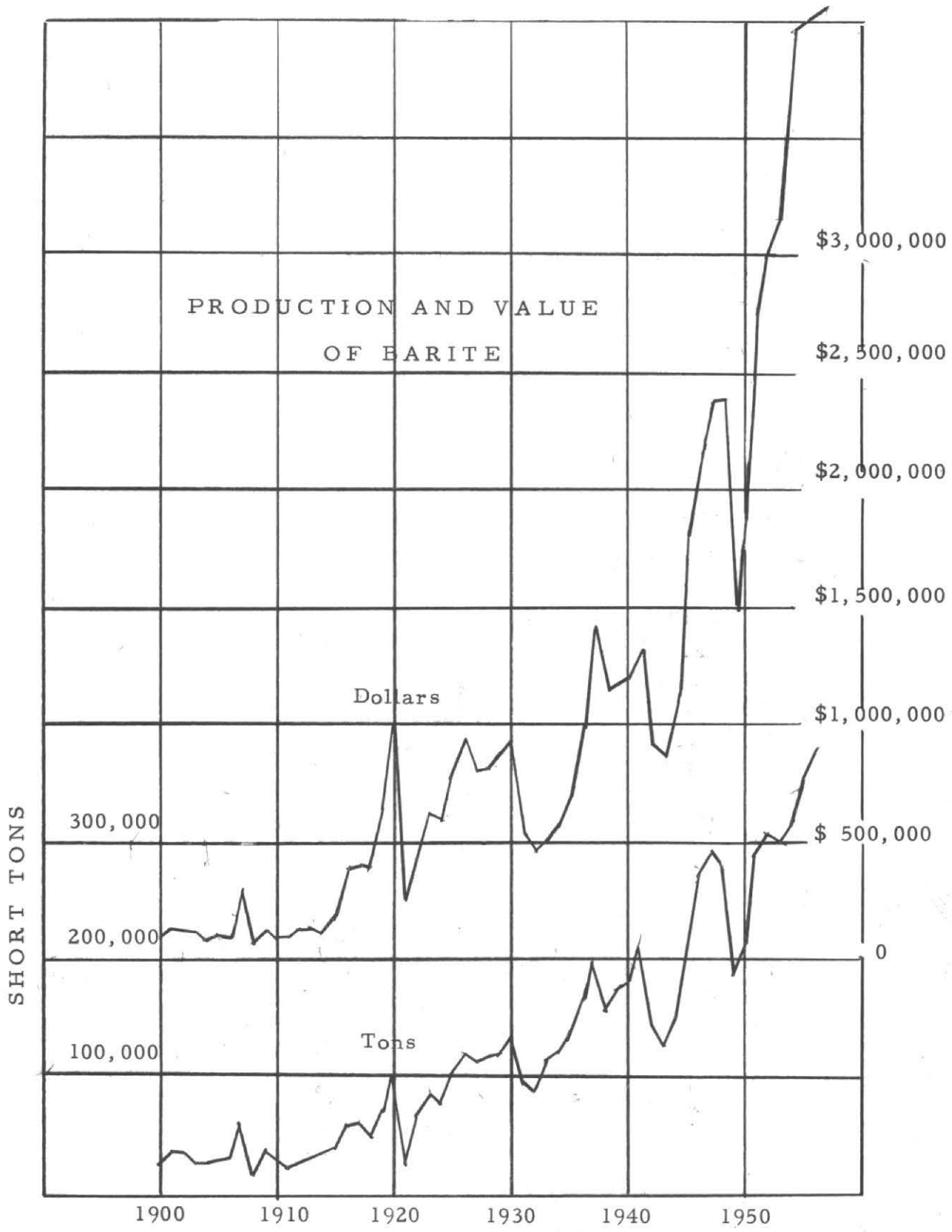
Future developments in the barite industry are not easy to predict. If the price remains favorable, mining can continue for many years at the present rate. As long as there is a demand for barite from the oil-well drilling industry, it seems likely that prices will be maintained at present or higher levels. Foreign barite will probably not compete unless tariff rates are lowered.

There is an area of some 75 square miles in Washington and adjoining counties covered with residual clay from the Potosi and Eminence formations, containing some barite. Assuming that one-third of this will prove to be productive, there would be in the neighborhood of 15,000 acres available for mining. Allowing a minimum of 150 pounds of recoverable barite per cubic yard of dirt as the limit of profitable operation and an average

thickness of eight feet of workable ground, this would yield about 15,000,000 tons of barite. Since a number of unknown factors such as probable producing area, yield per cubic yard, and thickness enter into this estimate, it is probable that the figure may have to be revised. Potential production from the central Missouri district has not been included because of the difficulty of estimating reserves in that region. Since the above estimate was made a little over 2.5 million tons has been produced.

Another factor that may have some bearing on future production in the possibility of recovering barite from the mud ponds of present and past operations. Experiments under way at this time indicate that such material can be successfully treated to recover the fines.

It appears likely, therefore, in view of the above facts that barite production in Missouri can be maintained at the present rate for about 50 years.


PRODUCTION AND VALUE
OF BARITE
Dollars
Tons
SHORT TONS
300,000
200,000
100,000
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$ 500,000
0
1900
1910
1920
1930
1940
1950