LEAD AND ZINC

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IN THE

UNITED STATES

COMPRISING AN ECONOMIC HISTORY OF THE MINING AND SMELTING OF THE METALS AND THE CONDITIONS WHICH HAVE AFFECTED THE DEVELOPMENT OF THE INDUSTRIES

BY

WALTER RENTON INGALLS

Editor of the Engineering and Mining Journal, Editor of The Mineral Industry, Member American Institute of Mining Engineers, Member Institution of Mining and Metallurgy, Member Society of Chemical Industry, Member American Chemical Society, Member American Electrochemical Society, Etc.

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PREFACE

This work was prepared at the request of the Carnegie Institution of Washington, and with its assistance. It is to form a part of the Economic History of the United States which is to be published by the Carnegie Institution. This independent publication has been courteously permitted by Hon. Carroll D. Wright, chairman of the Department of Economics and Sociology, of the Carnegie Institution. I take this opportunity to express my thanks to the Institution, to Hon. Carroll D. Wright, and to Mr. Edward W. Parker, of Washington, who has been in immediate supervision of the part of the economic history relating to the mining industry, for their valuable assistance and earnest coöperation.

Acknowledgment is due also to many who have supplied information which has been of assistance in the preparation of this work. I express my thanks especially to Mr. Dwight A. Jones, president of the St. Joseph Lead Co., Mr. Elias S. Gatch, president of the Granby Mining and Smelting Co., Hon. O. P. Austin, chief of the Bureau of Statistics of the Department of Commerce and Labor, Mr. David H. Newland, assistant State geologist of New York, Mr. John P. Meany, manager of Poor's Manual of Railroads, and Mr. Charles M. Hicks, mine superintendent for the Bertha Mineral Company, Austinville, Va. I am particularly indebted to Mr. Arthur S. Dwight, who kindly read the chapter on metallurgy and favored me with valuable criticisms and suggestions.

In the preparation of this work attention has been directed especially to the features contributing to the development of lead and zinc mining as important sources of the supply of the metals. Consequently many interesting historical records of the early discovery of lead ore and the feeble, spasmodic attempts to mine it, are dismissed with brief references. These have been well described by W. H. Pulsifer in "Notes for a History of Lead," and I have considered it unnecessary to go over the same ground. The early discoveries and attempts at mining are of much antiquarian interest, but of little from the economic standpoint. The total production of lead in the United States previous to the nineteenth century was insignificant and zinc mining did not begin at all until about the middle of the nineteenth century.

Walter Renton Ingalls.

New York, March 1, 1908.

CONTENTS

PART I. LEAD

PART II. ZINC

INTRODUCTION

Lead and zinc are closely associated in nature, their ores commonly occurring in conjunction, especially their sulphide ores. There is less association of their oxidized, or carbonate, ores, since in the process of oxidation the original zinc sulphide is converted first into sulphate, which is very soluble and may therefore be leached away by some action of nature; but in a large number of cases, as for example at Leadville, Colo., the occurrence of pure lead-carbonate ores above the water level is followed by the occurrence of mixed lead and zinc sulphides below the water level. Both lead-sulphide ore and zinc-sulphide ore occur alone, but the occurrence in association is more common, and the importance of the joint consideration of the two metals from the industrial standpoint increases as the oxidized ores are exhausted and the smelters have to fall back on the sulphide ores, which have already become by far the more important, in the metallurgy of both lead and zinc, all over the world.

It will be observed from a study of the literature of economic geology that the deposits of both lead and zinc ore, whether in association or alone, form most kindly in connection with a dolomite or limestone country rock. Most of the great lead and zinc ore deposits of the world occur in formations of those species of rock.

In their metallurgy there is also an intimate association of the two metals. In the first treatment of the ores, by jigging or other methods of separation, there is generally obtained a galena concentrate, which goes to the lead smelter for the extraction of its lead content, and a blende concentrate, which goes to the zinc smelter for the extraction of its zinc content. With few exceptions, the crude ore has first to be separated in some such manner. The limitations of mechanical practice do not, however, permit a clean separation of the minerals to be made, save in rare instances, and the lead concentrate consequently almost always contains some zinc, and vice versa the zinc concentrate contains some lead. The presence of zinc is objectionable to the lead smelter and the presence of lead is objectionable to the zinc smelter, but in neither case does the presence of the other metal in limited proportion prevent successful smelting. But while the lead smelter is bound inevitably to lose all the zinc contained in the lead ore that he smelts, the zinc smelter may recover a large proportion of the lead in the zinc ore, after the zinc itself has been extracted. Thus a very large proportion of the pig lead produced in Belgium is recovered from zinc-ore residues, and this practice has been inaugurated in the United States and is without doubt destined to increase in importance.

Finally, the chief use for pig lead is in the manufacture of white-lead pigment, and one of the large uses of zinc is in the manufacture of white pigment, which in the trade is a direct competitor of white lead. But white lead and zinc oxide are to a large extent used in a pigment compounded of both, so that it is conceivable that the lead and zinc which existed originally in the same ore deposit, and were mined and separated by a common operation, might be smelted by a combination process and finally after conversion into finished products might be mixed again for use in the arts and be subject to common dissipation under the action of weather and time.

Up to 1901 it might have been possible to consider independently the lead and zinc industries of the United States, but from the economical standpoint it will never more be possible to do so.

The existence of lead ore in the territory that now comprises the United States became known in the earliest explorations, and mining was quickly begun on such deposits as appeared workable. In southeastern Missouri and southwestern Wisconsin, where the discovery of workable deposits antedates all other important discoveries of lead in the United States, the operation of the mines has continued uninterruptedly up to the present time, at which Missouri gives promise of producing more lead than in all its past history, while a rejuvenation of mining in Wisconsin is beginning. There is in these two regions an antiquity of mining and continuity of record that is comparable with the history of some of the famous districts of Europe.

The history of lead mining in the United States is capable of division into epochs, marked by important discoveries, or industrial developments of determining effect. It is a coincidence that these have occurred to a considerable extent at decennial periods. From 1720 to 1820 the total production of lead was small compared with the annual production at the present time. The entire output during the 100 years was only about one-seventh the output of a single year at the beginning of the twentieth century. It was derived almost wholly from southeastern Missouri, territory which did not become a part of the United States until the Louisiana purchase in 1803. In 1821 attention began to be attracted to the lead mines of Wisconsin, discovered many years previously, possibly as early as 1634, and certainly as early as 1658, but unattended to because of the Indian occupancy of the region. A few years later mining was in full swing, and by 1828 the output had become important. The 50 years from 1821 to 1870 may be called the Wisconsin period in lead mining in the United States, the major part of the lead produced in the country having been derived from its mines. A good deal of mining was done in Missouri during this period, with a slowly increasing production, which however did not exceed 5000 tons per annum until after the discovery of the Joplin district in 1850 and fell off again after 1860. Up to 1871 practically all of the lead produced in the United States was from non-argentiferous ore.

The great development of the lead industry in the United States dates from about 1871, which may be considered the beginning of the argentiferous period. Numerous causes contributed to the development at about that time, but the most important was the completion of the Pacific railway, which furnished an outlet to market for the product of the ore previously discovered in Utah and Nevada. The great ore deposits at Eureka, Nev., were discovered in 1869. The great Emma lode was discovered in Cottonwood Cañon, Utah, in 1870. The Horn Silver mine at Frisco, Utah, was discovered in 1875. These mines were the principal producers of lead in the ten years 1871–1880. The next decade was the era of Leadville, Colo., whose mines had already become large producers in 1878, but attained their maximum in 1882. Toward 1890 their output began to wane materially, but during the ten years, 1881–1890, they produced nearly 33% of all the argentiferous lead smelted in the United States. The decade 1891–1900 is especially characterized by the rise of the mines of the Cœur d'Alene, Idaho, while the dominant feature of the decade beginning with 1901 is the consolidation and coördination of the industry.

The most important mines of lead worked in the United States previous to 1801 were in Madison, St. François, and Washington counties in southeastern Missouri. Madison County, wherein the Mine la Motte was the only producer, is credited with an output of 8000 tons of pig lead from 1720 to 1800; St. François County with 500 tons from 1740 to 1800; and Washington County with 9500 tons from 1725 to 1800. During the first two decades of the nineteenth century, these counties continued to be the chief producers of lead, in fact the sole producers save for a few sporadic undertakings elsewhere, and the small output of the Indians in Wisconsin. The Missouri output from 1801 to 1820 was about 25,300 tons, an average of approximately 1250 tons per annum. It may be assumed, therefore, that the total production of lead in the United States from the beginning of mining up to 1821 was about 44,000 tons. From 1825 to the present date we possess reasonably accurate statistics of annual production. These are given in detail in the body of this treatise.

The history of zinc in the United States is much less engaging than the history of lead, partly because it is briefer, partly because it displays less variety, being limited until a few years ago to comparatively few districts, and partly because it is in no way interwoven with the romance of the opening of the great portion of the country which lies west of the Rocky Mountains. Indeed, the history of zinc in the world is relatively brief, dating only (so far as we know) from the beginning of smelting by John Champion at Bristol, England, in 1740,[1] although there is ground for the belief that the Chinese previously knew and practised the art of smelting, and that the English process was based on information gained in the East. However, spelter did not become an article of any considerable commercial importance in Europe until the decade 1811–1820. Consequently the brevity of its industrial history in the United States, the whole of which is comprised within the experience of living zinc metallurgists, is not to be marveled at.

Zinc was first made in the United States about 1838, at the Government Arsenal in Washington, from the red zinc ore of New Jersey, for preparation of the brass for the standard weights and measures ordered by Congress. The process was so expensive, however, as to preclude any idea of producing zinc commercially in the same manner. The regular manufacture of zinc was first undertaken in 1850 at Newark, N. J., by Richard Jones, but this proved a failure, and attention was then directed to the manufacture of zinc oxide straight from the ore, which problem was successfully solved by Samuel Wetherill in 1851. Efforts to make spelter were continued, however, and along toward 1860 works were erected in New Jersey, Pennsylvania, and Illinois, some of which have been in regular operation ever since. The early sources of ore supply were the mines in Sussex County, N. J., at Friedensville, Penn., and in Wisconsin, where the presence of zinc must have been known from the very beginning of lead mining, the two ores occurring in close association. In Missouri, zinc was not made until 1867, when small works were erected at Potosi, in Washington County. The mines of the Joplin district became productive in 1873, their ores being shipped first to Illinois for smelting. Joplin rapidly increased in importance and became the source of the major part of the zinc produced in the United States; indeed, at the present time it still occupies the premier position among the American zinc-producing districts. The commercial history of the zinc industry in the United States is, consequently, to a large extent the history of the Joplin district.

[1] Authorities differ as to the precise date.

PART I

LEAD

I

OCCURRENCES OF LEAD ORE

WITH the exception of iron there is none of the useful metals so widely distributed in the United States as lead, and iron and copper are the only ones of which there is more produced. In this chapter it is proposed to describe briefly the principal lead-mining districts, the occurrence, character, and grade of their ores and the industrial conditions which have affected their exploitation.

The principal ores of lead are galena (lead sulphide), cerussite (lead carbonate), and anglesite (lead sulphate), which rank in importance in the order mentioned. Lead ores are associated almost always with the ores of other metals, galena commonly occurring with zinc-blende and iron pyrites, less frequently with copper pyrites, while lead carbonate is found generally with the oxides of iron and manganese. Lead ores are furthermore almost invariably silver-bearing, even the mineral ordinarily called non-argentiferous having usually a trace of the precious metal. The terms argentiferous and non-argentiferous, indeed, as commonly used with respect to lead ores, are merely relative, and it would not be easy to draw the dividing line between the two classes, unless at the point at which it ceases to pay to extract the silver, which of course varies under different conditions.

In 1893, I wrote as follows:[1] "The ores commercially classed as argentiferous (*i.e.*, those whose silver contents form an important, perhaps the more important, part of their value) furnish nearly two-thirds of the world's supply of lead. On the other hand, a constantly increasing amount of silver has been coming from the silver-lead smelters during the last ten years, so that the silver-milling processes — like amalgamation and lixiviation — which belong to the metallurgy of silver alone have fallen in relative importance, and probably more than one-half of the total output of silver in the world now comes from the lead desilverizers. The mining and metallurgy of the two metals, silver and lead, and the industrial conditions affecting their production, are so closely woven together that it is difficult to consider either of them alone."

Since that time the tendency of the silver-milling processes to disappear has become more pronounced; indeed, they may be said to have

[1] The Mineral Industry, II, 384.

disappeared in the United States, although they still survive in Mexico. On the other hand gold milling has been rejuvenated in the wide-spread application of the highly valuable cyanide process, while silver-lead smelting has found a mighty competitor in silver-copper smelting. According to Waldemar Lindgren, out of a total production of about 56,000,000 oz. of silver in 1904, about 22,000,000 oz. was derived from the smelting of lead ore (his classification of lead ore being ore with upward of 4.5% lead), 16,000,000 oz. from copper ore, 16,000,000 oz. from silicious ore, and 2,000,000 oz. from zinc ore.[1] It is to be remarked, however, that a large part of the silicious ore and a considerable part of the copper ore are smelted along with the lead ore, wherefore their silver contents are finally obtained by the lead desilverizers.

The lead-producing regions of the United States may be classified as being of the Atlantic Coast, Mississippi Valley, Rocky Mountains, and Pacific Slope, the last including the mines in California and Washington. The mines of the Atlantic Coast were of importance in the early history of the country, when the demand for lead was small, but gauged by modern standards they were never aught but insignificant. Nor have the mines of the Pacific Slope been of any special importance, with the exception of a single district — Cerro Gordo, in Inyo County, California — which had a fitful prominence.

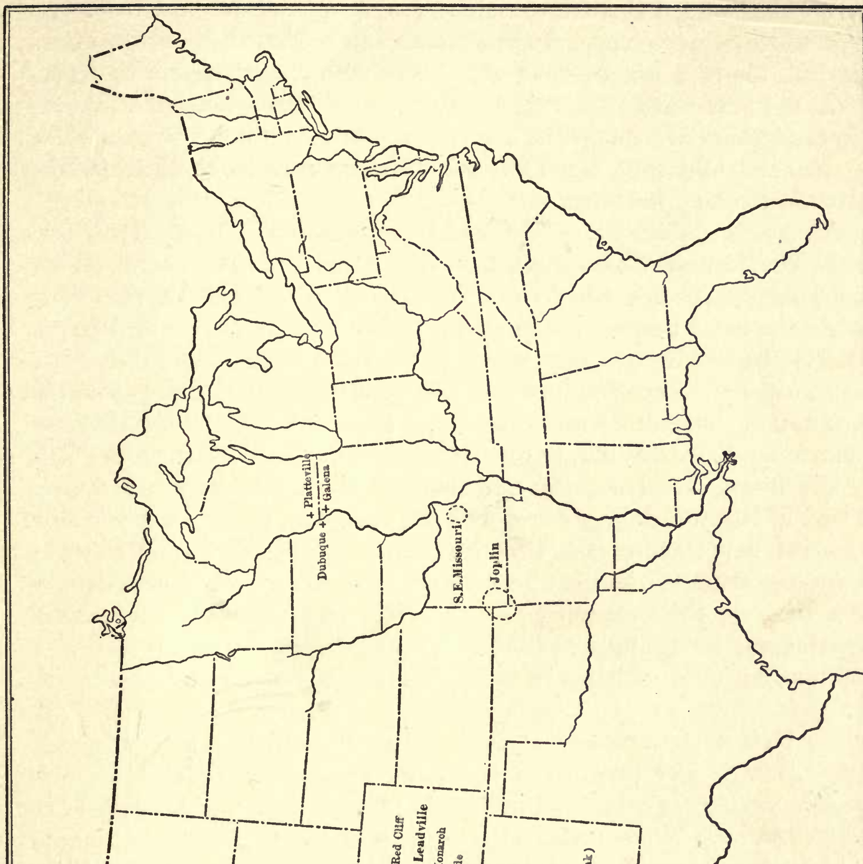
Atlantic Coast

The production of lead on the Atlantic Coast, which was never large, has now become insignificant, and reference to the localities where ores have been mined is chiefly of antiquarian interest. The only mines which have made an output sustained through a series of years are those near Rossie, St. Lawrence County, N. Y., which were opened on veins in Archæan gneiss, carrying galena in a gangue of calcite; at Guymard, Ellenville, and Wurtsboro, in the vicinity of Port Jervis, N. Y., opened on veins of galena, associated with blende, in Cambrian quartzite; and deposits in Wythe County, Va., which are described in the division of this work relating to zinc, being more important as a source of zinc than of lead.

The Mississippi Valley

The lead-producing districts of the Mississippi Valley constitute three principal groups, viz., Southeastern Missouri, Southwestern Missouri (including the southeastern corner of Kansas), and Wisconsin-Iowa (including the northwestern corner of Illinois). Lead is also mined in the Rosiclare district in southern Illinois, and across the Ohio River, in Kentucky; and in central Missouri; but those deposits are commercially insignificant. The lead produced in the Mississippi Valley is classed as

[1] Mineral Resources of the United States, 1904, p. 155.



The Principal Lead Mining Districts of the United States.

non-argentiferous, the silver content of the ores being too low to pay for its extraction, save under special conditions. Except in southeastern Missouri, the lead ores occur in connection with zinc ores, and the latter are at the present time, as for 25 years past, the more important, wherefore description of the deposits is put in the division of this work relating to zinc, and only brief reference will be made here as to their present status in the lead industry.

Southeastern Missouri. — The lead mines of this district are the oldest in the United States, excepting those in the vicinity of Santa Fé, N. M., and Tucson, Arizona, which were worked by the Spaniards at a very early date, but for silver, not for lead. There are two classes of deposits, viz. (1) the fissure and pipe veins, and (2) the disseminated ore. The former class is of ancient working; the latter is of comparatively recent exploitation, but commercially is the far more important of the two. There is an extensive literature pertaining to these ore deposits.

The disseminated deposits are not only the most important sources of lead in Missouri, but also are, with the exception of the Cœur d'Alene, the most important of the United States. They are of comparatively recent exploitation. The early production of lead in Missouri was derived from the superficial deposits, and the veins and reticulated deposits of Washington, Franklin, Jefferson, St. François, and Madison counties. Their output has been large in the aggregate, although never large in any one year. They are still mined, especially at Potosi, Palmer, and Valle, and by methods which show but little change from those practised in their early history. For this reason a detailed account of the occurrence of the ores and the methods of mining is of particular value in throwing light on the conditions under which a large part of the domestic output of lead previous to 1871 was produced. The following account is based on notes of a professional investigation in Washington County in 1901.

The most important mining centers in Washington County are Potosi and Palmer. In both neighborhoods, galena is found in nests in the red clay overlying the country-rock, and in place in the country-rock, the latter being the more important source of the mineral. At Palmer, the ore in place occurs in the form of a network of small channels, criss-crossing in all directions. Considered broadly, the entire system of channels constitutes an ore-shoot, or run of ore, lying nearly horizontally. The network exists not only on one level, but on two or three, and perhaps more, immediately underlying. These different horizons are connected by vertical crevices, sometimes mineralized. The formation may be imagined as a broad zone of fracturing in all directions, in which mineral deposition has occurred along the crevices or joint-planes in favorable strata of the rock.

The channels of ore are individually very small, but the ore is pure, except for barite, which is easily separated. The thickness of the ore may be from 1 in. to 18 in., occasionally more; a thickness of 12 in. is considered very good indeed. The width of the ore may be from 2 ft. to 12 ft., but it does not average more than 4 ft., and anything more than 3 ft. is regarded as good mining ground. The local miners follow these channels with the smallest possible opening, the dimensions of a drift being rarely more than 4×4 ft., unless the width of the ore is in excess of 4 ft. Thus, in following a 4-ft. channel of ore of 6 in. average thickness, the miner will break 16 cu. ft. of ground and will get 2 cu. ft., or, approximately, 850 lb. of ore, assaying upward of 80% lead. The length of these channels is sometimes very considerable, amounting to several hundred feet. The richness of the ore, when found, is such that it will stand the breaking of considerable barren ground to get it, providing the frequency of the channels be sufficient. As to the latter factor, the experience at Palmer is indicative.

The most productive mines at Palmer have been the Flint Hill and the Parole. The former was discovered in August, 1899. In the first year of its exploitation it produced about 1500 tons of ore. The area of mineralization, so far as yet determined, is about 300 ft. wide and 800 ft. long, but the major portion of the ore was got from a tract 200×400 ft., or, approximately, two acres. The ground was leased in lots of 75×75 ft. to 100×100 ft., according to depth (the shafts ranged from 40 to 90 ft. in depth). The maximum production of a 75×75-ft. lot was 130 tons. The maximum production of the whole mine in a single month was about 180 tons, which came through about 25 shafts, each operated by one man on the surface and two underground. The Parole mine was discovered in 1879, and was productive up to 1898, during which period it is estimated to have yielded, approximately, 9000 tons of ore. The mineralized area was approximately 2000×2000 ft., or about 90 acres. The shallowest shaft was 22 ft. in depth; the deepest was 145 ft. The difference in depth is due to the rise of the hill and the slope of the strata from one end of the mine to the other. Ore was found in the Parole mine at several levels. The uppermost was mineralized chiefly with barite. The second, which was 5 ft. lower, was the most productive of lead ore. The third, which was about 10 ft. below the second, showed good ore, but was not much worked, because the water encountered at that depth was more than could be handled by the mining methods in vogue. In the Flint Hill mine also three ore horizons were proved, the second being about 10 ft. below the first, and the third about 10 ft. below the second.

At Potosi, in Washington County, and at the Valle and Mammoth-Frumet mines, in Jefferson County, the occurrences of ore are quite similar to what it is at Palmer, but the Valle mines are unique for the quantity of zinc ore (smithsonite) they afford. The Bugg mine, at Potosi, is described by Winslow[1] as showing a network of ore channels, following the stratification of the limestone, which cross and unite in all directions, the width of these channels being 3 to 10 ft. and their height generally only a few feet, but sometimes as much as 20 ft. Ore was worked in this mine at three horizons, and a noteworthy feature was a vertical crevice, from 0 to 10 ft. in width, which traversed the workings, and was traceable at the surface for over a quarter of a mile. In the Garatee mines of the Valle group there were ore horizons at 65, 95, and 135 ft., which were connected at some places by vertical chimneys. At the Valle mines proper there were three horizons, the first and second about 20 ft. apart, and the third about 8 ft. below the second. At the Perry mine there were four horizons, and at the Bisch mine there were two. The Valle mines, which are still operated, produce annually from 300 to 500 tons of lead ore and 1500 to 2000 tons of zinc ore.

Franklin County is characterized by the occurrence of galena in vertical crevices or veins, some of which are doubtless fissure-veins. A good many of these have been exploited on a small scale in the past, and one of them, namely, the Virginia mine, which was the most important in the county, was worked on rather a large scale. This mine was opened on a fault fissure, cutting vertically through magnesian limestone, varying in width from 1 to 15 ft., and filled with clay and barite in which galena was imbedded, while the galena sometimes formed a solid streak. At one place in the mine, at least, there was a good-sized body of nearly pure galena, averaging 5 ft. in width. The mine was opened by shafts from the surface for a distance of upward of 2500 ft. along the outcrop of the vein, and two or three deep shafts were sunk, one of them to a depth of 480 ft. The mine was discovered in 1834, and is said to have produced upward of 13,000 tons of ore. Its operation was intermittent and was finally abandoned, because of mismanagement and legal vicissitudes; for many years now the mine has been idle. All of the old shafts are completely filled, the old workings are therefore inaccessible, and there is no reliable information as to what was their appearance when work was finally abandoned, but the remains of the old hoisting plant, concentrating mill and smelting furnace bear witness to the extent of former operations.

At many places in Washington County nests of galena are found in the residual red clay overlying the region, and considerable lead is got from them, but not so much now as formerly. Similar deposits of barite are worked, however, for a large and increasing production, this region having become the most important source of barite in the United States. The supply of that mineral is limited only by the distance of economical

[1] Report of the Missouri Geological Survey, on lead and zinc, vols. VI and VII.

carting, since there are large quantities in the remoter portions of the county which it has not yet been profitable to touch; the mines at Palmer, and elsewhere, show a good deal. This surface lead and barite undoubtedly come from the decay of rock which once contained such deposits in place as are found at Palmer, Potosi, and elsewhere.

The lead production of these small mines is, in the aggregate, not inconsiderable. In 1901, according to the statistics of the State Inspector of Lead and Zinc Mines, the output of Jefferson County, chiefly the Valle mines, was 701 tons, of Franklin County 1007 tons, and of Washington County 1834 tons; a total of 3542 tons. In 1902 the output of Jefferson County was 750 tons, of Franklin 1309 tons, and of Washington 2000 tons; a total of 4059 tons. The output is entirely high-grade ore, most of it lump galena, hand sorted. There are a few large landowners from whose property the major part of the ore is derived. Their practice is to give parties of miners the right to dig on small lots of ground, usually 75×75 ft. or 100×100 ft., the miners having to turn over their product to the company at a fixed price per ton, generally $30, when lead is worth about 4 c. at St. Louis. The party of miners usually comprises three men, one to work on top and two underground. They sink a shaft of as small dimension as feasible, say 3½×3½ ft., at an expense dependent upon the depth and the amount of excavation in rock. The cost is low, since miners can be hired in the district for $1 per day, and they will work cheaper for themselves. In cases where the company is prospecting on its own account, the cost of sinking in clay is 40 to 50 c. per foot, by contract, including the cribbing. In rock, the cost is $3 to $5 per foot; in such rock that a progress of 4 ft. per week can be made, the cost is about $4 per foot. After the shaft has been sunk and ore has been discovered, the cost of mining per ton of ore depends chiefly upon the size of the ore channel and the distance to which it is followed. In a general way, the cost of mining is $6 to $12 per ton. In a channel 2 ft. thick and 6 ft. wide, a party of three men produced 18 tons of ore in five days. A lot 150×150 ft., on which a shaft 70 ft. deep was sunk, produced from ore channels, varying from 6 in. to 18 in. in thickness and 3 ft. to 6 ft. in width, 200 tons of ore, worth $6000 at the pit's mouth, at a profit of $5000, or for a mining cost of $5 per ton. A lot 75×75 ft. yielded 130 tons of ore at a mining cost of $6.15 per ton. These were exceptionally good results.

The mining is done in a very primitive way. Hoisting from depths to nearly 100 ft. is done by hand; from greater depths, by horse-whims; but there are few shafts more than 100 ft. deep. When water is encountered, operations are checked. The ore is followed horizontally by making the smallest possible opening in which a man can work, irrespective of comfort or efficiency. The ore and waste are dragged out to the shaft in a box, sometimes mounted on wooden wheels running on wooden rails, for distances as great as 400 ft. through a drift, following the undulations of the stratum, in which the trammer must progress on his knees, and wherein he can in no place stand erect. A drift 4 ft. in height is considered very commodious.

From the above description of the primitive methods, which still are practised, it is easy to picture the conditions under which lead was produced in Missouri from the first of the nineteenth century down to the time when the disseminated deposits began to be worked.

The disseminated lead ore of southeastern Missouri is mined at Bonne Terre, Flat River, Doe Run, Mine la Motte, and Fredericktown. The ore is a magnesian limestone impregnated with galena in crystalline grains from $\frac{1}{16}$ to $\frac{1}{2}$ inch in diameter, the mineralization occurring in "runs" or shoots, lying approximately horizontal, of great size. At Bonne Terre there was a stope nearly 3000 ft. long, 100 to 200 ft. wide and 25 to 60 ft. high.[1] The ore-bodies vary in thickness from 5 to 100 ft., in width from 25 to 500 ft., and they have exceeded 9000 ft. in length.[2] The Bonne Terre ore-body, which has been the longest and most energetically worked, has been followed for a length of nearly 9000 ft., has produced 350,000 tons of pig lead and is still far from being exhausted.[3]

The geological occurrence of these important ore deposits has been described in an ample literature. In this work, consideration is limited to the economic factors which have determined their exploitation.

The ore occurs in a shaly, magnesian limestone of Cambrian age. There is no vein structure, no crushing or brecciation of the enclosing rock, but the ore-bodies have well defined axes or courses, and remarkable reliability and persistency. The limestone is usually darker, more porous, and more apt to have thin seams of very dark (organic) shale, where it is ore-bearing than in the surrounding barren ground. The ore-bodies, however, fade out gradually, with no sharp line between the pay-rock and the non-paying, and the lead is rarely, if ever, entirely absent in any extent of the limestone of the region. While the main course of the ore-bodies seems to be intimately connected with the axes of gentle anticlinal folds, numerous cross-runs of ore that are associated with slight faults are almost as important as the main shoots, and have been followed for 5000 ft. in length. These cross-runs are sometimes richer than the main runs, at least near the intersections, but they are narrower, and partake more of the type of vertical shoots, as distinguished from the horizontal sheet-form.

[1] W. P. Jenney, "Lead and Zinc Deposits of the Mississippi Valley," Trans. Am. Inst. Min. Eng., 1893.

[2] H. A. Wheeler, "Notes on the Source of the Southeast Missouri Lead," *Engineering and Mining Journal,* March 31, 1904.

[3] Wheeler, *loc. cit.*

Most of the ore-bodies occur at, or close to, the base of the limestone, and frequently in the transition rock between the underlying sandstone and the limestone, though some important bodies have been found from 100 to 200 ft. above the sandstone. This makes the working depth from the surface vary from 150 to 250 ft. for the upper ore-bodies to 300 to 500 ft. deep to the main or basal ore-bodies, according as erosion has removed the ore-bearing limestone. The thickness of the latter ranges from 400 to 500 ft.

The ore of the entire disseminated district is of low grade. Its only value is in its lead content, the silver which it carries being commonly too small in amount to pay for separation. The mineralization grades off into the country rock, wherefore the limits of the ore-bodies are marked chiefly by what it will pay to mine. Reduction in mining and milling costs and improvement in methods have consequently enabled a lower and lower grade of ore to be worked. At the present time the average yield of the ore mined and milled is about 5% of concentrate, assaying 65% lead, or in other words, out of 2000 lb. of ore 65 lb. of lead are obtained in the concentrate. Assuming an extraction of 80% of the lead in the crude ore, this would indicate a tenor of about 80 lb. or 4% of lead per ton of crude ore. There is no consecutive record of figures available to indicate the grade of the ore worked through a long series of years, but the percentage was never high. According to Munroe,[1] the average grade of the ore mined at Bonne Terre in 1887 was about 8% of lead. In the report of the Missouri Geological Survey, prepared in 1893, it was stated as 5% lead.

There being no other metals of greatly significant value in these ores, the profit in their mining has been more dependent upon the price of pig lead than in any of the other great producing districts of the United States. A yield of 65 lb. in the form of galena concentrate and an extraction of 92.3% in the smelting result in a final product of 60 lb. of pig per ton of ore, corresponding to a value of $2.40 when pig lead is at 4 c., St. Louis.

In the best smelting practice of recent time about 98% of the lead in these ores is recovered, giving a yield of 63.7 lb. of pig lead per ton of ore. The cost of production is approximately as follows:

Mining and milling	$1.40
Freight on 0.05 ton at $1.40	.07
Smelting, 0.05 ton at $6.00	.30
Total	$1.77

This corresponds to 2.78 c. per pound of pig lead delivered at St. Louis. Under more favorable conditions as to grade of the ore and wages of

[1] Trans. Am. Inst. Min. Eng., 1888.

labor the cost has been as low as 2.25 c. per lb. It is to be remarked, however, that the above figures do not allow for any profit, or interest, and no amortization on the investment, which is necessarily large.[1]

The successful exploitation of these deposits of low-grade lead ore is dependent upon cheap mining and milling, which implies the necessity of operating on a large scale, with the highest order of mining and milling machinery. The deposits are of such magnitude and proved permanence that the investment of large amounts of capital in plant has been warranted. This requirement has naturally made the district one for the operations of large companies only, and has put it beyond the means of small companies or individuals. With few exceptions the operations are conducted on the scale of 1000 tons of ore per day, at least.

The conditions of the district favor cheap mining. The ore-bodies present great faces for stoping, and the ore breaks easily. No timbering is required. The depths are moderate, varying from 150 to 500 ft. Comparatively little dead-work is necessary. Prospecting is largely done by diamond drill, which the experience of the district has proved to be a reliable guide. Coal (from southern Illinois) costs only $2.20 per ton. Rates of wages in 1905 were $1.85 per nine hours for miners and $1.75 for shovelers, but labor is less efficient than in other districts where wages are higher. Under these conditions the cost of mining in 1901 was about $1 per ton, including general expense and delivery of the ore to mill. Reduction of the working time from nine hours to eight hours in 1903, and deterioration in the character of the work done, increased the cost materially.[2]

The following statistics, taken from the Seventeenth Annual Report of the Lead and Zinc Mine Inspectors of Missouri, indicate the importance of the disseminated lead district of Southeastern Missouri as compared with the other large lead-producing districts of the United States:

The Bonne Terre mines (St. Joseph Lead Co.) from 1869 to 1903, both years inclusive, produced 375,000 tons of pig lead. The Desloge Lead Co., near Flat River, from 1894 to 1903, produced 73,105 tons of lead ore. The Central Lead Co., at Flat River, from 1895 to 1903, produced 72,000 tons of lead ore. The Doe Run Lead Co., at Flat River and Doe Run, from 1888 to 1903, produced 154,750 tons of lead ore.

Taking the lead ore (concentrate) as yielding an average of 60% in pig lead, these four companies produced up to the end of 1903 about

[1] It will be observed from a subsequent chapter that the wages for labor rose largely from 1902 to 1907, and there was a corresponding increase in the cost of mining. My estimate of 2.78 c. per lb. as the cost of producing lead is representative of the conditions in 1903–1905. In 1907 the cost was probably about 3.5 c. (See *Engineering and Mining Journal*, Jan. 4, 1908.)

[2] *Vide* foot-note on p. 227; also the section of a subsequent chapter on labor conditions.

405,000 tons of pig lead, and allowing for the output of the Mine la Motte and three companies at Flat River which recently became productive, it is safe to say that the lead output of the disseminated district of southeastern Missouri has been fully twice as large as that of Eureka, Nev., which was discovered about the same time. It has been exceeded only by the output of Leadville, the Cœur d'Alene and Wisconsin, but while Leadville and Wisconsin have risen and waned, southeastern Missouri, like the Cœur d'Alene, has steadily increased. In 1902 the Cœur d'Alene was estimated to have produced 26% of the total lead output of the United States, and southeastern Missouri 20%.[1] The lead production of the disseminated district in 1873 was about 2500 tons; in 1883, about 8500 tons; in 1893, about 20,000 tons; and in 1903, about 70,000 tons.[2]

The Rocky Mountains and Pacific Slope

At the present time the major part of the lead produced in the United States is derived from the argentiferous ores of the States and Territories west of the Rocky Mountains, where the silver-lead industry began to attain importance with the discovery of the great ore deposits at Eureka, Nevada, and the completion of the Pacific railway, both in 1869, although lead ore had previously been mined and smelted on a small scale in Arizona, Colorado and Montana. At the same time, the rich mines of Cerro Gordo, Inyo County, Cal., began to be largely productive.

Arizona

Tombstone. — The ores of this district occur in fissure veins intersecting a series of sedimentary rocks, and also in irregular bodies in limestone. The ores are of two kinds, (1) quartz ores containing silver and gold with some lead, which were treated by amalgamation with quicksilver, and (2) basic ores, the characteristic of which is manganese. The greatest fissure of the district was the Contention-Grand Central vein. Tombstone was formerly a producer of lead, the ore being smelted locally, but the output was never of much consequence in the lead industry of the United States.

Patagonia. — In the Mowry mine lead carbonate ore was found at the contact between granite and limestone. This property has lately been worked, after a long period of idleness. The mine is noteworthy because it was one of the first silver-lead deposits in the far West to be worked by Americans.

[1] W. R. Ingalls, "Sources of Lead Production in the United States," *Engineering and Mining Journal*, Nov. 28, 1903.

[2] H. A. Wheeler, "Notes on the Source of the Southeast Missouri Lead," *Engineering and Mining Journal*, March 31, 1904.

California

California has afforded only one important lead-producing district, viz. Cerro Gordo, in Inyo County, which made an important output of lead between 1869 and 1880, and developed a thriving and instructive smelting industry. Some other lead-producing districts were subsequently developed in the same county, especially Darwin, but after the exhaustion of Cerro Gordo, the output of lead in California became insignificant.

Cerro Gordo. — In a formation of slate overlying a compact, crystalline limestone, intersected by porphyries of various character, veins of silver-lead ore occur in the limestone, or at the contact between the slate and limestone. The veins dip steeply. Their filling is quartz and quartzite, in which the ore is found in nests, pockets, and irregularly shaped deposits. The ore was galena, anglesite, and cerussite, large bunches of compact anglesite with a kernel of galena being a common occurrence, and was rich in both lead and silver. In 1874 the Union mine produced 12,171 tons of ore averaging 47% lead and 87 oz. silver per ton. With increasing depth, the galena ore predominated. The veins varied greatly in width, swelling out to 40 ft. in places, and pinching almost to nothing in other places. The Union mine was the largest producer and for a while was worked very profitably.

Darwin. — Veins of lead carbonate ore, changing to galena, comparatively rich in both lead and silver, have been worked since 1874, but their aggregate production has not been of much importance.

Colorado

This State was for many years the leading producer of lead in the United States. At present, although its output of lead ore has decreased, it still contains several important lead-smelting centers, and the quantity of ore reduced within its borders is much larger than the production of its own mines. There is one smelting works in regular operation at Denver, two at Pueblo, one at Leadville, and one at Durango. A part of the bullion produced at those points is desilverized in Colorado, but the more part is shipped to eastern refineries.

The greatest lead-producing district of Colorado has been Leadville. Statistics of its output are presented in another chapter of this work. Other important lead-producing districts have been Monarch, Aspen, Lake City, Ten Mile, Gunnison, Georgetown, Rosita, Creede, and Red Cliff.

Aspen. — This camp in Pitkin County began to produce a considerable quantity of lead ore in 1884, and for several years following made rather a large output, but the value of its ores being chiefly in silver, the mines to a large extent became unprofitable upon the drop in silver in 1893, since which time they have been operated only on a small scale. The Aspen ores, which were chiefly of oxidized character, and usually associated with lime and baryta, were found generally at the intersections of a series of vertical cross-faults with two bed faults in Carboniferous limestone and dolomite, but also in less important deposits, although in similar relations to faults, in strata both older and later. The Aspen ores were especially noteworthy because of their large percentage of barium sulphate, an objectionable constituent from the smelter's standpoint. Their tenor in lead was not high as a rule, and Aspen was essentially a silver camp, rather than a lead camp, but in recent years its lead output has become rather large.

Creede. — Strong fissure veins, occurring in igneous rocks, carry galena and blende with a quartz gangue, the minerals being separated by jigging. The ore is easily milled, affording a high-grade lead, and a high-grade zinc product. This district was discovered in 1892, since which time it has been worked continuously.

Custer County. — Mines near Rosita, Silver Cliff, and Ilse were formerly large producers of lead. The Bassick mine was opened on a chimney consisting of an agglomerate of andesite and other volcanic material impregnated with galena and other sulphides. The chimney was roughly elliptical, 100×20 ft. to 100×30 ft., and was followed to depth of 1400 ft. without losing the ore. The Bull-Domingo mine was opened on a similar chimney. The Terrible mine, at Ilse, was opened on a wide porphyry dike, impregnated with crystals of cerussite. The crude ore averaged 10 to 12% lead and 1 oz. silver per ton. It was dressed to a product assaying 70% lead and 1.5 oz. silver. The Bull-Domingo mine yielded concentrates assaying 70% lead and 1.4 oz. silver per ton. The Bassick ore was richer in silver. These mines were important producers of lead from about 1882 to 1890.

Leadville. — This famous mining district situated in Lake County, near the head of the Arkansas River, was once the largest source of lead ore in the United States, and is still of considerable importance. The ore deposits occur at the contact of a formation of Carboniferous limestone with an overlying sheet of white porphyry, and in channels in the limestone itself. The ore-bearing area is extensive, but by far the most of the mineral has come out of a section less than two miles square. The country-rock is much folded and faulted, and disturbed by intrusions (dikes and sheets) of gray porphyry of later age than the white porphyry. The porphyry-limestone contact dips east at a moderate angle, and is exposed at the surface by the upthrow of several great fault series, especially the Carbonate and Iron faults. These exposures, both presenting long outcrops, afforded easy access to the ore-bodies at the beginning of mining in the district.

The ore occurred in shoots, or channels, of great size and remarkable continuity, of which a large number, approximately parallel in their courses, and to a considerable extent connected with one another by arms or branches, were opened. From the surface to the water-level the ore was lead carbonate (cerussite) and lead sulphate (anglesite), imbedded in a great body of manganiferous limonite; below the water level it consisted chiefly of a mixture of blende, galena, and pyrite, changing in the case of several shoots to nearly pure pyrites, occasionally cupriferous to a small extent. In the deposits of mixed sulphides there were found important masses of high-grade galena.

Leadville as a mining district has been remarkable for the variety of its ores, which contributed to the development of a great smelting industry. The ores produced may be roughly classified as lead carbonate, lead sulphide, lead-iron sulphide, pyrites (cupriferous and non-cupriferous), manganiferous limonite, and silicious. All of these are treated by the lead smelters. In general, the ores are more valuable for their silver content than for their gold content, but there have been some very rich gold mines, for example, the Little Johnny. Manganiferous iron ore, too low in silver to be profitable as flux to the lead smelters, has been shipped in large quantities to iron and steel works. Zinc-blende is sold in large amounts to zinc smelters. In one or two mines ore has been obtained sufficiently rich in bismuth to make it valuable for that metal.

The dimensions of many of the ore-bodies of Leadville were immense. The Evening Star-Maid of Erin ore shoot was in many places 30 ft. thick and 200 ft., or more, in width. The ore shoot extending through the Stone, Minnie, Col. Sellers, and Moyer mines was 400 ft. wide in the Minnie and nearly 70 ft. thick.

Monarch. — This district, situated at the head of a branch of the South Arkansas River, in Chaffee County, was a large producer of lead ore between 1882 and 1890. The ores, oxidized in character, occurred in deposits in limestone, near the surface and easily mined. Some of the deposits were of great size; in 1884 there was a stope in the Madonna mine, which was then making a large output, nearly 300 ft. long, 60 ft. wide, and 40 ft. high. The Monarch ores consisted chiefly of lead carbonate, much of it being in the form of sand, colored by ferric oxide. The average grade in lead was 20 to 45%, and in silver 5 to 12 oz. per ton. The following analysis was typical of the ore: Sesquioxide of iron, 32.99%; sesquioxide of manganese, 0.93%; alumina, 2.99%; oxide of zinc, 4.17%; lime, 1.78%; lead sulphate, 12.47%; lead carbonate, 32.35%; silica, 4.24%; sulphuric anhydride 3.30%; carbon dioxide, 6.73%; water, 6.68%.

Red Cliff. — Deposits of ore containing galena and anglesite occur in the valley of the Eagle River, especially at Red Cliff, at the contact between Carboniferous limestone and quartzite or porphyry. The mines of this district have produced as much as 3000 tons of lead in a year, but recently their output has been comparatively unimportant.

Ten Mile. — At Robinson and Kokomo, in Summit County, bodies of argentiferous galena, pyrite, and blende, and above the water-level their oxidized products, occur at the contact between Carboniferous limestone and an overlying sandstone, or at the contact between the limestone and sheets or dikes of porphyry. These mines were discovered in 1880, and for a few years were worked on a considerable scale, several smelting works being erected in the district. The mines proved disappointing, however, and were soon for the most part abandoned, although work has been continued in the district to the present time.

The ore deposits of the Ten Mile are of enormous size, but are chiefly pyrites, or pyrites and blende, of low grade in silver. Streaks and pockets of galena occur in the great mass of mixed ore, and there are some strong shoots of lead ore, which have been worked successfully, as in the White Quail mine. The ore-bearing formation of the Ten Mile outcropped at the surface and was easily opened, dipping at a gentle angle, but the oxidized ores, which were richer than the sulphides, extended only to a small depth.

Rico. — At Rico, Dolores County, deposits of silver-lead ores occur at the contact of Carboniferous limestone with intrusive porphyries. A smelting works was formerly operated at this place. Large bodies of mixed zinc-lead sulphide ore remain in the old mines, which now are being reopened.

Idaho

The principal lead-producing district in this State is the Cœur d'Alene, which has been indeed for many years the most important source of lead in the United States. Outside of the Cœur d'Alene the only lead mines in Idaho that have made a large output have been those of the Wood River district, and the Viola mine at Nicholia, Lemhi County.

Cœur d'Alene. — This district is situated in Shoshone County, in the northern part of the State, extending over an area about 10×22 miles. The first discoveries of lead ore were made on the eastern side in 1884; in the following year mines were opened in the western part. Production increased very rapidly and in 1891 there were 40 developed mines, of which 26 were classed as producers.

The country-rock of the Cœur d'Alene consists of slates, greywackes, and quartzite, thrown into east and west folds. In these rocks are fissure veins, in which argentiferous galena is associated with large quantities of siderite, together with some blende and pyrite. The gangue of the ore is quartz. In some veins the minerals are well segregated in individual streaks, the galena for example forming seams containing 60 to 80% lead. In other veins, or in other parts of the same vein, the various minerals are intimately mixed.

The ore-bodies are very large, some of them containing millions of tons of ore. The ore as mined contains 5 to 25% lead. The average for the district is probably about 10% lead and 7 oz. silver per ton.[1]

The Bunker Hill lode at Wardner had been worked, up to 1903, for a continuous distance of 6000 ft. on its strike, while openings further on were considered to be on the same fissure, though its continuity had not been proved. The Mammoth-Standard lode in the Canyon Creek district has been productive for a length of 2400 ft. As mined in the Standard, the ore-body was 5 to 50 ft. in width, averaging about 17 ft.

The immense size of these great ore-bodies, the fair grade of the ore, and the favorable natural conditions for their exploitation combined to make the Cœur d'Alene become the greatest lead-producing district of the United States, its only drawbacks having been remoteness from the great smelting centers and labor difficulties.

The lodes are so situated that they can be worked to a large extent through adit levels. Up to 1903 at least 70% of the ore previously mined had been extracted through adits, at no charge for hoisting and pumping, and of the remaining 30% at least two-fifths had been hoisted through underground shafts, to be subsequently hauled out through tunnels. The Tiger-Poorman was the only mine operated always by shafts from the surface.[2]

Three methods of mining are used in the district: (1) back-stoping and timbering; (2) back-stoping, timbering, and filling; (3) back-stoping and filling without timbering. All the mines of the region make more or less extensive use of the excellent water-power that is available locally, while in 1904 a 90-mile electric transmission from Spokane Falls was completed. In 1904 the wages paid miners were $3.50 per day; muckers, $3 per day. The general cost of mining and milling is $2.50 to $3.50 per ton. In 1902 the Bunker Hill & Sullivan Mining Co. produced 260,500 tons of ore at a cost of $2.09 per ton; in 1903 it produced 288,713 tons at a cost of $1.75 per ton. The transportation of the crude ore to the mills is a problem of importance to most of the mines of the Cœur d'Alene, only a few having mills at the place where the ore reaches the surface. In other cases the ore has to be carried considerable distances, the cost varying from 8 to 20 c. per ton. The ore is concentrated in mills of large capacity and good design at a cost of 25 to 35 c. per ton. From 75 to 85% of the lead in the ore is recovered in the concentrate, which is shipped as a product averaging about 50% lead and 30 oz. silver per ton.

[1] J. R. Finlay, Trans. Am. Inst. Min. Eng., XXXIII, 242.

[2] J. R. Finlay, *loc. cit.*

Southeastern Missouri and the Cœur d'Alene are the only lead-producing districts that have been developed in the United States, which have evidenced such permanence as to render a study of their cost of production a matter of economic value. In most of the other lead-producing districts, the lead has been essentially a by-product, as at Joplin, or the ore has been obtained from bonanzas as at Alta, Frisco, Nicholia, and the greater ones at Eureka, and greatest at Leadville, which have been characterized by a rise and fall and extremely variable cost of production. Southeastern Missouri and the Cœur d'Alene on the other hand have developed very large bodies of low-grade ore, in the exploitation of which engineering has been a greater factor than in extracting the richer bounties of nature.

The cost of production in the Cœur d'Alene varies greatly with the price of silver, which is an important by-product. As illustrative of the conditions at the present time, in an article in the *Engineering and Mining Journal* of Jan. 4, 1908, I deduced from the published reports of the Federal Mining and Smelting Co. that its mining and milling cost per ton of crude ore was $3.11 in 1905, $3.05 in 1906, and $3.08 in 1907, while the cost per pound of lead was 0.70 c., 0.29 c., and 0.33 c. respectively. It appears that while the cost for lead decreased rather largely from 1905 to 1906, the cost of mining and milling decreased only a trifle. The difference is explainable by an increase in the grade of the ore. This appears from the statistics which show that in 1906 the crude ore raised from the mines yielded an average of 7.21% lead and 4.48 oz. silver per ton, while in 1905 the figures were 6.64 and 4.05 respectively. Moreover, the value of silver increased largely from 1905 to 1906, and this has a highly important bearing on the mines of the Cœur d'Alene. Thus if the figures of the Federal Mining and Smelting Co. for 1907 were computed on the basis of 50 c. per oz. for silver, instead of 68.15 c., it would appear that the cost of a pound of lead would have been approximately 1 c. instead of 0.33 c.

Of course it will be understood that these estimates mean that 1 c. or 0.33 c., as the case may be, must be received for a pound of lead in the Cœur d'Alene for the mining company to come out even. The cost on the basis of delivery at New York is another matter. This again is a fluctuating affair, depending upon the grade of the concentrate, the profit expected by the smelter, and other factors; but allowing a reasonable profit to the smelter, the cost of freight, smelting, and refining on concentrate containing 45 to 50% lead may be fairly estimated at 2.33 to 2.5 c. per lb. of lead. It may be inferred, therefore, that under the conditions of the Federal Mining and Smelting Co., with silver at 50 c. per oz., the cost of delivering lead at New York is at least 3.33 to 3.5 c. per lb., but with proper allowances for amortization of mining and milling plant, etc., the actual cost must be close to 4 c. per lb. With silver at 67½ c. per oz., on the other hand, the cost is 2.65 to 2.8 c. without allowance for amortization, and probably about 3.3 c. with it.

The cost of production to the Bunker Hill & Sullivan company figures out in much the same way as the Federal, but more favorably, because of the higher grade of its ore and its lower cost of mining and milling. In the year ending May 31, 1907, this company mined 336,630 tons of ore, yielding 40,169 tons of lead and 1,645,719 oz. of silver. The average yield of the ore was about 12% lead and 5 oz. of silver per ton. The direct operating expenses were $665,379; the total expense, including new construction, exploration, litigation, taxes, and insurance, and in fact all charges, was $934,657. The average price for silver during this period was 67.497 c. per oz., at 95% of which the company realized for silver $1,055,268, which was more than $100,000 in excess of the total cost of production; consequently, the property would have been profitable if nothing at all had been received for its lead production. If, however, the price for silver had been only 50 c. per oz., the amount realized for the silver product would have been less than the total expenses and the lead product would have cost about 0.2 c. per lb. However, even then the total cost of this lead delivered at New York would have been only a little more than 2.5 c. per lb. The Bunker Hill & Sullivan product is undoubtedly the cheapest large supply of lead in the United States at the present time.

The cost of production in the case of some mines has been decreased materially during the last 15 years; but in other cases there has been no great change. The cost of mining and milling at the Bunker Hill & Sullivan mines in 1891 was $4.55 per ton;[1] the cost of milling was 44 c. The Helena & Frisco Mining Co. in 1891 extracted 51,604 tons of ore at a cost of $2.45 per ton;[2] the cost of milling was 45.6 c. per ton. The latter figures compare not unfavorably with some of those of the present time, but on the whole the operating costs in the district were much higher in 1891 than they are now. Freight and smelting charges also were much higher. These conditions are discussed more fully in a subsequent chapter.

Custer County. — Silver-lead mines have been worked at Bayhorse, Clayton, Squaw Creek, and Slate Creek.

Kootenai County. — At the southern end of Lake Pend d'Oreille, in a formation of limestone and quartzite, some large lodes of low-grade galena ore have been developed.

Lemhi County. — Between 1882 and 1887 a large production of lead was made by the Viola mine at Nicholia, 65 miles west of Dubois, a station on the Butte branch of the Oregon Short Line. The ore, which was a sand carbonate, assaying about 12 oz. in silver and 60% lead, was derived

[1] *Engineering and Mining Journal,* March 18, 1893. [2] Official report.

from a lens-shape deposit in a shaly blue limestone, near a quartzite contact. It was approximately 1000 ft. long, from one to 70 ft. in thickness, and went down at a dip of 12° to 15° for about 200 ft., where it merged into oxidized iron ore, 50 ft. thick, carrying a small percentage of lead.

The Texas and Spring Mountain districts, covering 15 miles of the slopes of the mountains that form the opposite side of the broad Birch Creek Valley, leading from Nicholia, have veins of lead ore, both carbonate and sulphide, in a limestone formation.

South Mountain. — Mines of low-grade lead ore, containing a good deal of zinc, have been worked to a small extent in this district.

Wood River. — Numerous veins of galena ore, rich in silver, occur in a limestone formation.[1] Up to about 1893 a considerable production of lead was derived from them, and recently attention has been redirected to the district. Bellevue, Hailey, and Ketchum are the important centers.

Montana

The principal lead-producing districts of Montana have been Glendale (Beaverhead County), Wickes (Jefferson County), Barker and Castle (Meagher County). Smelting has been conducted at several of those points, but the center of that industry is Helena, where is located a large plant of the American Smelting and Refining Co.

Barker. — Deposits of silver-bearing galena occur along the contact between granite-porphyry and limestone.

Castle. — Lead ore occurred as chimneys in limestone and at the contact of limestone with igneous rocks. The ore, which was carbonate and sulphate, with oxide of iron, and gangue of silica, was oxidized to an unusual depth. The principal mines were the Cumberland and Yellowstone. The former had a small smelting works at Castle. The high cost of transportation to Livingston (75 miles distant), the nearest railway point, retarded the development of the district and operations were finally suspended in 1893.

Glendale. — Deposits of argentiferous galena, blende, copper and iron pyrites, and their oxidation products, lie parallel with the bedding planes of a blue-gray limestone. The average grade of the ore in 1892 was reported by the Hecla Consolidated Mining Co. as follows: First class, 36% silica, 23.35% lead, 45.6 oz. silver. Second class, 7.2% lead and 16.7 oz. silver, this being dressed to 33.85 % lead and 50.2 oz. silver.

Neihart. — A series of fissure veins intersect a formation of gneisses and schists. In some parts the veins are barren. In other parts they carry large bodies of galena, associated with blende and pyrite, and a gangue of quartz and barite.

[1] J. F. Kemp, Ore Deposits of the United States, p. 273.

Wickes. — Galena ore, containing blende and pyrites, in a gangue of quartz, occurs in fissure veins (from 1 to 10 ft. wide) near the contact of granite and liparite, but cutting both rocks. The Helena Mining and Reduction Co. (Alta Montana mine) and the Gregory mine have been the chief producers.

Nevada

The only lead-producing district of great industrial importance ever developed in this State was Eureka. Lead ores have been mined and smelted at Oreana, Pioche, White Pine, and elsewhere, but the deposits at those places never proved of material consequence.

Eureka. — The famous lead ore deposits of Eureka occur in a zone of much faulted and crushed limestone of Cambrian age, which dips at a steep angle and lies between formations of shale and quartzite. Crossing these stratified rocks are dikes and intrusive masses of quartz-porphyry and rhyolite, which were influential in the deposition of the ore. The latter is found in fissures, crevices, and caves in the crushed limestone. The ore was oxidized to a depth of about 1000 ft., below which sulphides appeared.

The principal mines of Eureka are situated on Ruby Hill, which rises to an elevation of about 7300 ft., two miles west of the town. On this hill, going from southeast to northwest, are the Jackson, Phœnix, Eureka Consolidated, Richmond, and Albion mines, following in the order mentioned. Ore was found in each of these properties, but only in the Eureka Consolidated and the Richmond were the deposits of great magnitude. The geology of the Eureka district, including Ruby Hill, was described by Joseph S. Curtis in "Silver-Lead Deposits of Eureka, Nevada," which was one of the earlier monographs published by the U. S. Geological Survey, and ranks still among the best. Mr. Curtis' field work was begun in July, 1881, and concluded late in 1882; the book was published in 1884. Unfortunately, even when the field work was begun, the mines had passed their prime, and when the monograph was published their production had run down to a comparatively small figure. However, the report is of superlative value at present, when the mines are being reopened.

I shall not attempt to go much into detail in describing the geology of Ruby Hill. There is a wedge of crushed limestone lying on the southwest side of the Ruby Hill fault, the wedge lying between the Ruby Hill fault and a secondary fissure which joins the main fissure at the depth of 500 to 1500 ft. The line of junction of the two fissures increases with depth in going northwest, *i.e.*, from the Eureka Consolidated into the Richmond. Consequently, in going in that direction the vertical cross-section of the crushed limestone increases both in width and in depth.

The Ruby Hill fault is a fissure of remarkable persistency and sharp definition. The faulting of the formation thrust upward the Prospect Mountain quartzite, immediately underlying the ore-bearing limestone, upon the southwestern side, so that the quartzite and crushed limestone are now in contact at the secondary fissure. At the junction of these two fissures they appear to cross each other and at great depth there is probably another wedge of limestone in reverse position.

In the upper wedge of crushed limestone the ore occurs in deposits of very irregular form, sometimes resembling lodes, sometimes "stocks," and sometimes beds. According to Curtis the ore-bodies of any size were always capped by caves, or in some way connected with such openings in the rock and with fissures. This connection of ore-bodies with fissures is universal in the district. Curtis believed that the caves were formed subsequently to the deposition of the ore, partly by the action of water carrying carbon dioxide, and partly by the shrinkage of the ore in its decomposition. The origin of these caves, whether before or after the deposition of the ore, is a highly important point. Since the decomposition of the original ore, the latter has in many instances been redistributed by the flow of underground water.

The ore above the water level is principally composed of galena, anglesite, cerussite, and mimetite, with very little quartz and calcite, the gangue being for the most part hydrated oxide of iron. The ore carries both gold and silver. Below the water level the ore is chiefly composed of pyrite, arsenopyrite, galena, and blende.

The description of the ore deposits of Ruby Hill as occurring in forms resembling lodes, stocks, and beds is undoubtedly scientific, but I doubt if it conveys a thoroughly good idea of the occurrence of these ore-bodies. They occur as large masses, sometimes more or less ellipsoidal in form, in the crushed limestone. But what really constitutes the ore-body? In the early days it was only the mineral high in lead that was considered to be ore; lead and silver bearing limonite was "gangue." At present the former "gangue" is ore.

Considering all the mineralized matter to be ore, which is proper from the present standpoint, the ore deposits of Eureka consist of masses of oxidized silver-lead mineral, of irregular form, imbedded in larger masses of limonite containing a comparatively little gold, silver, and lead, the ultimate form of which is unknown, because the iron ore was not extracted in the former working.

An excellent idea of these ore-bodies is obtained from the surface workings on the western side of Ruby Hill, where there were enormous outcrops of iron ore, and also toward the top of the hill. These form, I believe, one of the most extensive iron outcrops ever known in North America. (The iron outcrop at Leadville, Colo., was more extensively covered by surface gravel.) There was little or no lead ore showing in the original outcrop at Eureka, but certain seams, which were followed down, rapidly swelled into great bodies of ore, and at the present time in the old quarries may be seen small seams of yellowish lead ore, ramifying into the red iron ore, which were overlooked by the tributers. The great excavation represents lead ore extracted, together with iron ore that was taken out incidentally, but the quantity of the latter apparently was not proportionately large, because the old dumps show comparatively little.

The conditions underground are similar to, indeed I may say identical with, those exemplified at the surface. Some of the surface deposits, in fact, extended right into the hill, one of them developing into the famous Hicks stope underground, and there are workings which go clear through Ruby Hill, coming out on the eastern side at what is the 100-ft. level of the Locan shaft. The ore that is now being mined at the surface on the western side of the hill is dumped down through one of the old shafts to this level, through which it is trammed to the bins at the eastern side of the hill.

The great ore-bodies throw out branches, veinlets, and streamers, so to speak, for long distances, the form being comparable to that of a cuttle-fish, with a large central body and tentacles extending in many directions. This made prospecting comparatively easy because the drifts driven on any level, if reasonably close together, were fairly sure to strike some tentacle of an ore-body if any existed. In following up such a leader the main ore-body was found sooner or later.

New Mexico

The most important lead-mining districts of this State have been Cook's Peak, Magdalena, and Socorro.

Cook's Peak. — This district, situated in Grant County, about nine miles north of Florida, on the Atchison, Topeka & Santa Fé railroad, has produced a good deal of galena ore from fissure veins in porphyry. The average grade of concentrates shipped in 1892 and 1893 was 43% lead, 61.6 oz. silver, and 0.08 oz. gold.[1]

Lake Valley. — The mines of Lake Valley, in Doña Aña County, were opened on deposits of silver-lead ore at the contact of blue limestone with an overlying porphyry, the formation being similar to that at Leadville, Colo. The ores were of several varieties, the general components being silica, oxides of iron, and manganese, some galena at times, and some zinc. As producers of lead these mines were never very important, but they afforded some rich silver bonanzas.

[1] *Engineering and Mining Journal*, Jan. 6, 1894, p. 15.

Magdalena. — Contact deposits between the slates and porphyry, in the Magdalena Mountains, 30 miles west of Socorro, have furnished large supplies of lead carbonate ore, assaying about 25% lead and 8 oz. silver per ton. Associated with the lead ore are deposits of calamine, and mixed zinc-lead sulphides. The Graphic and Kelly have been the most important mines. They are now considered more valuable as zinc mines than as lead mines.

Utah

Utah has several important lead-producing districts, and a great smelting industry, which is centered at Salt Lake City. Several of its lead-producing districts, especially Bingham, are historic, having been developed in the earliest days of mining in the territory west of the Rocky Mountains and maintained their importance down to the present time.

Bingham. — This important mining district, which yields both copper and lead ores, has a complicated geological structure of limestone beds of Carboniferous age, intercalated with shales and quartzites and intersected by intrusions of monzonite porphyry. The entire formation is excessively fractured, crushed, fissured, and faulted. The argentiferous lead ores, oxidized above and unoxidized (galena and pyrite) below the water level, occur in veins filling fissures which trend northeast-southwest, and traverse all kinds of rocks known in the district. The veins are widest in limestone and in shales which contain calcareous and carbonaceous matter. The geology of this district is described in a monograph of the U. S. Geological Survey by J. M. Boutwell. The first discovery in Bingham Cañon was made by George B. Ogilvie in 1863, and on Sept. 17, 1863, the Jordan Silver Mining Co. was organized to locate claims. This is the earliest recorded location in Utah.[1] The first shipment of ore from Utah was a carload of copper ore from Bingham Cañon, hauled to Uinta, on the Union Pacific, and forwarded by Walker Brothers to Baltimore in June, 1868.[2] However, the early importance of Bingham was as a silver-lead mining district. Copper mining, for which Bingham now is famous, did not seriously begin until nearly the end of the century.

Cottonwoods. — The most important mines in Little Cottonwood Cañon occur in Devonian limestone, or at the contact between two formations of limestone. In the Emma mine there was a great pear-shape mass of ore, at the maximum about 60 ft. long and 40 ft. wide, measured horizontally, and approximately 120 ft. from top to bottom.[3] The sudden termination of the ore with depth is explained by the theory that

[1] Contributions to Economic Geology, U. S. Geological Survey, 1902, p. 107.

[2] H. H. Bancroft, History of Utah, p. 741, through Contributions to Economic Geology, U. S. Geological Survey, 1902, p. 107.

[3] Mineral Resources West of the Rocky Mountains, 1871, p. 321.

it was a shoot that had been cut off by a fault,[1] but that has never been proved or disproved. The ore was an earthy ferruginous carbonate of lead, containing nodules of galena. It was very rich in both lead and silver, the first 10,000 tons produced averaging 160 oz. silver and 45 to 50% lead.

The Flagstaff mine, about 3000 ft. northwest of the Emma, also occurred as a bed vein in limestone strata, possibly an extension of the Emma vein, but the ore-body nowhere attained such magnitude as in the Emma mine. The character of the ore was, however, quite similar. Neither in the Emma or Flagstaff mines did the ore-body outcrop at the surface. Other mines in Little Cottonwood, occurring in the same limestone formation, showed similar characteristics.

The Miller mine, in American Fork Cañon, occurred in limestone near the contact with a quartzite. The ore-body was irregular, splitting up and branching out into the country rock. In some places it was quite thick, but never more than 15 ft. The ore was a ferruginous lead carbonate, containing considerable galena. Ore mined during a part of 1872 averaged 56% lead, 40 oz. silver, and 0.6 oz. gold.

These famous bonanzas were early exhausted, and no other mine of large production has ever been developed in the district, but operations have been continued quite steadily down to the present time, and an output, considerable in the aggregate, is made by a number of small mines.

Frisco.— The Horn Silver mine, at Frisco, Beaver County, is opened on a great contact vein between rhyolite (hanging wall) and limestone, which is known to extend two miles, but has been valuable only within the Horn Silver lines. The vein strikes north and south and dips 70° east. It varies in width from 20 to 60 ft., but has pinched twice in going down. The ore above the water level was chiefly a silver-bearing anglesite, carrying considerable barytes. In parts it was very rich in both lead and silver. Below the water level large bodies of zinc-lead sulphides were encountered, and the mine has now become a producer of zinc ore.

The Carbonate mine, 2.5 miles northeast of Frisco, opened on a vein in hornblende andesite, and the Cave mine, which had irregular pockets of lead-bearing limonite (containing from 5% to 7% lead) in limestone, have been small producers.

Park City. — The great veins of Park City, Summit County, carry argentiferous galena ores, besides the silver-milling ores, and in the Ontario and Daly mines the two classes have been separated by sorting, the lead ores being shipped to smelters at Salt Lake City. The Crescent, Anchor, and other veins have silicious lead ores, which are dressed, affording a galena concentrate assaying about 30% in lead.

[1] Mineral Resources West of the Rocky Mountains, 1874, p. 336.

The geological formation at Park City comprises a sedimentary series of quartzite, limestone of Carboniferous age, and calcareous sandstones and shales, together with intrusions of igneous rocks. Three main types of ore occurrence have been recognized, viz., fissure veins, replacements in limestone, and contact deposits. In the first the ore carries either silver and lead, with or without zinc, or gold with some silver, and occurs between well-defined walls. In the second the ore is chiefly valuable for silver and lead and takes the form of elongated lenses in limestone, roughly parallel to the bedding. In the contact deposits the ore contains copper and gold, with or without lead and silver, and forms in irregular masses, pockets, lenses, and pencils in metamorphic limestones adjacent to intrusive bodies.[1]

Superficial alteration has descended to great depth. Some ore-bodies in limestone have been almost entirely altered to oxides, carbonates and sulphates to the depth of 900 ft. below the present surface. At present both the oxidized and sulphide ores are mined. Lead ore is mined from all forms of deposits. Some high-grade shipping-ore is sorted out, but the bulk of the production is derived from low-grade ore, assaying 6 to 10% lead, which is concentrated in large, well-equipped mills, to a product assaying 30 to 35% lead. Some of the mills produce zinc ore as a by-product. Park City is included in the five great lead-producing districts of the United States at the present time.

Stockton. — Bed veins in limestone, or between limestone and quartzite, have contained rich shoots of silver-lead ore. Fissure veins also have been worked, but have been of less importance.

Tintic. — Three ore-bearing belts, one to three miles long, generally parallel with the stratification of vertical blue limestones, but sometimes running across them, have been exploited. In one belt the ore-bearing zone is 300 to 600 ft. wide, and bears in places rich shoots of carbonate ore. The lead production of Tintic has been considerable, but the major part of its ore production has been in silicious silver ore, and at present its output of lead ore is insignificant.

[1] J. M. Boutwell, Contributions to Economic Geology, 1902, pp. 39–40.

II

CHRONOLOGY

The following chronology presents the history of lead mining in the United States in a brief form and is a useful reference in connection with the statistics of production:

1621: Lead was mined and smelted near Falling Creek, Va., to supply the local demand for bullets and shot. This was the first mining and smelting of lead in what is now the United States.

1632: In a report made on the minerals of New England, lead ore is mentioned. (Bishop, History of American Manufactures, I., 470.)

1650: Supposed beginning of mining by Jesuits in Pima County, Arizona.

1651: Grant of lead mine at Middletown, Conn., to Gov. John Winthrop.

1682: Lead ore supposed to have been discovered in Wisconsin by Nicholas Perrot. (R. D. Irving, Mineral Resources of Winscosin, Trans. Am. Inst. Min. Eng., VIII., 498.)

1700: Discovery of lead in Missouri by Penicaut, one of Le Sueur's party. The same expedition discovered lead near the southern boundary of Wisconsin in August of the same year.

1712: Grant by Louis XIV. of the Crozat patents, with special privileges respecting the discovery and operation of mines in the then territory of Louisiana. Little or no mining was done under this patent until about 1720.

1717: Transfer of Crozat patents to the Mississippi Company, promoted by John Law, which prepared for active mining.

1719: First attempt to mine and smelt lead in Missouri, made by Sieur de Lochon, in behalf of the Mississippi Company, near Meramec River. Results unsuccessful.

1720: Philip Francis Renault, appointed director-general of the mines of the Mississippi Company in 1719, arrived at Kaskaskia with 200 artisans and miners and 500 slaves, and sent out exploring parties from there, one of which discovered the deposits of Mine la Motte, in Madison County, the mine taking its name from M. La Motte, a mineralogist accompanying Renault, under whom it was operated.

1723: Grant of Mine La Motte to Renault.

1724–6: Discovery of lead at Old Mine and Mine Renault, north of Potosi, Washington County, Mo.

1730: A company of German miners was sent out to the colony of New Netherlands by Baron Horsenclaver. These miners explored the Highlands and made many ventures in mining and smelting.

1731: Failure of the Mississippi Company and reversion of its charter to the Crown.

1738–40: About this time the Mine La Motte was considered public property, and the people in general were allowed to work at it. It furnished almost all the lead then exported from the Illinois (Moses Austin).

1740: Operation of lead mine near Northeast, Dutchess County, N. Y. The mine produced a small quantity of ore, but not profitably. The ore was sent to Bristol, England, and to Amsterdam.

1742: Return of Renault to France, bringing to a close the first period of mining in Missouri.

1750: Discovery of the Wythe mines, Virginia, by Col. Chiswell. Worked during the Revolutionary War, and afterwards intermittently up to 1838, and since then rather continuously.

1754: Lead ore was known to exist at Southampton, Mass., as early as this year, and lead was mined at Worcester, Mass. (Bishop, I., 493.)

1762: Cession of Louisiana to Spain.

1763: Discovery of Mine à Burton, at Potosi, Mo., and immediate inauguration of exploitation. This, together with Old Mine and Mine Renault, both near Potosi, and the Mine La Motte, were the principal mines worked during the next 30 years.

1765: Development of lead mine at Southampton, Mass. Work suspended by Revolutionary War and not resumed until 1809. Never became important.

1766: Capt. John Carver found lead ore in abundance at Blue Mound, Wis. The Indians knew of it, but did not know how to obtain the metal.

1767: Governor Clinton, of New York, directed attention to the existence of valuable veins of lead ore in that colony, and stated that the British Government had leased a mine of argentiferous galena to Frederick Philipse. A large refinery of lead or of iron existed at Sing Sing prior to, or at the beginning of, the Revolution. (Bishop, I., 527, 533.)

1769: Destruction of settlement at Mine La Motte by Chickasaw Indians and abandonment of the mine, which was not reopened until 1780 or 1782.

1778: Operation of lead mine near Birmingham, Blair County, Pa; resumed in 1795, and again in 1864. Never important.

1788: The first mining in the Wisconsin-Iowa region was done at Dubuque, Iowa, by Julien Dubuque, who received grant of a lead mine from the Fox tribe of Indians. Dubuque worked this mine until his death (in 1809).

1789: Tariff on lead fixed at 1 c. per lb.

1795: Discovery of the Mine à Lanye, about 16 miles southeast of Potosi, Mo.

1797: Discovery of the Mine à Maneto, on Big River, St. François County, Mo.; also Mine La Platte, about two miles from Big River, near the southeast corner of Washington County.

Arrival in Missouri of Moses Austin from Wytheville, Va.; improvement of smelting methods, erection of shot-tower, and works for manufacture of sheet lead.

1801: Discovery of Mine à Joe, later called Bogy Mine, on Big River, St. François County, Mo.

1803: Discovery of Mine à Martin near Potosi, and several other deposits in Washington County, Mo.

Louisiana purchased by the United States. Most of the French and Spanish concessions, when they had been continuously occupied, were confirmed by a commission.

1806: Discovery of New Diggings, near Potosi, Mo., which for a few years produced about 1000 tons of galena per annum.

Discovery of mines at Hazel Run, about five miles northeast of Bonne Terre, St. François County, Mo., which are said to have yielded 500 tons of lead in the first year.

1807: Act of Congress reserving all lead lands in territory of Louisiana and authorizing the Governor to grant three-year leases to discoverers at royalty of 10% of the product. (American State Papers, 2d ed., IV., pp. 526, 555.)

1811: Discovery of Shibboleth mines, near Cadet, Washington County, Mo., which in the first year are said to have yielded 2500 tons of ore, equivalent to 1563 tons of lead.

1812: Tariff on lead raised from 1 c. to 2 c. per lb.

1814: The Fourche à Courtois mines, at Palmer, Washington County, Mo., were discovered.

1816: Tariff on lead fixed at 1 c. per lb.

1820: Lead ore worked at Ellenville, N. Y., but with little success. Several veins worked there about 1854 and two Scotch hearths erected.

1821: Attention attracted by explorers to the Wisconsin lead region.

1824: Import duty on lead raised from 1 c. to 2 c. per lb.

Discovery of Sandy mines, near Hillborough, Jefferson County, Mo., which soon became large producers.

Joseph Schutz discovered the Valle mines, seven miles north of Bonne Terre, St. François County, Mo.

1825: Bisch's mine, near the Valle mines, was discovered.

1826: Development of Eaton mine, near Madison, Carroll County, N. H. Vein leanly mineralized with blende and argentiferous galena.

1828: Tariff on lead raised from 2 c. to 3 c. per lb.

1830: Golconda mine in Franklin County, Mo., discovered.

1832: Discovery of small veins of lead ore near Lubec, Me., and beginning of development; results never successful.

Final withdrawal of the Indians from Wisconsin.

1834: Discovery of Virginia mine, near St. Clair, Franklin County, Mo., extensive developments being immediately undertaken. Smelting begun in 1835.

In consequence of the large number of illegal entries, the miners and smelters of Missouri refused to pay royalties and the Government was unable to collect. (J. D. Whitney, Metallic Wealth of the United States, p. 405.)

1835: Operation of lead mines at Rossie, N. Y.; continued until 1840.

1836: Discovery of Washington, known later as Silver Hill, mine in Davidson County, N. C. Worked almost uninterruptedly until 1852. Reopened in 1855.

Erection at Webster, Washington County, Mo., of first Scotch hearth furnace in Missouri. (G. C. Swallow, Report of Geological Survey of Missouri, II., 59.)

1837: Reed and Hoffman erected works for manufacture of white lead at St. Louis. Other works were erected soon afterward at the same place.

Operation of vein of lead ore near Redbridge, N. J.

1838: Value of cerussite ore, "dry bone," first recognized in Missouri, leading to the erection of new furnaces and an increase of product. (James E. Mills, Geological Report on the Mine la Motte Estate, p. 47.)

1839: Discovery of lead ore at Rosiclare, Hardin County, Ill.

1846: Operation of lead mine near Shelburne, Coos County, N. H.

Tariff on lead reduced to 20 per cent. ad valorem.

1847: Congress decided to sell the National lead lands in the Mississippi Valley.

1848: The Avon mines, Ste. Genevieve County, Mo., produced eight tons of lead.

Mining of lead ore begun two miles east of Joplin, Mo., by William Tingle.

1850: Mining done on small scale near Phœnixville, Chester County, Pa.

Mining begun near Granby, Newton County, Mo., in which vicinity operations were well under way by 1857 and a large output was being made.

The air, or Drummond, furnace was first tried for lead smelting in Newton County, Mo.

1851: Mining begun on Center creek, near what was later called Minersville, now Oronogo, near Joplin, Mo.

Erection of first Scotch hearth furnace in southwestern Missouri, located near mouth of Cedar creek, Newton County.

Lead-smelting furnace erected on West Sugar Loaf creek, Ark., this being the first in that State.

1852: Resumption of mining at Rossie, N. Y.

1853: Resumption of mining at Ancram, Columbia County, N. Y.

1855: The Mowry mine, south of Tucson, Ariz., purchased by Major Ewell and others.

1857: Tariff on lead reduced to 15% ad valorem.

Establishment of town of Granby, Mo., and erection of furnaces by Peter E. Blow and Ferdinand Kennett.

1858: Discovery of rich vein of lead ore at Guymard, N. Y.; operated until 1868 and later.

The Mowry mine passed into the hands of Lieut. Sylvester Mowry, who from this date until 1862 operated it on a considerable scale. This appears to be the first silver-lead mine west of the Rocky Mountains to have been operated in an extensive way. The Confederate army is reported to have been supplied with some lead from this source.

1859: Discovery of mines at Georgetown, Colo.

1861: Tariff on lead raised to 1 c. per lb., and later in the year to 1.5 c. per lb.

Mine la Motte furnaces destroyed by United States Government, but soon rebuilt.

1862: Plant of the Mowry mine, Arizona, destroyed by Federal troops.

1863: First discoveries of argentiferous lead ore in Little Cottonwood cañon, Utah.

Discovery of the Jordan mine, Bingham cañon, Utah.

Discovery of silver-lead mines at Castle Dome, Ariz., which, on account of Indian hostilities, were not actively worked until 1869.

1864: First locations at Eureka, Nev., but no important developments were made until 1869, in which year the great silver-lead deposits were opened.

Organization of St. Joseph Lead Co., which purchased La Grave mines at Bonne Terre, Mo. Active operations begun in 1865.

Tariff on lead raised to 2 c. per lb.

1865: Organization of Granby Mining and Smelting Co. to work the mines at Granby, Mo.

Erection and operation of smelting works at Argenta, Mont.; commonly credited as the beginning of silver-lead smelting in the United States.

1866: Establishment of the Selby smelting and refining works at San Francisco, Cal.

1867: Discovery of silver-lead ore in the Magdalena Mountains, N. M.

Discovery of rich deposits of silver ore at White Pine, Nev.; these were the first large bodies of silver ore found in a limestone formation in the United States, and the information gained from them led directly to the discovery of the silver-lead deposits of Eureka soon afterward.

Smelting begun at Oreana, Nev.

1868: The Emma mine, Little Cottonwood, Utah, was located in August of this year, but no large shipments were made until July, 1870.

1869: The junction of the Union Pacific and Central Pacific tracks was made at Promontory, Utah, May 10, 1869. The Utah Central railway was completed to Salt Lake City in December, 1869. The completion of the Pacific railways greatly stimulated prospecting along their lines, making available to market the lead in ores previously discovered in Utah and Nevada.

Development of silver-lead mines at Cerro Gordo, Cal.

Inauguration of diamond-drill prospecting by St. Joseph Lead Co. at Bonne Terre, Mo., and discovery of disseminated ore at depth of 120 ft.

The important silver-lead deposits of Eureka, Nev., began to be productive. The American practice of silver-lead smelting has been developed chiefly from the methods introduced in this district.

1870: First important developments in the districts of Big and Little Cottonwoods, Bingham cañon, Stockton and Tintic, Utah.

The Miller mine in American Fork cañon was discovered, but was not worked extensively until 1871.

Construction of narrow-gauge railway system in Colorado begun by Denver & Rio Grande Railway Co.

Discovery of lead mines at Rosita, Colo.

The mines of Eureka, Nev., became large producers.

Beginning of shipments from the great Emma deposit, Little Cottonwood cañon, Utah. This was the principal source of lead in Utah up to 1875, when the deposit was exhausted.

Invention of the siphon tap for lead blast furnaces by Albert Arents, and its application at Eureka, Nev.

Erection of lead-smelting works at Omaha, Neb.

Discovery of lead ore in large quantity at Joplin, Mo., followed by the rapid development of that district.

1871: The mines of Big and Little Cottonwood, Utah, made large shipments.

Discovery of silver-lead ore in Parley's Park district, now Park City, Utah.

Chicago an important smelting and refining center.

1872: The Ontario vein, Park City, Utah, was located June 19.

Discovery of silver ore at Georgetown, N. M.

Refining of lead begun at the Germania works, Salt Lake City, Utah.

E. Daggett installed cast-iron water-jackets at the Winnamuck smelting-works, Utah, these being the first water-jackets in Nevada-Utah smelting practice and the first cast-iron jackets employed anywhere.

Discovery of lead ore in Cherokee County, Kan.

Tariff on lead reduced to 1.8 c. per lb.

1873: Discovery of silver-lead mines in Wood River district of Idaho.

The United States, by Act of Congress, February 12, discontinued the coinage of silver dollars. This Act did not demonetize silver in words, although it did so in effect. The silver dollar was not named in it. Precisely what the Act did was to authorize the coinage of silver half-dollars, quarter-dollars and dimes below standard weight, and of a new silver coin for Asiatic commerce, of standard weight, to be called the "trade dollar," and to prohibit these coins from being legal tender for more than five dollars in any one payment. The German Government, by Act of July 9, provided for the retirement of its silver coins and the sale of the bullion. By a Treasury order, September 6, France limited the amount of silver to be accepted by its mint. These actions, which were soon afterward followed by similar ones in other countries, were closely involved with the silver question, and the decline in the value of silver, which began at this time, culminating in the crisis following the closing of the Indian mints to the private coinage of rupees, June 26, 1893, had a powerful effect on the silver-lead industry.

1874: Early in this year, argentiferous lead-carbonate ore was found on Iron Hill, Leadville, Colo., and the Lime and Rock claims were located.

Discovery of silver-lead ore at Darwin, Inyo County, Cal.

Installation of dust-chambers at several Western lead-smelting works and adoption of methods for further treatment of matte.

1875: Discovery of Horn Silver mine, Frisco, Utah.

Mining was begun at Webb City, Mo.

Tariff on lead raised to 2 c. per lb.

First shipments from Leadville, Colo.

Mining was begun at Carterville, Mo.

Investigations by Anton Eilers and others determined the correct principles in preparing charges of ore for smelting, a development of great economic importance.

1877: The Bassick mine, near Silver Cliff, Colo., began to show evidence of value.

First smelting works erected at Leadville, Colo.

1878: Discovery of the silver-lead deposits of Sierra Mojada, Coahuila, Mexico.

Great excitement at Leadville, Colo., where many new discoveries were made. The output of ore began to be large.

Mines of Hecla Consolidated Mining Co., at Glendale, Mont., became productive.

Discovery of lead-carbonate ore in the eastern part of Gunnison County, Colo.

Blast furnaces substituted for reverberatory at works of St. Joseph Lead Co.

The American Pig Lead Association, an alliance of the principal lead miners and lead smelters of the United States, was formed to maintain the price of lead at minimum of 4 c. per lb. The attempt failed.

Introduction of Lewis & Bartlett process at Lone Elm smeltery, Joplin, Mo.; this was the first application of cloth-filtration of fume in the metallurgy of lead.

Desloge mill and furnace, adjacent to works of St. Joseph Lead Co., Bonne Terre, Mo., put in operation.

First location made at Tombstone, Ariz.

1879: First important discoveries in the Wood River district of Idaho. Ore had been known to exist in this district since 1873, but developments were checked by Indian troubles and not actually begun until 1880. The district became productive in 1881, making the first important output of lead in Idaho.

Discovery of lead-carbonate ore at Rico, Colo.; also at Red Cliff, Colo., and at Kokomo, Colo. Considerable excitement in the Gunnison country, Colo.

Discovery of promising deposits of silver ore at Aspen, Colo., and in the San Juan region in the southwestern part of the same State.

Lead mines discovered at Barker, Meagher County, Mont.

1880: Completion of the Southern Pacific Railway through Arizona.

The Denver & Rio Grande Railway reached Leadville, Colo.

Discovery of Silver Valley mine, Davidson County, N. C.

Strike of miners at Leadville, Colo.

Discovery of lead ore at Robinson and Kokomo, Colo.

Excitement in the Gunnison district of Colorado, which did not, however, materialize into developments of great importance.

St. Louis & San Francisco, Missouri Pacific, and Kansas City, Fort Scott & Memphis railways extended into Joplin district, Mo.

1881: Establishment of smeltery at Socorro, N. M., for treatment of ores of Socorro and Magdalena.

1882: Discovery of the Viola mine at Nicholia, Idaho.

Red Cliff, Colo., began to make a considerable output.

1883: Maximum output of Leadville, Colo.

Monarch district, Colo., began to be large producer of lead, output attaining maximum in 1885.

Destruction by fire of mill and mine buildings of St. Joseph Lead Co., at Bonne Terre, Mo., replaced immediately by large and improved works.

The Viola mine, at Nicholia, Lemhi County, Idaho, began to be productive.

Tariff on lead continued at 2 c. per lb.

1884: Aspen, Colo., began to produce a considerable quantity of lead ore.

The Neihart district of Montana began to attain prominence.

Opening of extensive bodies of lead-carbonate ore at Cook's Peak, Grant County, N. M.

First discoveries in the Cœur d'Alene district, Idaho.

Destruction by fire of works of Desloge mine, at Bonne Terre, Mo., and purchase of mine by St. Joseph Lead Co.

1886: Mines at Aurora, Lawrence County, Mo., began to be developed.

Discovery of Wardner district on the south fork of the Cœur d'Alene River, Idaho.

First production of lead ore in the Cœur d'Alene district, Idaho.

Mexican lead ore, especially from Sierra Mojada, began to be imported into the United States in important quantity.

1887: Opening of Doe Run mine, near Farmington, Mo.

Contest between local and valley smelters in the market for Leadville ore, with advantage in favor of latter, owing to railway discriminations.

1888: Attempted corner in the lead market, leading temporarily to high prices, but resulting finally in the failure of Corwith, the chief speculator.

1889: Establishment of the silver-lead smelting industry in Mexico, the rapid development of which greatly reduced the supply of Mexican ore available for reduction by American smelters.

Development of disseminated ore at Flat River, Mo.

Tariff on lead continued at 2 c. per lb., and lead in ore made dutiable at rate of 1.5 c. per lb.

1890: Completion of Mississippi River & Bonne Terre Railway and removal by St. Joseph Lead Co. of its smelting-furnaces from Bonne Terre to Herculaneum.

Completion of Northern Pacific and Oregon Railway and Navigation Co.s' tracks into the Cœur d'Alene district.

1891: Discovery of silver-lead ore at Creede, Colo.

Incorporation of the National Lead Co., this concern succeeding the National Lead Trust, organized a few years previously.

1892: Development of large bodies of silver-lead ore at Cook's Peak, N. M., and heavy shipments from that point.

The Maid of Erin mine, Leadville, Colo., shipped its last lot of lead-carbonate ore in December, exhausting its great deposit and practically marking the end of the production of this class of ore at Leadville.

Strike of miners in the Cœur d'Alene district on account of reduction in wages.

Invention of the Howard skimmer for handling zinc crust, which was one of the most important of the mechanical improvements in the Parkes process of desilverization. First put into practical use at the works of the Pueblo Smelting & Refining Co., Pueblo, Colo. The Howard press was invented a little later.

1893: The report of the Herschell committee, closing the Indian mints to the private coinage of rupees, was published June 26, causing a decline in the price of silver from 81 c. to 62 c. per oz., and contributing to the industrial panic which occurred this year, leading among other things to the suspension of operations in many silver-lead producing districts of the United States.

All of the mines in the Cœur d'Alene closed temporarily on account of low prices for lead and silver.

All of the smelters at Leadville suspended operations in the autumn, only two of them subsequently resuming.

Importations of small amounts of lead ore from British Columbia.

1894: Second strike of miners in the Cœur d'Alene.

Tariff on pig lead reduced to 1 c. per lb., and on lead ore to 0.75 c. per lb.

Formation of association of the principal smelters of Colorado to limit prices to be paid for ores. The combination went to pieces early in 1895 and sharp competition was again inaugurated.

1896: First patent secured on the Huntington-Heberlein process, a far-reaching and revolutionary improvement in the metallurgy of lead. The process was developed at Pertusola, Italy, by Thomas Huntington, an American citizen, and Ferdinand Heberlein, a German.

Strike of miners at Leadville, Colo., which practically stopped all production during the last six months of the year.

In August of this year the price for lead fell to the lowest point on record in the United States, 2.60 c. per lb., New York, having been accepted for several lots. The average for August was 2.73 c., and for the year 2.98 c. The lowest price at St. Louis was 2.43 c.

1897: Tariff on pig lead raised to 2⅛ c. per lb., and on lead in ore to 1.5 c. per lb. (Dingley bill.)

The old works of the St. Louis Smelting and Refining Co. at St. Louis, which had been idle for a long time, were again put in operation to smelt ores for southeastern Missouri and the Joplin district. From this time St. Louis increased rapidly in importance as a center of lead production.

1898: Organization of Empire State-Idaho Mining and Development Co., the beginning of consolidations in the Cœur d'Alene.

The St. Louis Smelting and Refining Co., a constituent of the National Lead Co., acquired property in the disseminated district of Missouri and began its development, leading to a large production of lead in the course of a few years.

1899: Organization of the American Smelting and Refining Co., which acquired a large number of the silver-lead smelting and refining works of the United States. Several of these were promptly dismantled.

Third general strike of miners in the Cœur d'Alene, dynamiting of the Bunker Hill & Sullivan mill, April 29, proclamation of martial law, and final reopening of the mines on a non-union basis.

Entrance of the Guggenheims, under the name of the Federal Lead Co., into the disseminated district of southeastern Missouri.

Strike of smelter workmen in Colorado early in June hindered operations for many weeks.

Great increase in use of lead for electrical purposes (covering cables, etc.).

1900: Organization of Guggenheim Exploration Co., which acquired, among other property, the capital stock of the Federal Lead Co. and of the Missouri Smelting Co.

1901: Absorption by the American Smelting and Refining Co. of the smelting interests of M. Guggenheim's Sons, the latter becoming, however, the dominating factor in the amalgamated company.

The American Smelting and Refining Co. assumed control of the lead market, fixing the price both for producers and consumers, and regulating the output by agreement with the large producers and by adjustment of its smelting charges in connection with small producers. A very large accumulation in the stock of lead on hand occurred this year, which, however, was successfully disposed of in 1902 and 1903.

1902: Betts's electrolytic lead-refining process installed at Trail, B. C.; the first electrolytic lead refinery to be put in practical operation.

Strike of miners at Flat River, southeastern Missouri.

Output of Cœur d'Alene district, Idaho, limited by arrangement between the leading producers and the American Smelting and Refining Co.

The American Smelting and Refining Co. put the marketing of its lead on a contract basis, filling orders for prompt shipment only at a premium of 2.5 c. per 100 lb., this being done to induce consumers to cover their requirements ahead and carry the stocks that formerly the smelter often had to carry.

Further steps were taken by the American Smelting and Refining Co. to centralize its smelting operations, the Philadelphia plant, at Pueblo, Colo., being closed, and the famous old smeltery and refinery at Kansas City being abandoned and soon afterward dismantled.

1903: Consolidation of many of the large mines of the Cœur d'Alene by the Federal Mining and Smelting Co.

Organization of the United Lead Co., which secured control of nearly all the manufacturing plants making sheet lead, pipe and shot, 21 in number, together with a few white-lead works.

Western Mining Co. organized as a subsidiary company of the Guggenheim Exploration Co., acquiring several of the principal lead-producing mines at Leadville, Colo.

In July there was a strike of the smelter-men at the Grant works of the American Smelting and Refining Co., and the plant was closed by the company and abandoned.

1904: Termination of miners' strike in southeastern Missouri. The labor troubles in this district had been a festering sore for two or three years.

1905: Adoption of the Huntington-Herberlein process by the American Smelting and Refining Co. It had previously been introduced in Italy, Germany, Spain, Great Britain, New South Wales, Tasmania, Mexico and British Columbia.

Redirection of attention to many of the old mining districts, including Cerro Gordo, Cal., and Eureka, Nev. Consolidation of Eureka and Richmond companies.

Purchase of the Selby works, at San Francisco, by the American Smelters Securities Co., a sub-company of the American Smelting and Refining Co.

Organization of the United States Smelting, Refining and Mining Co., taking over several independent works, with plans to enter into competition with the American Smelting and Refining Co.

1906: Reopening of many old silver-lead mining districts, idle for from 10 to 30 years previous, including Eureka, Nev., and Cerro Gordo, Cal.

The United States Smelting, Refining and Mining Co. erected an electrolytic lead-refinery near Chicago, Ill., this being the first of this kind in the United States.

The Guggenheim interests practically secured control of the National Lead Co., thus bringing the major part of the lead-consuming industry of the United States into direct affiliation with the American Smelting and Refining Co.

III

METALLURGY

The development of the lead industry in the United States has been especially affected by improvements in mining and milling methods, in transportation facilities and in metallurgical practice. The last two factors, which are closely connected, have been the more powerful. Transportation has made possible the exploitation of ore deposits in remote places, unfavorable to local smelting, and the establishment of large, economical plants at central points. These large plants, commanding technical skill of the highest order, have presented opportunities for the development of improvements in practice, which would have been slow in maturing, or quite impossible, in smaller and isolated plants, and these improvements have led to economies of far-reaching effect. In order to appreciate the bearing of this great factor in the history of the industry, it is necessary to consider carefully the principles of the metallurgy of lead.

The art of extracting lead from its ores is based on these principles: (1) the reduction of lead oxide by carbon, or carbon monoxide; (2) the reaction between lead sulphide and lead sulphate or oxide, resulting in a double decomposition; and (3) the decomposition of lead sulphide by metallic iron. All of these reactions are endothermic, *i.e.*, they absorb heat, which must be supplied extraneously. The first principle is the basis of what is known as the roast-reduction method of smelting, in which lead oxide (or lead silicate, or some other oxidized compound) must be prepared from sulphide ore by a preliminary roasting. The second is the basis of what is known as the roast-reaction method. And the third is the basis of the precipitation method. All of these methods are employed practically in the United States at the present time, either alone or in combination, the latter being most commonly the case; also, the principles are not practically so sharp as theoretically stated, the reactions fundamental to one process invariably playing a certain part in the other processes.

If a lead ore were absolutely pure, there would be no other consideration in the smelting processes than those reactions which relate to lead and its chemical combinations; but practically lead ores are never pure, the valuable minerals being mixed with a certain proportion of foreign matter, which must be separated by making a slag of it. In the roast-reaction method of smelting, it is true, no slag properly speaking need be made, the reduced lead being liquated out from the worthless impurities, but the latter will still retain a high percentage of lead, and in order to effect a high degree of extraction from the ore it must be subjected to a further smelting process in which a true slag is made. In making a slag, the object is to combine the impurities into a fusible silicate, which when molten will be of comparatively low specific gravity, so that the heavier lead will settle to the bottom of the crucible, whence it may be drawn off separately, while the lighter slag will float on top. Besides the slag and metal, there is formed practically another substance, called matte, which is lighter than the metal but heavier than the slag; and sometimes also a substance called speiss, which is heavier than matte. Matte is an artificial sulphide, consisting in lead smelting usually of the sulphides of iron, lead, and copper (if copper be present in the ore), and owes its origin to the incomplete elimination of the sulphur of the ore. Similarly, speiss is an artificial arsenide of iron.

The difference between lead smelting in principle and in practice is chiefly due to the incompleteness with which the basic reactions are carried out, and the qualifying effect of the impurities that are commonly met with in the ores. Thus certain metallic impurities are reduced with the lead, contaminating it and necessitating a subsequent refining process. Other impurities affect the composition of suitable slags. Others still affect the running of the furnace. It is the reconciliation and neutralization of these various difficulties that constitute the duty of the metallurgist, whose purpose is to treat a ton of ore in such way that the difference between the value of the products extracted and the expense of treatment will be the maximum, the value of the products depending largely upon the percentage extracted, and the expense of treatment including interest and amortization charges on the capital invested in plant, etc. It is only since about 1885, however, that the art of lead smelting has been reduced to any such basis of precision.

The most primitive form of lead smelting in the United States was practised with the log and ash furnaces employed in Missouri prior to 1850. These furnaces and the method of their operation are described briefly in a subsequent chapter. They employed the roast-reaction system of smelting and were applicable only to non-argentiferous galenas, of very high grade in lead. They were for the most part displaced about 1840 by the Scotch[1] hearth furnace. Later on reverberatory furnaces of

[1] This term is not strictly accurate, since the furnaces of this class that were introduced into America were early modified materially from their prototype as employed in Great Britain. They are described more precisely as the American-Scotch hearth, which term is to be found in many metallurgical treatises, but is never heard in practice, the term Scotch hearth having been adopted for brevity.

the Flintshire type came into use, but never extensively, nor with such success as to develop a permanent metallurgical practice. The Scotch hearth, however, has survived, and in its modern development is the basis of a highly efficient process in the treatment of certain classes of ore, especially high-grade non-argentiferous galena.

Neither the Scotch hearth, nor the reverberatory furnace, which were in use in Missouri and Wisconsin when the silver-lead deposits west of the Rocky Mountains began to be developed, is well adapted to the treatment of argentiferous ore, or to the treatment of ore containing less than 60% of lead, while the smelting of carbonate ores alone in those ways is of course infeasible. The adoption of the blast furnace was therefore the only resort, although many persons had to learn this by their own experience, erecting hearths and reverberatories with of course disastrous results.[1]

In the early history of blast-furnace smelting of silver-lead ore in the United States, the work was done chiefly for the reduction of the ore of a single mine, or single group of mines, as at Eureka, Nev., Cerro Gordo, Cal., and at several places in Utah. The charges were generally rich in lead. Their silver and gold contents went of course chiefly into the lead, but although they were commonly the most important elements of value in the ore, the process was essentially one of lead smelting.

Later on, when many of the rich lead deposits became exhausted, when the tonnage of rebellious[2] gold and silver ores greatly increased, when transportation facilities had been largely improved, and when the smelting industry had become concentrated in a comparatively few centers, drawing ore supplies from numerous districts, the average percentage of lead in the ore smelted fell to a low figure, and although in the aggregate the production of lead increased immensely, the process of reduction became essentially one of gold and silver smelting, the lead in the ore functioning as collector of the precious metals and being viewed metallurgically from that standpoint.

It is useful, therefore, to consider the art of lead smelting in its present development as being divided under three heads, viz.:

(1) Reduction of non-argentiferous galena, in which all the methods of smelting are applicable, if the ore be sufficiently rich in lead.

[1] At the inception of lead smelting in Colorado, Utah, and Nevada, numerous attempts were made to employ hearths and reverberatories, some of these, especially in Utah, being rather ambitious. These attempts were so ill-advised, their campaigns were so short and their results so entirely failures, that it is not worth while to review them here. The only serious attempt to smelt argentiferous lead ore in reverberatory furnaces in the United States, which developed into a practice, if only a short-lived one, was made at Chicago, Ill. This is referred to further on in this chapter.

[2] This word when applied to gold and silver ores indicates those of a character not readily amenable to the milling processes.

(2) Reduction of special classes of argentiferous ore, the product of one mine or a few mines, in which the blast furnace only is advisable. This head covers the conditions that formerly existed at Eureka, Cerro Gordo, Horn Silver, and elsewhere, which still exist in isolated instances. The character of the charge and the bullion are chiefly dependent upon the composition of the ore, while the slag is governed by the composition of the ore and the availability of the necessary fluxes and may vary within rather wide limits.

(3) Reduction of general mixtures of argentiferous ores, the product of many mines. The most important part of the present lead-smelting industry falls under this head. The ores are mixed to make a slag of definite composition and a bullion of nearly uniform grade, which vary only within narrow limits. The percentage of lead in the composite ore, *i.e.*, the furnace charge, is comparatively low, and is designed to be only what is necessary to collect the gold and silver most efficiently. To improve the collection of gold and silver a proportion of copper is generally added to the charge, which results in the production of a cupriferous matte as a between product.

The third system is essentially gold and silver smelting on a lead basis, and is commercially analogous precisely to smelting on a copper basis. These two kinds of smelting are indeed competitive, the same ores being to a large extent amenable to treatment in either way. However, the copper smelter is not desirous of receiving lead-bearing ores, while the lead smelter needs a certain proportion of copper-bearing ore. In the treatment of mixtures properly compounded, smelting on a copper basis is more profitable than on a lead basis, and the tendency of metallurgical practice during the last ten years has been toward its adoption wherever feasible. The two kinds of smelting are now to be witnessed in operation at the same places, and even side by side in the same works (*vide* Salt Lake City, Utah; Aguas Calientes, Mexico, and elsewhere).

In smelting any kind of lead ore in any way, the sulphur must be burned off and the impurities must be combined in a slag, fusible at approximately 1100° to 1200° C., and of specific gravity not to exceed 3.6, or but little more. The slag must be of a composition which will form at the right point in the smelting process, will be thoroughly liquid, in order to insure a satisfactory separation from the matte, and will require the minimum consumption of fuel, the chief part of which in blast-furnace smelting is always consumed in effecting the formation of the slag. A good slag will cause the charge of ore and flux to descend evenly and regularly in the furnace, avoiding the formation of accretions in the hearth or on the walls, keeping the lead in the crucible red-hot and preventing any creeping up of the fire and the ensuing danger of loss of lead and silver by volatilization.

The sulphur is eliminated in various ways, which may be enumerated as follows:

(1) *Roasting.* Performed usually in hand-raked reverberatory furnaces with a single, long hearth. Brueckner cylinders are also employed, but most of the other forms of mechanical furnaces are inefficient, because of the stickiness of lead ore in roasting, wherefore the attempts to apply them have been generally abandoned. Lead ores, being usually low in sulphur, are not self-burning in the ordinary roasting furnace, and decomposition of lead sulphate being effected only by reaction with silica, forming lead silicate, the necessary temperature must be chiefly supplied by the combustion of carbonaceous fuel. In good practice the consumption of coal (Colorado bituminous and other western grades) is about 30% of the weight of the ore roasted. The roasting of lead ore may be done in three ways, viz.:

a. Ordinary roasting, in which the ore is simply desulphurized, at the same time being more or less sintered. Often the ore is partially fused, so that upon withdrawal from the furnace it crusts or may be pounded into cakes, which may be called "sinter-roasting."

b. Slag-roasting, in which the ore is completely fused.

c. "Lime-roasting," or "Pot-roasting," a recent improvement, which will be discussed more fully further on.

Slag-roasting is performed in modifications of the ordinary reverberatory furnace, designed so as to permit the maintenance of a suitably high temperature at the discharge end.

It is objective in roasting to reduce the sulphur as low as possible, without entailing undue losses in other directions, since it is reckoned roughly that each unit of sulphur remaining in the ore increases the cost of smelting 25 c. per ton. The sulphur is more completely eliminated by sinter-roasting than by ordinary roasting, and more completely by slag-roasting than by sinter-roasting, but at the same time the loss of lead by volatilization is heavily increased and in slag-roasting is so high that the process has been abandoned in the United States, save in one or two instances, while sinter-roasting has had no wide practice, and ordinary roasting, by which the sulphur is reduced to about 4%, had become the generally adopted method until recently displaced by the "lime-roasting," or "pot-roasting" processes.

(2) *Roast-reaction.* Lead sulphide burned partially to sulphate reacts with undecomposed sulphide, setting free metallic lead and sulphur dioxide. This process is effected in the reverberatory smelting furnace (Flintshire, Tarnowitz, etc.) wherein the charge is first partially roasted and the reaction is then effected under increase of temperature. Also in the Scotch hearth, wherein the roasting and reacting go on contemporaneously. In the modern blast furnace, which has lines and is

operated under conditions promoting oxidation, roasting and reacting play an important part.

(3) *Precipitation.* In which the ore is charged raw into the blast furnace and the lead sulphide is decomposed by iron, precipitating metallic lead, while the sulphur combines with the iron, forming a matte, from which the sulphur is subsequently eliminated by roasting. The quantity of matte to be roasted is apt to be as much as the quantity of ore smelted, but the loss of lead is less than if the ore were roasted originally. There are other drawbacks, however, and this method which has never had any wide application in the United States is now employed in only one or two instances, if at all. The reaction takes place to some extent in any blast furnace, however, and it together with the reaction between the sulphide and sulphate described under the previous caption is largely relied on in modern practice, wherein galenas of high grade in lead are commonly charged raw into the blast furnace to save the comparatively high loss of lead which is inevitably suffered even in ordinary roasting. Precipitation smelting may also be done in the reverberatory furnace, but that method is quite inefficient and has seldom been practised either in America or Europe.

(4) *Lime-roasting.*[1] Wherein galena mixed with lime or gypsum is subjected to the action of air under conditions which produce a strongly oxidizing effect, so that once started it will decompose an entire charge of ore, the reaction being exothermic and requiring no extraneous fuel besides the relatively small quantity needed to start it. The ore is charged into a large cast-iron pot, having a perforated grate at the bottom on which a small coke or wood fire is made. Air at low pressure blown into the pot at the bottom and through the charge of ore effects the reaction. The desulphurization is more complete than in ordinary roasting, and the reaction being effected at a comparatively low temperature, or rather with a localization of high temperature, the loss of lead and silver is very much reduced, while the cost of the process ought not to be higher than ordinary roasting and may be very much lower.

Desulphurization by lime-roasting is exemplified in the Huntington-Heberlein process, in which the ore, mixed with limestone, is partially roasted in a reverberatory furnace before being treated in the converter; in the Carmichael-Bradford process, in which the ore is mixed with gypsum and converted directly; and in the Savelsberg process, in which

[1] This term may not survive, inasmuch as it is believed by many metallurgists that the limestone plays no part in the process except to act as a diluent of the sulphides, which under proper conditions can be burned just as effectively by a blast of air alone. This has indeed been demonstrated by the process invented by Mr. Arthur S. Dwight and Mr. R. L. Lloyd, which is now (1908) being introduced (see *Engineering and Mining Journal*, March 28, 1908). If this be so, the term "blast roasting" will supersede "lime-roasting"; and also "pot-roasting."

the ore is mixed with limestone and converted directly. The Savelsberg process is in use at Stolberg, Rheinland, and at Ramsbeck, Westphalia; the Carmichael-Bradford process at Broken Hill, New South Wales; and the Huntington-Heberlein process at works in Italy, Germany, Spain, Great Britain, Australia, Tasmania, Mexico, and British Columbia. The Huntington-Heberlein process was adopted after extensive experiments by the American Smelting and Refining Co., and in 1905 the installation in all of its plants was begun.

The desulphurization of galena by lime-roasting is the most important of recent advances in the metallurgy of lead, since the elimination of sulphur in other ways, but especially by ordinary roasting, has been one of the most costly steps, both in direct cost and loss of metal, in the entire smelting process.

Although the Huntington-Heberlein process, the primary of the lime-roasting processes, has now been in practical use for upward of ten years, it was originally introduced under such conditions of secrecy that there was little or no scientific investigation of its principles, and not until 1905 did there begin to be any considerable literature concerning it. The literature up to the middle of 1906 was summarized in a work entitled "Lead Smelting and Refining," edited by me and published by the *Engineering and Mining Journal.* At that time there was a divergency of views as to the theory of these processes, some metallurgists holding that lime or gypsum played some chemical part in the reactions, and others holding that the desulphurization was solely atmospheric, the lime (which might be replaced by some other substance, such as ferric oxide) playing merely the part of diluent of the particles of galena. The fact that the process was being actually performed in 1906 without the presence of lime in the charge was a strong support of the latter theory, and an argument that "pot-roasting" might be a better name for these processes than "lime-roasting," but on the other hand the evidence that lime or gypsum, when present, do actually act in a chemical way is also strong. It is needless to enter further into this discussion in this work, it being sufficient to state that the new processes, whatever their nature, are recognized as one of the most important, perhaps the most important, of the recent improvements in the metallurgy of lead.[1]

After elimination of sulphur by ordinary roasting or by lime- or pot-roasting, the ore is ready for smelting in the blast furnace. Naturally oxidized ores go of course to the blast furnace without any preliminary treatment, save breaking to the proper size.

The function of the blast furnace is to reduce the metal and slag the impurities so that a separation can be made. This separation is effected

[1] W. R. Ingalls, "Lime Roasting of Galena," Trans. Am. Inst. of Min. Eng., vol. XXXVII.

by the difference in specific gravity of the various products. The specific gravity of liquid (molten) lead is about 10.5; that of matte ordinarily ranges from 4.5 to 5. In order to insure a satisfactory separation of matte and slag, therefore, the specific gravity of the latter should be at least one degree lower than the lightest matte. Both the matte and the slag must be thoroughly liquid at the temperature of issue from the furnace. Consequently, the matte must be free from components which make it mushy, like zinc, and the slag must be of a composition which is easily fusible at 1100 to 1200° C. The cleanness of the slag, *i.e.*, its freedom from gold, silver, lead, and copper, is dependent chiefly on these physical conditions. The lead content of a good slag should not exceed 1%; the silver content should not exceed 0.8 oz.; the gold content should not be more than a trace. In order to achieve such a result the specific gravity of the slag should not be more than 3.6, and it should be of approved chemical composition.

In making a slag, the metallurgist is practically limited by the elements which commonly occur in ores, and to cheap fluxes like limestone. The commercial slag is a silicate of two or more bases. The fundamental constituents are silica, iron, and lime. The iron may be replaced to some extent by manganese, and the lime to some extent by magnesia, zinc, and baryta. These elements ordinarily constitute 90% of the slag. The remainder is chiefly alumina, barium sulphate, soda, and potash, etc. In preparing the furnace charge, a mixture of ores and fluxes is made in such proportions as to produce a slag of the desired composition. In lead smelting the permissible range in silica content is rather narrow, varying from 28 to 36%, and ordinarily also the percentages of ferrous oxide and lime range only within narrow limits, the percentages stated nominally as ferrous oxide and lime including their equivalents respectively of manganese oxide and magnesia or zinc oxide.

Types of slags which have been commercially employed in American smelting practice are shown in the following table:

Mark	SiO_2	FeO	CaO	Mark	SiO_2	FeO	CaO
A	35	28	28	G	28	50	12
B	34	34	24	H	33	33	24
C	34	34	*a* 17	I	33	36	16
D	30	40	20	J	30	36	20
E	30	48	12	K	36	40	20
F	28	54	6	L	32	33	23

a Besides 7% ZnO.

Iles recommends a slag of approximately the composition 32% silica, 34% ferrous oxide, and 20% lime, which was the type employed by him in a long experience at the Globe works at Denver, Colo.

Besides the silica, iron, and lime constituents, it is necessary to observe that other elements keep within certain limits. Thus, the percentage of zinc oxide should not exceed 7; that of alumina should not exceed 6. The average composition of the slags made in the American plants of the American Smelting and Refining Co. in October, 1901, is shown in the following table, which is illustrative of present practice in this respect:

Plant	Ag.	Pb.	SiO_2	FeO	MnO	Zn	CaO	MgO	BaO	Al_2O_3
Globe	0.46	0.38	31.3	26.2	8.0	5.1	14.5	2.5	0.7	6.9
Grant	0.86	0.43	30.2	27.5	6.7	5.9	14.8			6.4
Pueblo	0.90	0.80	30.9	26.6	9.0	4.0	14.2	1.2	2.4	6.2
Eilers	0.88	0.88	31.4	25.6	10.7	5.7	14.2	1.2	0.9	6.7
Philadelphia	0.80	0.80	30.8	31.1	5.3	5.6	12.3	1.3	1.2	6.9
Durango	0.83	1.11	30.7	32.5		5.8	19.4		1.3	
Arkansas Valley	0.80	0.90	31.5	31.6	6.3	5.3	14.8	2.6	1.2	4.5
Germania	0.56	0.84	37.6	27.0	2.7	5.1	20.8			
East Helena	0.70	0.96	34.7	28.1	2.0	6.9	20.4	1.4		3.0
Silver City	0.20	0.50	36.4	30.2	0.8	4.3	15.1	1.0		8.1

The efficiency of the lead-smelting process depends chiefly upon (1) the method of sulphur elimination, affecting the cost of the operation, the loss of gold, silver, and lead, and the physical condition of the product delivered to the blast furnace; (2) the design and construction of the blast furnace and its accessories, the method of operation, the physical condition of the material charged, the correct composition of the slag, the character of the bullion produced and the means to collect dust and fume; (3) the means for handling products throughout the process.

The better the character of the slag, the faster will be the running of the furnace, *i.e.*, the greater the quantity of charge smelted per square foot of hearth area,[1] and the lower the loss of lead and silver in the slag and in the fume. The lower the proportion of very fine ore in the charge, the faster will be the running of the furnace and the smaller the percentage of flue dust to be collected and rehandled. The better the character of the bullion, the less irregularity in the management of the furnace and the less the cost of refining. A detailed consideration of all of these governing and largely interdependent factors is impossible in a brief statement of the principles of the art as developed in modern practice, but such will be found in the standard treatises on the subject. It is aimed here to emphasize the predominant effect of the slag character, *i.e.*, the make-up of the furnace charge, in determining the cost and efficiency

[1] The hearth area is the horizontal section of the furnace on the line of the tuyeres

of the smelting process. It may almost be said that the successful development of the silver-lead smelting industry hinged upon this matter. As the histories of the various lead-smelting districts are examined, it will appear strikingly how the process was quickly made successful in those which had the advantage of a self-fluxing character of ore, like Eureka, Nev., and how it was struggled with in many other districts which had only one kind of ore, incapable of making an economical slag; and how, as lead smelting became a well understood art, it came to be recognized that an assured and adequate supply of the right classes of ore was the fundamental prerequisite for the inauguration of a successful business.

Given supplies of silica, iron, and lime, there is no difficulty in producing a slag of any desired composition, but the smelting might be so costly as to be unprofitable. The cost of smelting is properly based on the charge, *i.e.*, all of the material except fuel which is put through the furnace. It is the aim of the metallurgist to have the ore in the charge at the maximum possible percentage, *i.e.*, it is sought to obtain all of the ncessary fluxing elements in a proper proportion in the ores purchased for smelting, since the time, fuel, and labor required to smelt a pound of flux are the same as for a pound of ore, and for each pound of flux put into the charge there is one pound less of ore. It is consequently of the utmost importance to the smelter to be able to secure ores that upon mixture will contain the proper proportion of slag-forming substances and will obviate the necessity of making up the proper proportion by the addition of barren fluxes. It is seldom possible to attain the acme of that condition, a small proportion of lime-rock having usually to be added to the charge, while there is always a certain quantity of foul slag, flue dust, roasted matte, and other between-products that must be added to the charge; but in the modern American practice of silver-lead smelting the ore in the charge amounts usually to 80% or more.[1]

The price which a smelter will give for any particular ore is consequently determined by his fluxing requirements and the supply of various kinds of ore on hand or offered. The smelter refers to the difference between the cost of a ton of ore and the proceeds which he obtains from it as the "margin," out of which he has to pay the cost of smelting, the remainder of the margin being his profit. The margin varies greatly according to the class of ore treated and the profit is dependent upon the average; consequently it is sought to smelt as much "high margin" ore as possible.

[1] This means 80% or more of the charge, exclusive of the slag which is used in larger or smaller quantity, often rather large, to facilitate the running of the furnace. Great efforts are made to eliminate this "side-charge" but it does not appear possible to do so.

As a simple illustration, suppose there were available two kinds of ore, viz., a lead carbonate ore, containing 22.5% lead, 20% ferrous oxide, 4% lime, and 27% silica; and an argentiferous iron ore, containing 60% ferrous oxide, 4% lime, and 25% silica; and lime-rock containing 1% ferrous oxide, 50.5% lime, and 8% silica. Suppose it were desired to mix these ores so that the slag would have the composition 34% silica, 34% ferrous oxide, and 17% lime, it would be necessary to add to each ton of the lead ore, 0.25 ton of iron ore and 0.25 ton of lime-rock. The mixture would contain 15% lead. In the daily charge of a furnace, say 150 tons, there would be 100 tons of lead ore, 25 tons of iron ore, and 25 tons of lime-rock. Assume the cost of smelting to be \$3.75 per ton of charge, the cost per ton of ore would be \$3.75 × 6 ÷ 5 = \$4.50. In order to realize a profit of \$1 per ton, assuming that the full value is paid for gold, silver, and lead, the smelter must have a margin of \$5.50 per ton. But suppose the iron ore is so low in silver that it will not stand a treatment charge of more than \$2 per ton, the smelter, obliged to have it as a flux, must make up the deficit by an increased charge on the lead ore, which then would have to be \$6.37½.

This illustration shows also what advantage it would be to the smelter if he were able to substitute for the lime-rock an ore of similar content in lime, on which he could make a treatment charge. It shows also the advantage of making a slag as silicious as possible, which enables the maximum percentage of the usually profitable silicious ore to be carried in the charge.

The foregoing analysis of the commercial principles of lead smelting relates especially to the conditions involved in the operation of a custom smeltery, supplied by ore from numerous mines, in which the percentage of lead in the aggregate is comparatively small, the business being conducted not with the particular view of producing lead, but rather with that of smelting a large tonnage of ore. Nevertheless the same fundamental principles govern the smelter of the product of a single mine, or group of mines, although he may be more constrained in the matter of ore mixtures, and also the smelter of high-grade galenas, who may extract directly a large proportion of the lead in Scotch hearth or Flintshire furnaces, but is still obliged to effect the final separation of the gangue by smelting the gray slag in a blast furnace.

The supreme economic importance of the charge-composition is further illustrated by a comparison of the results in smelting at the works of the Eureka Consolidated Mining Co., at Eureka, Nev., and at the Winnamuck works of Bristol & Daggett in Bingham Cañon, Utah, in 1872, which at that time were the most advanced of any works in the United States, both in points of construction and metallurgical practice. The cost of smelting at Eureka was \$18.33 per ton of ore, not including general expense. The ore being self-fluxing, nothing had to be put into the furnace charge save ore and foul slag; the furnace charge per 24 hours consisted of 50 tons of ore, plus 2.5 to 5 tons of slag. The consumption of fuel (charcoal) was 22.8 bushels per ton of charge, or 24 bushels per ton of ore. At Bingham, the average charge for the year comprised 100 parts of ore, 35.19 parts of iron flux, 38.99 parts of limestone, and 16.16 parts of slag. The ore in the charge was therefore only 52.5% against 95% at Eureka. The consumption of fuel at Bingham was 79 bushels per ton of ore, but only 40 bushels per ton of charge, a figure much higher than reported for Eureka, but really not so much higher as appears since it includes the loss of charcoal by waste, which the Eureka figure does not. The iron flux cost $8.80 per ton of ore smelted, and the lime flux $1.94. If the cost of the fluxes were deducted, and if the charge smelted had consisted entirely of ore and slag, the cost of smelting per ton would have been only $19.14, a result quite close to that at Eureka.

These cases will make quite clear the points that the cost of smelting at various works is properly comparable only on the basis of charge tonnage, and that the cost per ton of ore became comparable, even in an approximate way, only when the development of the smelting industry at central points resulted in the smelting of ore mixtures of somewhat the same composition.

The history of silver-lead smelting in the United States, since its inception at Argenta, Eureka, and Cerro Gordo, has been a record of steady improvement, until at the present time the art has been brought to a higher degree of perfection than elsewhere in the world. The first furnaces were very small, of faulty construction, and were capable of nothing but brief campaigns, partly because of errors in design and partly because good fire-brick was unobtainable except at great cost. Charcoal was the only fuel available. There were but few skilled metallurgists, and even their knowledge of scientific furnace work was vague, their practice being governed chiefly by rule-of-thumb methods. Under those conditions it is not surprising that the cost of smelting and losses in slag and fume were high. At Eureka, in the early days, it cost $20 to smelt a ton of self-fluxing, carbonate ore, and losses of 40% of the lead and 30% of the silver contents of the ore were reported.[1]

[1] In considering the statements of loss of metal and percentages extracted, especially in the earlier times, there will be manifest many discrepancies and many reports that are difficult to reconcile. These are due to inaccuracies in the determinations. In determining the percentage of metal extracted, the only reliable method is a comparison between the original content of the ore and the quantity actually extracted. This implies the necessity of accurate weights and samplings, accurate methods of assaying, and accurate cut-offs. None of these conditions was scientifically complied with until comparatively recently. Even now, the silver-lead smelting industry em-

Statements of experience showing only small losses, results that would be creditable even in recent practice, are to be found in the literature of 1870–1880, but all of these must be rejected as doubtful at least, and in all probability quite inaccurate in view of the modern knowledge as to the magnitude of certain items of loss which previously had been unsuspected, and the fact that the best metallurgical determinations showed that the losses in 1870–1880 were indeed very high. The best evidence on this subject is afforded by a paper of Anton Eilers[1], who reported that tests at the only works in Utah where matte and flue dust were saved, showed an extraction of only 73 to 75% of the lead, while at one works at Eureka there was an extraction of 83% lead, 82.3% silver, and 96.4% gold, and at another works 81% lead and 85% of the precious metals.

The first great improvement in the art was the introduction of the siphon-tap by Albert Arents, introduced at Eureka in 1870, which revolutionized the method of discharging the bullion from the furnace. This was followed in 1876 by the investigations of Anton Eilers on the subject of lead slags, which was continued by Raht, Hahn, Schneider, Iles, and other metallurgists. Smelters then began to calculate their charges with something like accuracy, and the furnace running was vastly improved. About the same time came the general introduction of water-jackets, which had been invented several years previously, replacing fire-brick at the smelting zone of the furnace and increasing its life.[2] The construction, size, and form of the furnace had also been improved in other respects during this time, so that the length of campaign was extended and the cost of smelting was reduced. Noteworthy among these improvements was the adaptation to the lead-smelting furnace of the Lürmann tap-jacket by Anton Eilers; previously the furnaces had been tapped through a clay breast, which was always troublesome, wherefore the new method was warmly welcomed. These improvements had all been made

ploys to a large extent the fire-assay for lead, which notoriously gives too low results, especially on low-grade ores. In Missouri and the non-argentiferous districts only is the accurate method of volumetric estimation of lead in exclusive use.

[1] "Avoidable Wastes at American Smelting Works," Mineral Resources West of the Rocky Mountains, 1873, pp. 490–495.

[2] The history of the water-jacket has been given by Prof. H. O. Hofman in The Mineral Industry, XIV, pp. 409–410. A cast-iron jacket (of which a drawing is reproduced in the work cited) was prepared by Ellsworth Daggett in 1872 for the blast furnaces of the Winnamuck Mining Co., Bingham Cañon, Utah, which, so far as is known to-day, was the first cast-iron water-jacket ever used in a lead-blast furnace, although wrought-iron jackets had been used previously in a few cases, but not in Nevada or Utah (see Hofman, Metallurgy of Lead, p. 242). The cast-iron jackets for the Winnamuck furnaces were made at Council Bluffs, Ia., and were put in use Nov. 26, 1872. Later on, Anton Eilers designed the sectional jacket of cast iron, which has ever since been in common use. For many years this was known as the "Eilers jacket."

before smelting assumed important proportions at Leadville, Colo., where the development of the art received a new impetus. The cost of smelting in 1880 at Leadville averaged $15.25 per ton, and treatment charges $22 per ton. The average grade of the ore smelted was 69.5 oz. silver and 22.5% lead, about 96% of the former and 88% of the latter being saved.

With the rise of the valley smelters, developments in the silver-lead smelting industry became rapid and important. The concentration of work into a few large plants and the handling of larger quantities of ore in each tended to reduce general expenses. Labor-saving devices were introduced for handling ore, slag, matte, and bullion. Furnace management was brought to a high degree of perfection, and the furnaces themselves were improved vastly in construction and size. The progress in the art is well illustrated in a series of reviews of the status at the beginning of each decade.

1871:[1] Introduction of Piltz and Raschette furnaces at Eureka, the dimensions of the latter being increased to 36×54 inches at the tuyeres, with height of 10 ft. above the tuyeres.[2] Ratio of hearth area to throat area, 1:2½. The increase in size greatly enhanced the capacity of the furnace and the improved lines reduced metal losses. The only fuel used was charcoal, costing 15 c. to 34 c. per bushel of 1.59 cu. ft., according to locality. Nut-pine coal considered the best. Sturtevant fans chiefly employed for blast, but Root's blowers coming into use. Furnaces built of common brick or dressed stone, lined with sandstone, granite (at Argenta, Mont.), or fire-brick. Furnaces designed with open breasts (sump furnaces). Standard height from tuyeres to charge doors, 10 ft. Iron or brick smokestack on top of the furnace. Tuyeres water-cooled; situated 10 to 18 in. above level of slag spout. Galena ores prepared for smelting by slag-roasting in Mexican reverberatory furnaces, called galemadors (a corruption of galenadores), practised at Cerro Gordo, Cal., Big Cottonwood, Utah, and Corinne, Mont., the cost being about $4 per ton.

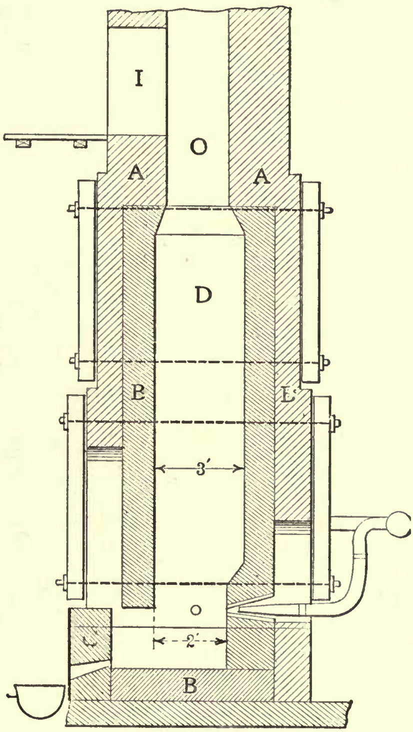
The works of the Eureka Consolidated Mining Co. comprised five furnaces of aggregate capacity of 150 tons of ore per day, blown by four No. 8 Sturtevant fans, run at 2100 r.p.m., and yielding air of pressure of 1 in. of mercury. The motive power for the fans, for an 8×10 in. Blake crusher, and a 6-in. pump was furnished by a 40 h.p. engine.[3] Furnaces Nos. 4 and 5 were 36×54 in., and had capacity of 35 to 40 tons

[1] "The Smelting of Argentiferous Lead Ores in Nevada, Utah, and Montana," by R. W. Raymond, A. Eilers, and O. H. Hahn, in Mineral Resources West of the Rocky Mountains for 1871, pp. 379–409.

[2] Previously the furnaces used in silver-lead smelting were rarely larger than 20×30 in. and frequently they were drawn together at the top. The capacity of such a furnace was about six to eight tons per 24 hours.

[3] The high power consumption per ton of ore in modern plants in comparison with

per day (about 2.8 tons per square foot). The furnaces had larger capacity with fine ore than with coarse. With the former, the ratio of fuel to ore was 4.6: 1; with the latter, 3.75: 1. The furnaces were run by three shifts, the crew for one shift consisting of 1 smelter at $4.50, 2 helpers at $4, and 2 feeders at $4 at each of the large furnaces; and 1 smelter, 1 helper and 1 feeder at each of the small furnaces. The slag composition was about 26.12% SiO_2, 52.80% FeO, 12% CaO, 5.8% Al_2O_3, and 2.79% PbO.



Type of Smelting Furnace used at Eureka, Nev., in 1871.

Eureka was the cradle of the art of silver-lead smelting in the far West; to Albert Arents, who was metallurgist there, is owed the invention of the siphon-tap, the construction of the first large and successful furnaces, and the reintroduction of the boshes in lead furnaces; but important as these developments were in paving the way for future progress in furnace design and mechanical details, Eureka did not offer any inno-

this low figure at Eureka in 1871 is indicative partially of the introduction of mechanical appliances for handling material, but chiefly of the greatly increased blast pressure employed in driving the furnaces.

vation in the smelting process itself, the same routine being followed there as of old, the docile, self-fluxing character of the ore giving economically satisfactory results without any necessary modifications.

At Salt Lake and vicinity, where the problem of smelting was less simple than at Eureka, the well-proved features of European practice were tardy of introduction. Dust and fume were wasted into the atmosphere in the absence of settling flues, and matte was carelessly thrown over the dump. It was not until 1874 that general attention began to be paid to those losses. In that year the Richmond Consolidated Mining Co., at Eureka, erected a dust chamber, and in the same year Wartenweiler began roasting and resmelting matte at the Winnamuck works, in Utah. The latter innovation was of importance not only in reducing loss of lead, silver, and gold, but also in restoring iron, lessening the quantity that had to be added to the furnace charge as barren and costly flux. Thus, at the Winnamuck works, the quantity of iron flux was cut down from 20% to 3.5% of the charge.

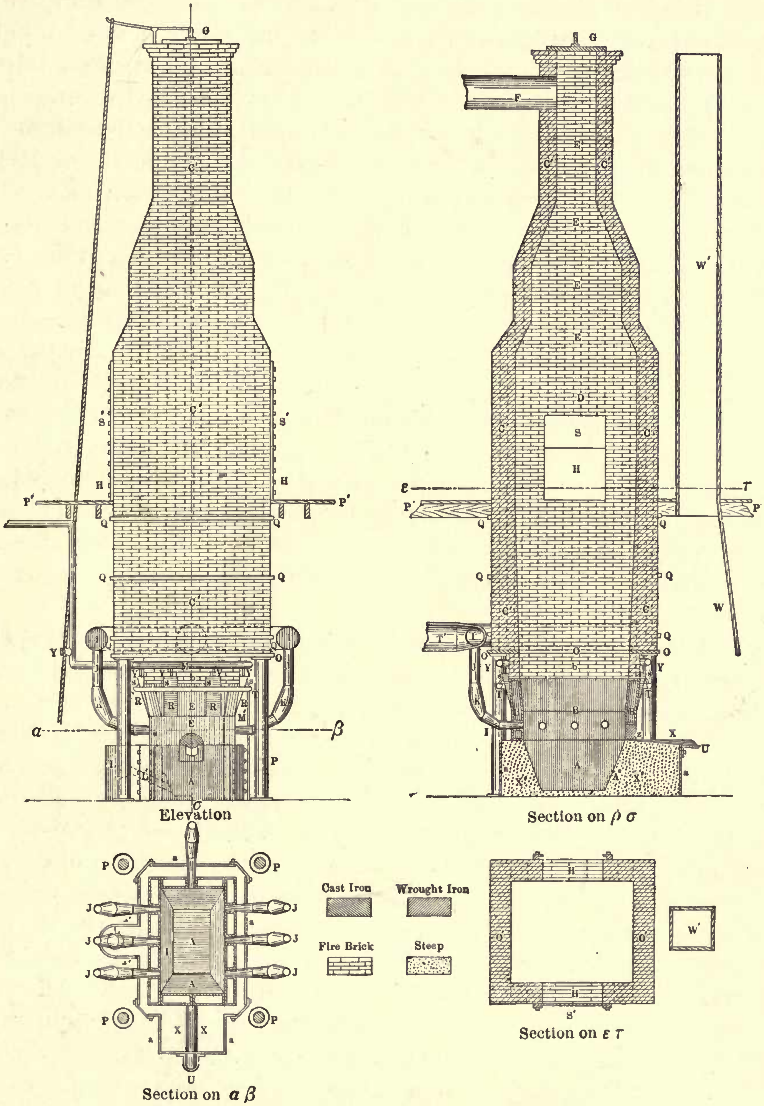
1881: Furnaces chiefly developments of the Raschette type,[1] which contrary to the Piltz form was capable of great increase in hearth area. Furnaces 36×94 in. at the tuyeres were in successful use, although the average size was 36×60 to 36×78 in. Water-jackets in common use. All of the better designed plants were provided with dust chambers, with which the furnaces were connected by a sheet-iron down-take at convenient height above the charge-floor. At the Grant works, Denver, Colo., the gases and fumes were drawn off below the level of the charge-floor,[2] a practice which was followed for many years subsequently at those works and elsewhere, but has not survived. Except at Eureka and a few other localities, all furnaces were provided with closed breasts, and the slag tapped off intermittently instead of continuously. Charcoal or coke, or both mixed, employed as fuel, charcoal being still extensively in use, but the tendency more and more toward coke. Consumption of mixed fuel at Leadville, 22 to 24% of weight of charge; in Salt Lake Valley, 14 to 17%. With charcoal alone, 26 to 28%. The blowers mostly in use were the Baker, which had driven out of the field nearly all the Sturtevant fans and a good many of the Roots'.[3] Sulphide ores roasted in reverberatories of 10 to 12 ft. width and 30 to 40 ft. length of hearth. Slag-roasting generally practised.

[1] Anton Eilers was prominent in the development of the Raschette furnace.

[2] *Engineering and Mining Journal,* XXV, No. 12.

[3] The Roots blower was originally of partial wooden construction, and consequently was mechanically imperfect. The Baker blower obtained its prestige through being wholly of metal. However, it was defective in principle and consequently was in turn driven out of use by the Roots blower, improved and made wholly of metal, and the Connersville, both the Roots and the Connersville being more efficient than the Baker in their delivery of air.

Metallurgically, the great advance between 1871 and 1881 was the accurate knowledge of lead slags that was gained. It had previously been known that a singulo-silicate, or something between that and a



Blast Furnace at Leadville, Colo., 1881.

bisilicate, was desirable, and also that simple singulo-silicates were not so easily fusible as compounds of two or more singulo-silicates. It had been found in practice, moreover, that a ratio of lime to ferrous oxide of 1:2 would produce a good slag. Notwithstanding this knowledge, a great deal of uncertain work was done until Anton Eilers and other metallurgists directed their attention to crystallized slags, which they regarded as real chemical compounds, and therefore of constant composition, while amorphous slags were considered as mere mixtures of different silicates, or solutions of one silicate in another. It was observed that certain crystallized slags behaved in the furnace better than others. If such a slag could be made at will, a great problem would be solved; any kind of ore could be smelted without trouble by giving it the lacking constituents in the ratio required to produce the desired slag. The solution of this problem involved the accurate sampling and analysis of all the ingredients of the furnace charge, and the weighing of the charge into the furnace instead of throwing it in by volume, the old "shovel system," wherein so many shovels of this and so many shovels of that were taken. With this improvement, silver-lead smelting was put on a scientific basis, and in conjunction with the improvement in furnace design and construction it had become a well-developed art by 1881.

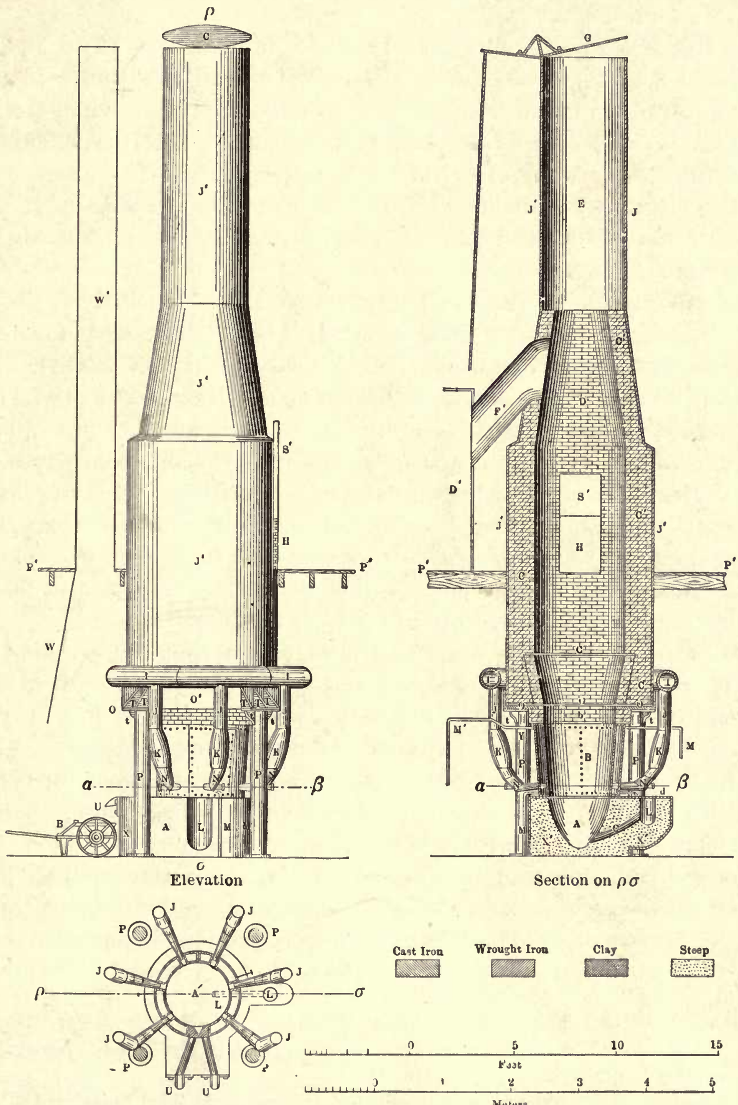
At Pueblo, Colo., in 1882, the Pueblo Smelting and Refining Co. had the largest and most complete plant in the United States, including a refinery. The Grant works, at Denver, which in convenience of design, efficiency, and cleanliness at that time surpassed all the others, had just been completed. The Colorado Smelting Co. was constructing a new plant at Pueblo.

The Colorado smelters aimed to run the excellent slag containing 30% silica, 40% ferrous oxide, and 20% lime. The Utah smelters, on the other hand, lacking iron in their ores, in view of the high cost of iron flux as compared with lime, aimed to make a slag in which the proportion of ferrous oxide to lime was 1:1. Slag made at the Horn Silver works corresponded to the composition 35% SiO_2, 25% FeO, 26% CaO, and 10% Al_2O_3. The handling of matte, speiss, and flue dust were troublesome problems to all the smelters. Matte was generally crushed and roasted in reverberatory furnaces, though heap-roasting was practised to some extent. The reworking of speisses was left in abeyance. Flue dust was commonly agglutinated with lime and resmelted along with the ore as fast as made. Hahn had suggested as early as 1878, however, the use of a brick-machine to make the flue dust into adobes (using the requisite percentage of lime) and it is possible that this idea was the germ of the modern practice of briquetting.[1] It is noteworthy also that the mechanical feeding of lead-blast furnaces, which is one of the most recent developments in lead-smelting engineering, was actually practised at Eureka, Nev., in 1871.

Ideas as to the physical character of the furnace charge also changed

[1] Mineral Resources of the United States, 1882, p. 344.

greatly from 1871 to 1881. Whereas in the former year it was thought that the ore and fluxes should be fine, iron flux being used in pieces the size of the fist, lime-rock in pigeon-egg size, and quartz in smaller pieces,[1]



Blast Furnace at Leadville, Colo., 1881.

in 1881 it was the practice to use both iron flux and lime-rock in pieces the size of the fist, and quartz in goose-egg size, while nowadays all

[1] R. W. Raymond, Mineral Resources West of the Rocky Mountains for 1871, p. 384.

material is charged much coarser. A. S. Dwight, in 1901, described the ideal charge as consisting of a mixture in which about one-third is pieces from 5 to 2 in. in diameter, one-third from 2 to ½ in., and the remaining third from ½ in. down.[1]

The loss of lead in smelting at Leadville in 1882 was 13 to 15%; of silver about 3 to 4%. Charges as low as 7% in lead were run. In 1879, when the terminus of the railway was 35 miles from Leadville, the cost of charcoal was 14 c. per bushel of 14 lb.; of coke, $36.70 per 2000 lb.; in 1882, the prices were 10½ c. and $15 respectively. The average fuel cost in smelting a ton of ore in 1879 was $8.92; labor, $5.20. In 1882 these costs were $5.66 and $2.79 respectively, although the ores in 1882 were less favorable to smelt.[2]

1893: Rectangular, water-jacket furnaces almost exclusively in use. Closed breasts. Tops open (Grant works), brick-stack and down-take above feed-floor (numerous works), and closed tops (Globe works). Furnaces from 36×86 to 42×120 in. in hearth area. Height 12 to 18 ft. from tuyeres to charge door. Blast pressure ¾ in. to 2½ in. mercury (6 to 40 oz.). Sulphide ores and mattes roasted in reverberatory, hand-raked furnaces, and in O'Hara, Pearce, and Brown mechanical furnaces. Cost of roasting about $2 per ton. Cost of smelting at Denver about $4.50 per ton. Dust chambers and other means for collecting dust and fume highly developed. Bag filtration in use at the Globe works, Denver. Extraction of lead in good practice 94% and upward; of silver, 95% and upward.

1901: Circular furnaces entirely out of use, except for smelting by-products in refineries. Rectangular furnaces of 48×144 and 48×160 in. at the tuyeres employed in the best practice.[3] Height from tuyeres to charge-floor about 16 ft. Capacity about 150 tons of charge (ore and flux) per 24 hours. Furnaces generally arranged with closed tops, communicating by down-take above the feed-floor with bag house, operated by mechanical draft, or with system of very long and very large flues (dust chambers), operated by chimney draft, the latter method being the more generally in vogue. Closed breasts, matte and slag being tapped into large forehearths[4] for settling the matte, the slag being removed in large pots drawn by locomotives. Water-jackets increased in height to

[1] Trans. Am. Inst. of Min. Eng., XXXII, 364.

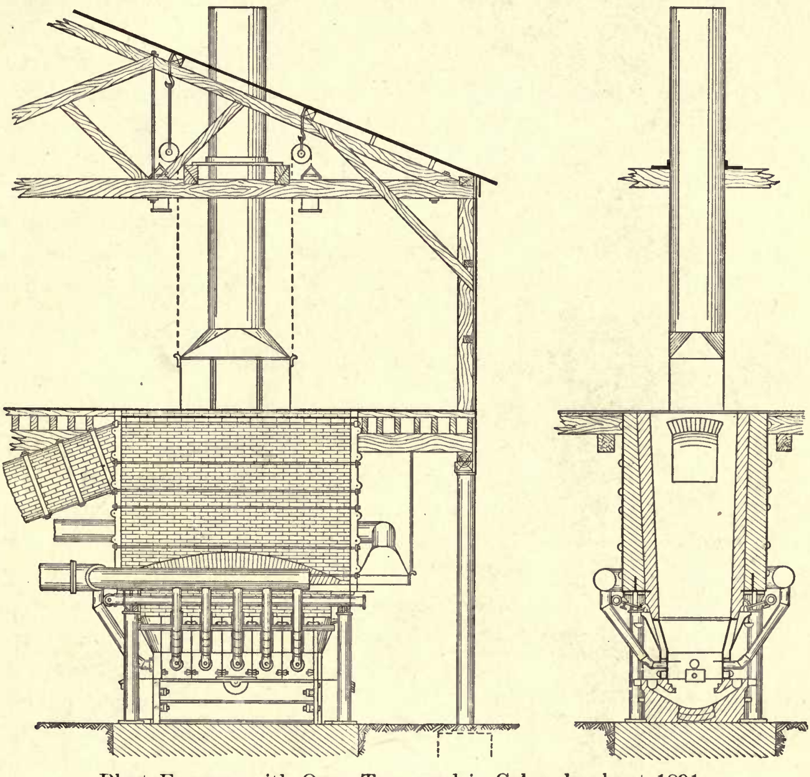
[2] O. H. Hahn, "The Smelting of Argentiferous Lead in the West," Mineral Resources of the United States, 1882, p. 341.

[3] Furnaces of greater height and greater hearth area were tried between 1891 and 1901, but the results were not satisfactory and furnaces of the dimensions stated above were reverted to as the most efficient and are now practically adopted as the standard.

[4] The introduction of these large forehearths, first by R. D. Rhodes at Leadville about 1895, and the further development of reverberatory furnaces for keeping the slag thoroughly molten, were improvements of great importance in reducing the loss of metals in the slag.

48 in., and even to 60 in. in some of the newest furnaces. Hearth area to throat area about 1: 2¼. Jackets with 10-inch bosh. Blast pressure, 40 to 64 oz., supplied by Roots' or Connersville blowers, with considerable use of piston-blowers and tendency toward their increased use.[1]

For the roasting of sulphide ores, the long, mechanical reverberatories, like the O'Hara, Brown, Ropp, and others, which had been extensively tried in the nineties, had been generally discarded, and standard



Blast Furnace with Open Top, used in Colorado about 1891.

practice had reverted to the ordinary, hand-raked reverberatory, with hearth 14×60 to 16×64 ft., and fireplaces with step-grates; and Brueckner cylinders for certain classes of ore.

The general arrangement of a modern lead-smelting plant and the principal mechanical features are indicated in the following description of the Murray plant of the American Smelting and Refining Co., which was begun in 1901 and completed in the summer of 1902: [2]

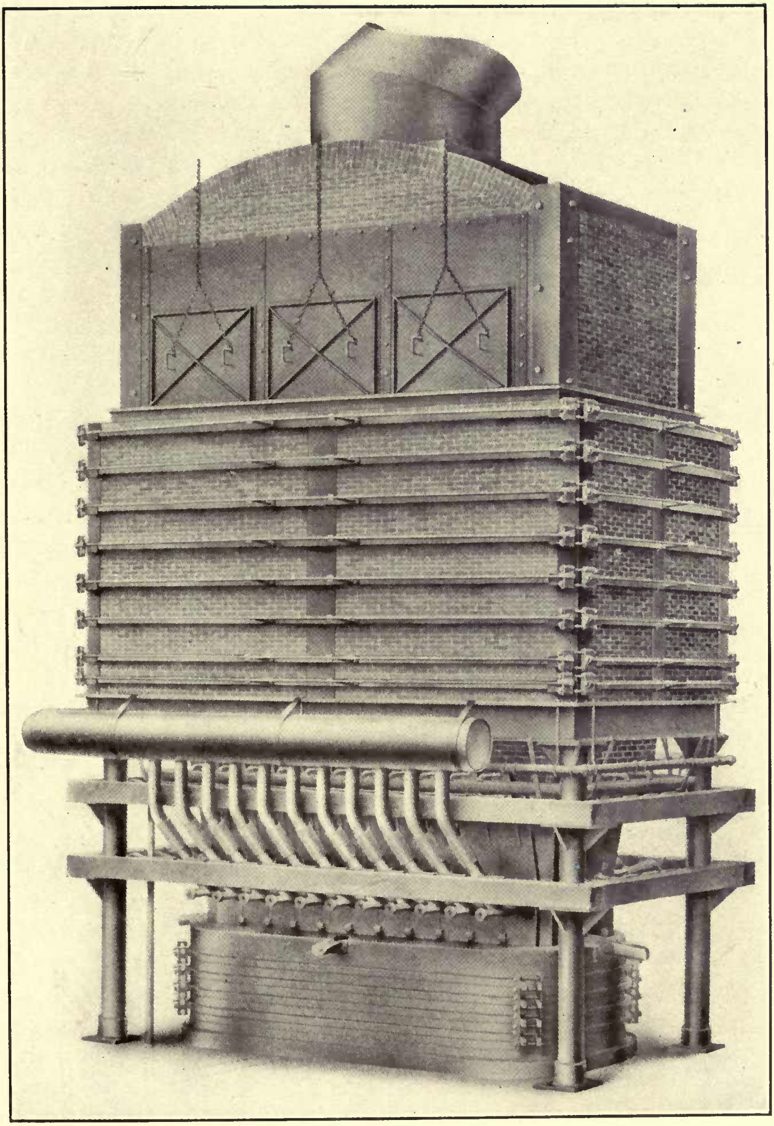
[1] This tendency toward the use of piston blowers lasted only a few years, the present tendency being to discard them.

[2] *Engineering and Mining Journal,* June 28, 1902.

"The new works are built on level ground; there has been no attempt to seek or utilize a sloping or a terraced surface, save immediately in front of the blast furnaces, where there is a drop of several feet from the furnace-house floor to the slag-yard level, affording room for the large matte-settling boxes to stand under the slag spouts. A lower terrace, beyond the slag yard, furnishes convenient dumping ground. Otherwise the elevations required in the works are secured by mechanical lifts, the ore, fluxes, and coal being brought in almost entirely by means of inclines and trestles.

"The plant consists essentially of two parts, the roasting department and the smelting department. The former comprises a crushing mill and two furnace houses, one equipped with Brueckner furnaces and the other with hand-raked reverberatories. The roasting furnaces stand in a long steel house; they are set at right angles to the longer axis of the building in the usual manner. At their feed end they communicate with a large, dust-settling flue, which leads to the main chimney of the works. The ore is brought in on a tramway over the furnaces and is charged into the furnaces through hoppers. The furnaces have roasting hearths only. The fire-boxes are arranged with step-grates and closed ash-pits, being fed through hoppers at the end of the furnace. The coal is dumped close at hand from the railway cars, which are switched in on a trestle parallel with the side of the building, which side is not closed in. This, together with a large opening in the roof for the whole length of the building, affords good light and ventilation. The floor of the house is concrete. The roasted ore is dropped into cars, which run on a sunken tramway passing under the furnaces. At the end of this tramway there is an incline up which the cars are drawn and afterward dumped into brick bins. From the latter it is spouted into standard gauge railway cars, by which it is taken to the smelting department. The roasted ore from the Brueckner furnaces is handled in a similar manner. The delivery of coal and ore to the Brueckners and the general installation of the latter are analogous to the methods employed in connection with the reverberatories.

"The central feature of the smelting department is the blast furnace house, which comprises eight furnaces, each 48×160 in. at the tuyeres. There are 10 tuyeres per side, a tuyere passing through the middle of each jacket, the latter being of cast iron and 16 in. in width; their height is 6 ft., which is rather extraordinary. The furnaces are very high and are arranged for mechanical charging, a rectangular brick down-take leading to the dust chamber, which extends behind the furnace house. The furnace house is erected entirely of steel, the upper floor being iron plates laid on steel I beams, while the upper terrace of the lower floor is also laid with iron plates. As previously remarked, the lower floor drops



Blast Furnace with Closed Top, 1901.

down a step in front of the furnaces, but there is an extension on each side of every furnace, which affords the necessary access to the tap-hole. The height of the latter above the lower terrace leaves room for the large matte-settling boxes, and the matte tapped from the latter runs into pots on the ground level, dispensing with the inconvenient pits that are to be seen at some of the older works. The eight furnaces stand in a row, about 30 ft. apart, center to center. The main air and water pipes are strung along behind the furnaces. The slag from the matte-settling boxes overflows into single-bowl, Nesmith pots, which are to be handled by means of small locomotives. The foul slag is returned by means of a continuous pan-conveyor to a brick-lined, cylindrical steel tank behind the furnace house, whence it is drawn off through chutes as required for recharging.

"The charges are made up on the ground level, immediately behind the furnace house. The ore and fluxes are brought in on trestles, whence the ore is unloaded into the beds and the fluxes into elevated bins. These are all in the open, there being only two small sheds where the charges are made up and dumped into the cars which go to the furnaces. There are two inclines to the latter. At the top of the inclines the cars are landed on a transferring carriage by which they can be moved to any furnace of the series.

"The dust flue extending behind the furnace house is arranged to discharge into cars on a tramway in a cut below the ground level. This flue, which is of brick, connects with the main flues leading to the chimney. The main flues are built of concrete, laid on a steel frame in the usual manner and are very large. For a certain distance they are installed in triplicate; then they make a turn approximately at right angles, and two flues continue to the chimney. At the proper points there are huge dampers of steel plate, pivotted vertically, for the purpose of cutting out such section of flue as it may be desired to clean. Each flue has openings, ordinarily closed by steel doors, which give access to the interior. The flues are simple tunnels, without drift-walls or any other interruption than the arched passages which extend transversely through them at certain places. The chimney is of brick, circular in section, 20 ft. in diameter and 225 ft. high. This is the only chimney of the works save those of the boiler house.

"The boiler house is equipped with eight internally fired corrugated fire-box boilers. They are arranged in two rows, face to face. Between the rows there is an overhead coal-bin, from which the coal is drawn directly to the hoppers of the American stokers, with which the boilers are provided. Adjoining the boiler house is the engine house, the latter a brick building, very commodious, light and airy. It contains two cross-compound, horizontal blowing engines for the blast furnaces, and two direct-connected electrical generating sets for the development of the power required in various parts of the works. A traveling crane spans the engine house. In close proximity to the engine house there is a well-equipped machine shop. Other important buildings are the sampling mill and the flue dust briquetting mill.

"A noteworthy feature of the new plant is the concrete paving, laid on a bed of broken slag, which is used liberally about the ore yard and in other places where tramming is to be done. The roasting furnace houses are floored with the same material, which not only gives an admirably smooth surface, but also is durable. The whole plant is well laid out with service tramways and standard gauge spur tracks, and the design has been obviously to save manual labor as much as possible."

Metallurgically, the smelting practice of 1901 was characterized by the composition of a slag as high as possible in silica and zinc, in order to carry in the charge the maximum of "high margin" ores, rather low in iron and correspondingly high in lime, because of the relative cheapness of lime flux. In order to effect the maximum saving of gold and silver, about 12.5% of lead was carried in the charge, and in addition thereto a certain proportion of copper, the latter entering the matte, which after roasting was concentrated by a resmelting up to a high copper content and passed on to the copper refinery. The treatment of these leady copper mattes was one of the most serious problems, their lead content being troublesome to the copper refiner. In ore-roasting, only those rich in sulphur were burned, the high-grade galenas being charged raw into the blast furnace, in order to reduce loss of lead by volatilization. Mechanical feeding of the blast furnaces was adopted at some works, and in spite of certain difficulties was looked to as the coming practice. The increased width and height of the furnaces, together with the increased proportion of fine ore in the charge, necessitated high blast pressure. The dust blown out of the furnace and collected in the flues was compressed into briquettes and resmelted in the blast furnace.

In good practice the proportion of ore in the furnace charge was about 80%. The consumption of fuel (coke exclusively) was 12 to 16% of the charge. In six months of 1901 the American Smelting and Refining Co. smelted 904,124 tons of ore, 62,870 tons of matte, 46,908 tons of by-products, 154,728 tons of lime flux and 3,653 tons of iron flux, a total of 1,172,283 tons. The material roasted was 304,034 tons of ore, 65,652 tons of matte and 2545 tons of by-products, a total of 372,231 tons. The consumption of coal in roasting was about 30% of the weight of the ore, the ore being burned down to 3 to 4½% sulphur. The cost of coke in Colorado was \$5 to \$7 per ton; in Utah, \$8.50; in Montana, \$9.50. The cost of coal in Colorado was about \$2 per ton. Lime-rock cost \$0.70 to \$1.40 per ton, but generally less than \$1. Roasting in reverberatory furnaces cost $2 to $2.30 per ton; in Brueckner cylinders $1.10 to $1.45; the burned ore containing 3 to 4.5% sulphur in the former case, and 4.5% to 6% S in the latter case. The total cost of smelting per ton of ore and flux charged was $2.50 to $5, including the cost of roasting the proportion of ore thus treated.

Since 1901, the chief improvements in the art of silver-lead smelting have been in remodeling the power plants, reducing the cost of power, an expensive item in view of the large power requirements of modern practice; the further development and increased use of mechanical charging; and the introduction of the Huntington-Heberlein process for the treatment of sulphide ores.

The gradual development of the rectangular blast furnace is shown in the following table, which is based on one prepared by H. V. Croll:[1]

Place	Company	Date	Hearth	Height
Eureka...	Eureka Cons. Mg. Co.	1871	36×54	10 ft.
Leadville .	....	1880	33×84	14
Denver...	Omaha & Grant Smg. Co.	1882	36×80	14.9
	San Juan & New York Smg. Co.	1882	36×96	12.6
Denver...	Globe Smg. & Ref. Co.	1887	36×100	17.0
	Rio Grande Smg. Co.	1888	42×120	17.0
Denver...	Globe Smg. & Ref. Co.	1892	42×140	16.0
Leadville .	Harrison Red. Wks.	1892	42×120	18.0
Salt Lake.	Germania Lead Wks.	1895	45×140	20.0
Salt Lake.	American Smg. & Ref. Co.	1901	48×160	20.0

The progressive reduction in the cost of roasting in hand-raked reverberatory furnaces at the Globe works, Denver, Colo., is shown in the following table, reported by Dr. M. W. Iles:[2]

1887	$3.945	1890	$3.531	1893	.....	1896	$2.840
1888	4.280	1891	3.530	1894	$3.429	1897	2.740
1889	4.120	1892	.....	1895	2.806	1898	2.620

The average cost of smelting per ton during the same period was as follows:

1887	$4.644	1890	$4.374	1893	$3.375	1896	$2.750
1888	4.530	1891	4.170	1894	3.029	1897	2.520
1889	4.480	1892	4.906	1895	2.786	1898	2.260

[1] *Engineering and Mining Journal*, May 28, 1898.
[2] *Engineering and Mining Journal*, Aug. 18, 1900.

Smelting of Non-Argentiferous Ore

The smelting of the non-argentiferous lead ore of the Mississippi Valley has been of less interesting development, either metallurgically or economically, than the smelting of silver-lead ores of the Rocky Mountains, because the problem is simpler and because the lead-producing districts being accessible by river routes, and moreover being early reached by railways, cheap transportation was enjoyed long before the districts in the far West. Even in the very early history of Missouri, lead ore was smelted at comparatively low cost, because cheap labor and fuel were available, and costs do not therefore show the great reduction that is manifest in the history of Utah and Colorado.

In considering the practice of lead smelting in the Mississippi Valley it is necessary to observe that lead alone is the object of the smelting and that the ore is delivered to the smelter in a concentrated form, nowadays chiefly as mill concentrates, assaying from 60% to 82% in lead. The proportion of gangue (chiefly silica in the Joplin district and chiefly dolomite in southeastern Missouri) is therefore comparatively small, and its removal by slagging would be a simple and cheap matter if the right kind of fluxes were available, which unfortunately is not the case.

The earliest smelting in Missouri, in the log and ash furnaces, was so primitive that it may be disregarded in a metallurgical discussion. It is referred to, however, in a subsequent chapter of this work. The cost of smelting was low, being only $4 per ton of ore as early as 1825,[1] but the extraction of metal was also low, amounting to no more than 75% of the lead content of the ore. The log furnace was used probably as early as 1720. In 1799 it began to be displaced by the ash furnace, introduced by Moses Austin, but it survived for many years after that and was employed at Cadet, Washington County, as late as 1864. The Scotch hearth was introduced about 1836 in Washington County. The air, or Drummond furnace, was first tried about 1850 in Newton County, and was extensively used in central and southeastern Missouri in 1871–1880 A Flintshire furnace was erected at the Frumet mine in 1870, and the same type was adopted at Granby about 1874 and at the Desloge works at Bonne Terre about 1875. They did not remain long in use at any of those works, but were readopted at Desloge about 1888. The first blast furnace (cupola) in Missouri was erected at Mine la Motte in 1870; the St. Joseph Lead Co. built its first one at Bonne Terre in 1874.[2]

Previous to 1871, the smelting methods practised in Missouri, either in the Scotch hearths or air furnaces, were crude. About 1871 the practice was varied by the introduction of Flintshires and cupolas, and from

[1] American State Papers, IV, 557.

[2] J. D. Robertson, Report of Missouri Geological Survey, VII, 489.

that time up to the present all four types of furnace have been in contemporaneous use, with not very much improvement until recently.

The air furnaces used in 1871–1880 were built of stone, with a sloping hearth 9×3 ft., and grate 5½×2½ ft. The usual charge was 1500 lb. of ore, which was worked off in eight hours by a crew of two men, with the consumption of one cord of wood per ton of ore. The extraction of metal was 80 to 90%. The gray slag, assaying 40 to 55% in lead, was generally thrown away. The following account[1] of the smelting at Palmer in 1901 shows that the practice was essentially the same as thirty years previously:

"The air furnace employed at Palmer is a rude reverberatory with a sloping hearth 9×3 ft., and a lateral fireplace at the lower end of the hearth. The lead, reduced by roast-reaction, runs down into a kettle outside of the furnace at the lower end of the hearth. Such a furnace, which is constructed at insignificant cost, is capable of smelting a charge of 2000 lb. of ore in eight to ten hours, with the labor of one smelter and one helper, and the consumption of one cord of wood. At Palmer, comparative trials between these air furnaces and Scotch hearths resulted in favor of the former. The men are paid according to the yield of lead they get from the ore, which will range from 1300 to 1400 lb. per ton, averaging about 1360 lb. The cost of smelting per ton of ore for a yield of 1360 lb. will be $2.60 for labor, and $1 for wood; total, $3.60. The cost of 1360 lb. pig lead, delivered at St. Louis, will be, therefore, approximately as follows: Ore cost, $30; carting, 80 c.; smelting, $3.60; carting and railway freight, $3.40; selling commission, 50 c.; total, $38.30, or about 2.80c per lb., or, say, 3 to 3.25c, allowing for general expense. The profit per ton of ore is $10.20 to $13.60, when pig lead is worth 4 c. at St. Louis. The raw ore probably assays 82 to 84% Pb. A yield of 1360 lb. of pig lead from 83% ore indicates a recovery of about 82% of the metal in the ore. A ton of ore makes also about 250 lb. of gray slag, which is high in lead, but is practically valueless, unless the smelter be near a railway. Assuming the gray slag to assay 40% Pb., the total metal accounted for is nearly 88% of the tenor of the ore, leaving 12% as loss by dusting and volatilization, but probably the loss by volatilization is somewhat greater than that; the ore is never assayed, and the exact recovery is, therefore, unknown. However, the practical result is certainly a very satisfactory one, considering the trifling outlay required for plant and the low cost of smelting."

The form of Scotch hearth originally used in Missouri was a rectangular pot, with a back and sides of stones dressed to cubical shape. The stones were subsequently replaced by cubes of cast iron, about 7 in. on

[1] From an article, based on personal notes, in *Engineering and Mining Journal*, Dec. 10, 1903.

the sides, which increased the life of the furnace, lead oxide having no effect on the iron, while it corroded the stone rapidly. The back and sides of solid iron were finally replaced by a hollow iron casting, through which water could be circulated, forming a water-jacket, and enabling the furnace to be run continuously without becoming too hot. At Rossie, N. Y., a furnace was employed for a time which obtained considerable notoriety as the American-Scotch hearth. In this the air-blast was forced through the jacket before passing through the tuyeres, being thus preheated. The expedient was found to result, however, in an increased volatilization of lead, and therefore did not find permanent adoption except at the Lone Elm works, at Joplin, where it was employed for the specific purpose of increasing the volatilization.

Valuable data of the smelting results with the early hearth furnaces are obtained from the records of the works of Noble Brothers, near Granby, Mo., in 1860–61, which have been reported by D. Brittain.[1] Ore cost $16 per 1000 lb.; 75% of the ore was extracted as pig lead; in twelve hours 24,000 lb. of ore yielded 18,000 lb. of pig lead. The process was divided into first-smelting and second-smelting, the first yielding 65% at a cost of $85.68 per 24,000 lb. of ore; the second, 10% at a cost of $28.04. Nine bushels of coal and ⅜ cord of fine split wood were provided for each hearth; likewise 3000 lb. of ore, this amount being smelted in six to seven hours, called a "tour." Out of every 24,000 lb. of ore were obtained 7000 lb. of slag which crushing and washing reduced to 5000 lb., divided into two parts, 3500 lb. being "rich slag" and 1500 lb. "poor slag." The first after smelting left 875 lb. of slag, reducible by crushing and washing to 650 lb. This was added to the original 1500 lb. of poor slag, and both were then smelted in a blast furnace, together with the 3500 lb. of rich slag, the 5650 lb. of slag producing 2400 lb. of pig lead, or about 42½%.

The labor required for the treatment of 24,000 lb. of ore was as follows: One superintendent, one engineer, one fireman, two smelters on each hearth (one front smelter and one back smelter), one coal man, one blacksmith, and one carpenter. The cost of smelting was as follows:

First Smelting

Hauling 24,000 lb. ore at $0.50 per 1000 lb.	$12.00
Crushing and washing at $0.35 per 1000 lb.	8.40
Sixteen smelters, front hands	16.00
Sixteen smelters, back hands	12.00
Superintendent	2.50
Engineer	1.25
Fireman	1.25
Coal man	1.00
Amount carried forward	$54.40

[1] *Engineering and Mining Journal,* Nov. 9, 1907.

Amount brought forward	$54.40
Blacksmith	1.00
Carpenter	1.00
Charcoal, 72 bushels at 7½ c.	5.40
Fine split wood, 3 cords at $5	15.00
Lime	.50
Wood for engine, 2½ cords at $1.50	3.75
Oils, candles, repairs, etc.	4.63
Total	$85.68

Second Smelting, 7000 *lb. Slag*

Crushing and washing at $1 per 1000 lb.	$ 7.00
Smelting 3500 lb. at $3.57 per 1000 lb.	12.50
Crushing and washing refuse	.87
Smelting 2150 lb. at $3.57 per 1000 lb.	7.67
Total	$28.04

Total Cost of Production

Ore, 12 tons at $32	$384.00
Smelting	113.72
Transportation to St. Louis at $1.36 per 100 lb.	244.80
Total cost of 9 tons of pig lead at St. Louis	$742.52

Receipts

9 tons pig lead at $5.40 per 100 lb.	$972.00
Selling commission at 2½ per cent.	24.30
	$947.70
Less cost in St. Louis	742.52
Profit	$205.18
Profit per ton	20.52

In its final form the Scotch hearth comprised a cast-iron pot, or lead well, about 24×22×10 in., on which set a three-sided water-jacket, the latter being surmounted by a sheet-iron hood communicating with a dust chamber or flue. The front of the furnace was open like a forge, and the lead well set on a brick pier so as to bring its rim about 27 in. above the floor. Cast with the lead well was a sloping apron on which the gray slag was drawn out, while the lead reduced in the well overflowed into a channel leading to a pot at one side of the furnace. Blast was supplied through three one-inch tuyeres in the back of the water-jacket.

The lead well being filled with molten metal, finely crushed ore was thrown on the bath in a small heap sloping up against the back-jacket, and under the influence of the air blast was caused to roast and react, the residual gangue being raked out periodically as "gray slag" or "browse" and fresh ore being thrown in. The blast was supplied by Roots' blower, or Sturtevant fan, commonly the latter, only a light pressure being required. In a shift of eight hours, two men would work off 3500 to 7000 lb. of ore, depending upon the size of the furnace, etc.

The gray slag, assaying usually about 40% in lead, and amounting in weight to 10 to 25% of the ore, varying according to the percentage of gangue in the latter, was sometimes smelted in a slag-hearth, if the quantity were sufficient. The slag-hearth was a rude blast furnace, having a low, rectangular shaft with perpendicular sides. The old English slag-hearth was first used, but it was so slow and costly in its operation that by 1871 it had become almost obsolete, being displaced by an improved furnace, devised in Wisconsin and from there introduced into Missouri. This furnace was 26×36 in. in hearth area, and 46 in. in height, with a sloping hearth and an outside crucible. There was one 3-inch tuyere, 10 in. above the hearth. The hearth was formed of brasque tamped in on a cast-iron bed-plate. The shaft was lined with fire-brick. The fumes were carried away from the furnace top by a hood or chimney, sometimes into a dust chamber, but ordinarily into the open air.

Such a furnace would smelt in sixteen hours from 15 to 18.5 tons of gray slag, assaying 35 to 40% lead, producing 7500 lb. of hard lead at the following expense:

2 chargers at $3	$ 6.00
4 helpers at $1.75	7.00
1 yard hand at $1.50	1.50
100 bushels of coke at $0.25	25.00
22 bushels of charcoal at $0.12½	2.75
Expenses for 10 h.p. engine	8.00
Oil, tools and sharpening	.30
Total	$50.55

This made a cost of $2.73 to $3.37 per ton of gray slag. The extraction of metal was, however, very low, amounting to only 62½% of the content of the material smelted. Of the loss, from 8 to 15% was suffered in the black slag and the remainder in dust and fume.[1] The lead produced in this smelting was rated as "hard," and sold in 1874 at a discount of ⅜ and ½ c. per lb. off the price of corroding lead. Obviously so wasteful a method of smelting could not survive, and it gave way to the regular cupola furnaces as soon as they began to be generally introduced, save in the case where it was aimed to volatilize a high percentage of the lead (Lone Elm works, Joplin, Mo.).

In their blast-furnace smelting the Missouri metallurgists started out on the same line as the silver-lead smelters, but they began with the circular form of furnace and stuck to it until about 1900. In other respects their progress was somewhat similar, though slower, but in spite

[1] J. Y. Bergen, Jr., Mineral Resources West of the Rocky Mountains, 1874, pp. 424–430.

of the simplicity of their smelting problem they were hampered by two factors, viz., the lack of fluxing ores and inability to obtain iron flux of high basic excess, except at relatively high cost, and the necessity of slag-roasting the lead ore with addition of barren silica, increasing the furnace burden and leading to inevitable high loss of lead.

In 1893 the cupola furnaces in use in southeastern Missouri were from 45 in. diameter (Mine la Motte) to 50 in. diameter (St. Joseph Lead Co.). The height from tuyeres to charge door was 12 to 18 ft. The furnaces were water-jacketed, run with closed breast, and siphon lead-tap. At the top the furnaces terminated in a brick stack, commonly without connection to a dust-chamber. A 48-in. furnace would usually put through 40 to 50 tons of charge per 24 hours, producing about 18 tons of lead. Blast was supplied by Baker or Roots' blowers at about 8 oz. pressure.

The ore was roasted in reverberatory furnaces with hearth 11×51 ft. to 11×55 ft., silica being added to serve as acid flux in slagging the ore. Such furnaces put through from five tons of ore per 24 hours, desulphurizing it to 3.5% S (Bonne Terre), to eight tons per 24 hours, desulphurizing it to 4 to 6% S (Mine la Motte), 0.4 to 0.5 cord of wood being required per ton of ore and the labor of three to four men per 12-hour shift.

The comparative cost of smelting by different methods in 1893 was reported as follows:[1]

Air furnace: Per charge of 1500 lb. of ore, one smelter $1.50, one helper $1.30, one half roustabout $0.55, and 0.25 cord of wood, $1.50, total, $4.85 = $6.27 per ton of ore.

Scotch hearth: Per charge of 3500 lb. of ore, one smelter, $2.50, one helper, $2, one engineer, $2.50, one roustabout, $1, one cord of wood, $2, five bushels of charcoal, $0.40, wood billets, $0.40, total, $10.50 = $7.88 per ton of ore.

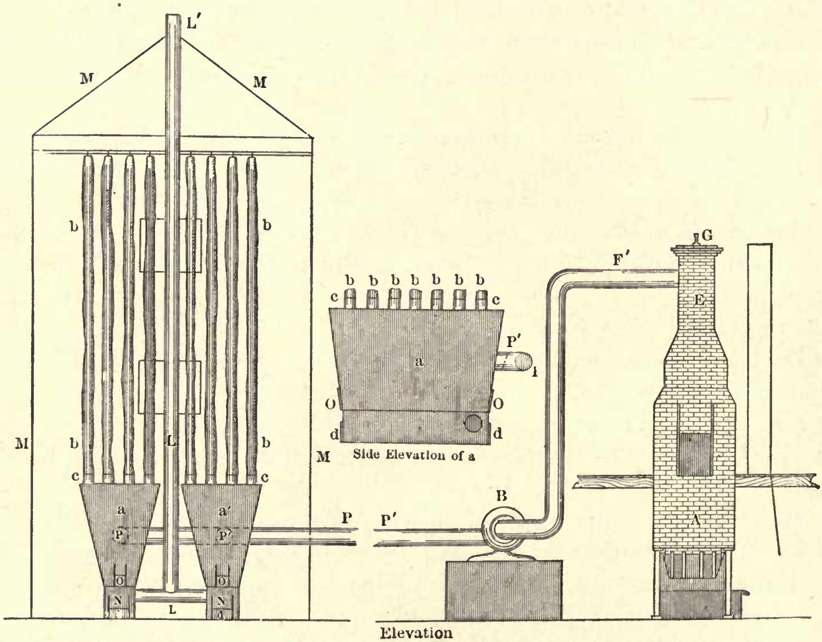
Cupola furnace: Roasting ore, $2.60, roasting matte, $0.44, smelting, $1.76, refining, $0.20, coke, $0.90, flux $1.07, wood, $1.48, repairs and supplies, $1.18, total, $9.61.

The only contribution of great practical value in the metallurgy of lead that has come from the practice in Missouri has been the adaptation of the system of filtering fume through cloth, employed from a comparatively early time in the metallurgy of zinc. This was due to Eyre

[1] J. D. Robertson, Report of Missouri Geological Survey, VII, ii, p. 494. These figures are misleading without further explanation. The figures for the Scotch hearth plant are based on a single furnace, but the cost per ton of ore would obviously be considerably lower in a plant of five furnaces, which would be run with the same labor cost for power. Also in the cases of both the air furnace and Scotch hearth, the cost of resmelting the gray slag is disregarded.

O. Bartlett, who had previously been engaged in the manufacture of zinc oxide in the East, and in connection with G. T. Lewis of Philadelphia patented a process for the direct manufacture of white lead direct from the ore in an analogous manner. This was applied at the Lone Elm smeltery at Joplin, Mo., in 1878.

The success of this system of fume filtration led very soon to its trial by one of the silver-lead smelters of Colorado, but it did not find any important application there until the Globe works were erected in Denver in 1887. It has continued in use at those works, also at East Helena, Mont., and a system based on the same principles has been used at the



Lead-smelting Furnace with Bag-filter, as first tried at Leadville, Colo.

works at Omaha, Neb., but otherwise cloth-filtration did not find favor in the eyes of the silver-lead smelters, the later plants being provided only with settling flues, until 1907, when attention was redirected to the advantages of the bag house. However, in the case of the smelting of the non-argentiferous ores of the Mississippi Valley the conditions are different. Nevertheless, although cloth filtration continued in regular use at Joplin, it did not find any other application until a plant was erected by the Missouri Smelting Co., at Cheltenham, St. Louis, late in the nineties. Then it began to be appreciated that the combination of the Scotch hearth and bag house was an improvement of the highest order in the smelting of non-argentiferous, high-grade galena, and two large plants which have been erected near St. Louis since 1901 have been designed according to that system, the efficiency of which has been proved to be so high that probably it cannot be surpassed even by the lime-roasting processes, which in Europe have largely displaced all other methods of smelting practised there.

The Lone Elm works were started in 1868, smelting with Scotch hearths. In 1878 an output of 712 tons of white lead was made, and this has been continued on a generally increasing scale ever since, but it was only after a long series of costly experiments that the process was perfected and a pigment of desirable quality produced. The works are now owned and operated by the Picher Lead Co.

In the Lewis & Bartlett process the ore is smelted in a double Scotch hearth, with two lead wells, each $48 \times 22 \times 10$ in., operated from opposite sides of the furnace. Above the lead wells there are cast-iron jackets, in which the air-blast is preheated, substantially as in the Rossie furnace. In this case the object is to volatilize lead, and the hotter the fire the more fume is produced and also the more is the quantity of ore that can be smelted. The fume is blown into a sheet-iron hood, which communicates with a dust-settling chamber, whence it is drawn through sheet-iron pipes of sufficient radiating surface to reduce the temperature to the point at which it can be safely filtered through woolen bags.

The double furnace smelts 24 tons of ore per 24 hours in summer, and 30 tons in winter, with the labor of 12 men (three shifts, 4 men per shift) and the consumption of 160 lb. of coal and 40 lb. of lime per 2000 lb. of ore. In smelting ore containing 73% of lead, about two-thirds is won immediately as pig lead, the remainder going into the gray slag and the flue dust and the fume. The gray slag amounts in round figures to 20% of the weight of the ore, the flue dust to 10% and the fume to 25%. The fume is collected by filtering through bags of unwashed wool, about 18 in. in diameter and 35 ft. in length, 3500 sq. ft. of cloth area being supplied per ton of ore smelted. In the collection of zinc oxide bags of unbleached muslin are employed, but in filtering the gas from burning galena or other sulphides, the sulphur trioxide in it soon destroys cotton. It was found after extensive experimenting that wool, with the natural grease of the sheep in it, was not so much affected. The fume, or "blue powder," is shaken periodically out of the bags into sheet-iron hoppers, whence it is removed to heaps on the ground and ignited, burning in about 10 hours to a pinkish-white, coherent crust, free from all carbonaceous matter and sulphide of lead.

The burned fume is smelted together with the gray slag and flue dust from the hearths and a little oxidized ore and fluxes in a shaft furnace called the "slag eye." This is a rectangular brick shaft with perpendicular sides, 24×24 in. in horizontal section and 6 ft. in height, the charge door being only 4 ft. above the bottom of the furnace. There are two rows of tuyeres, one at the bottom of the furnace and the other just below the charge door. The tuyeres pass through small water-jackets. The top of the furnace communicates with a large sheet-iron flue. This furnace is a modification of the slag-hearth previously described.

Connellsville coke is used as fuel. The furnace is run very hot, the object being to volatilize as much as possible of the lead. However, a certain portion is unavoidably reduced. This flows together with the slag into an outside settler. An average daily charge for one of these furnaces was 2800 lb. of gray slag, 1000 lb. of blue powder, 600 lb. of oxidized ore, and 450 lb. of impure fume. The furnace was managed by a crew of three men, working eight hours, or nine men per 24 hours. The lead produced in this smelting was quite impure, and the slag although considered poor enough to discard was still rather rich in lead. The pigment product of two furnaces was 8500 lb. per day on the average. The furnaces could be run only 15 to 30 days, when it became necessary to stop for repairs. The blast for the two slag-eyes and the hearth was supplied by two No. 5 Baker blowers.

The daily cost of running the works, smelting 24 tons of ore, in 1884 was as follows: [1]

12 smelters at hearth furnace at $2	$24.00
5 extra men at $1.50	7.50
2 paint packers at $0.25 per bbl. at $4.25	8.50
3 engineers at $1.75	5.25
1 teamster at $1.50	1.50
2 foremen at $2.50	5.00
12 smelters at slag-eye at $2	24.00
3 yard men at $1.50	4.50
5 extra men at $1.50	7.50
Total labor	$87.75
48 pecks of lime at $0.05	$ 2.40
48 bushels of coal at $0.07	3.60
2880 lb. of coke at $8.15	11.75
10 bushels of charcoal at $0.10	1.00
2.5 tons of steam coal at $1.87	4.75
General expenses	13.75
Total	$125.00

The above shows a smelting cost of $5.20 per ton of ore. In an experimental run on 28.662 tons of ore there was produced 25,549 lb. of lead in the hearth, 8798 lb. in the slag-eye, 14,387 lb. of paint, and 4030 lb. of slag to be thrown away. The lead content of the original ore being undetermined, the percentage of extraction cannot be reckoned. The cost of production was as follows:

[1] Dewey, Trans. Am. Inst. Min. Eng., XVIII.

Ore cost	$1,169.38
Freight on white lead at $0.45 per 100 lb.	64.51
Freight on pig lead to St. Louis at $0.24	89.63
Selling commission on pig lead at 1%	12.51
Selling commission on white lead at 2.5%	12.53
Royalty on patents, ½ c. per lb.	71.68
Smelting cost, $5.54 per ton	158.87
Total	$1,579.11

The Lewis & Bartlett process is of special interest because it led directly to the application of the bag-system of fume filtration to the Scotch hearth furnaces run for the production of pig lead, and not at all for pigment, and to the large blast furnaces used in silver-lead smelting in the far West, in both cases enabling a higher extraction of metal to be made, and in particular making of the Scotch hearth method of smelting a highly efficient process, which previously it was not, its chief defect being in the large loss of metal in dust and fume.

In 1901 there were in operation in the Joplin district three plants employing Scotch hearths, viz., one at Galena, Kan., one at Granby, Mo., and one at Joplin, Mo. In southeastern Missouri, the Mine la Motte, Central Lead Co., and St. Joseph Lead Co. had each a roast-reduction, blast-furnace plant; the Desloge Consolidated Lead Co. had reverberatory furnaces; some of the smaller concerns had Scotch hearths and air furnaces. At St. Louis, the Missouri Smelting Co. had a Scotch hearth and bag house plant. The St. Louis Smelting and Refining Co. had a blast-furnace plant, employing the precipitation process. The Pennsylvania Smelting Co., at Pittsburg, Penn., smelting ore from southeastern Missouri, also had a blast-furnace plant, employing the precipitation process. Economically the various processes in their better developments were applied on substantially equal terms; there was no striking advantage in any one. About this time, however, it began to be realized that it was more economical to carry the ore from the southeastern Missouri districts to St. Louis, for smelting, than to smelt it directly at or near the mines, the freight rates on a ton of ore and the pig lead derived from a ton of ore being substantially the same, while in smelting at the mines it was necessary to ship the coke and iron flux from St. Louis. In smelting at or near St. Louis consequently it was possible to save substantially all the freight on coke and iron flux required in the smelting, besides which there were the other advantages in obtaining labor, supplies, etc., marketing the product, etc., which result from proximity to a large city. In consequence of the appreciation of those conditions, the new smelting plants which have been erected since 1901 for the reduction of southeastern Missouri lead ore have been established near St. Louis. The Federal Lead Co. erected a large plant at Alton, Ill., and the St. Louis Smelting and Refining Co. built at Collinsville, Ill.

In both of the above plants, the Scotch hearth and bag house system of smelting was adopted, mechanical appliances for handling the ore, fluxes, and furnace products were extensively introduced, the size of the plants was greater than anything of the same character previously erected in the United States, and by virtue of these improvements the Scotch hearth and bag house system of smelting became undoubtedly the most economical method for the treatment of non-argentiferous galenas of high grade in lead.

In the practice of 1901 the roast-reduction method of smelting was best exemplified at the works of the St. Joseph Lead Co., at Herculaneum, on the Mississippi River, about thirty miles south of St. Louis. These works were not only the largest in use for the smelting of galena concentrates in the Mississippi Valley, but also they were the most complete and best constructed, being indeed the only works in the Mississippi Valley which in points of design and construction were in any way analogous to the large smelteries of the far West.

The ore was slag-roasted in reverberatory furnaces of the dimensions previously described, 8000 to 9000 lb. of ore being burned down to 3 to 5% sulphur in 24 hours, with the labor of two men per shift of 12 hours, the rate of wages being $1.60.

The smelting was done in three circular furnaces, 48 in. in diameter at the tuyeres and 60 in. in diameter at the top, and one rectangular furnace, 42×100 in., all of the furnaces being 12 ft. in height from the tuyeres to the charge door. Each furnace was directly connected with a No. $5\frac{1}{2}$ Baker blower, blast pressure 12 to 16 oz. Furnaces terminated at the top with a chimney; no dust chambers. Furnaces operated with closed breasts, and siphon lead-taps. The lead ran continuously from the wells into a spherical cast-iron pot where it was skimmed, the clean pigs and the dross being subsequently liquated separately. The ore smelted contained a small proportion of nickel and cobalt, which concentrated in the drosses and liquidation residues, these being subjected to a further smelting process, wherein the nickel and cobalt were concentrated into a matte.

The furnace charge consisted of three parts slagged ore, one part gray slag from other works, 1.25 part of iron cinder and one part of roasted matte. Owing to the comparatively low basic excess of the iron flux, it would have been most economical to make a slag rather high in silica and rather low in protoxide of iron, but on the other hand, it was desirable to produce a slag of low melting point, since otherwise a more impure pig lead would result. The lead produced by the blast furnaces generally contained about 0.2% copper which was reduced to 0.02% by liquating on a sloping cast-iron hearth with perforated holes, from which the molten lead was conducted into a 30-ton kettle wherein it was steamed from

$1\frac{1}{2}$ to 2 hours. The circular blast furnaces smelted 45 to 50 tons of charge per day, the rectangular furnace about 80 tons per day. The production of matte was about 20% of the weight of the ore. The matte was roasted in a Pearce mechanical furnace.

The furnace crew for the circular furnaces was one charger at $1.95, two charge wheelers at $1.60, one tapper at $1.90, one lead moulder at $1.50, and one slag pot puller at $1.60 per 12-hour shift, the total labor cost per 24 hours being $20.30. The crew of the large furnace per 12-hour shift comprised two chargers, four charge wheelers, one tapper, two lead moulders and two pot pullers.

The reverberatory furnaces in use at the Desloge works presented no great novelties from previous practice, save in their construction, which approximated that of the furnaces employed at Tarnowitz, Prussia. In hearth area they were 11×16 ft., with grates of 3×8 ft. Three charges of 3500 lb. each were smelted per 24 hours, each furnace being manned by one smelter and one helper per 8-hour shift. The consumption of coal was 0.8 to 0.9 ton per ton of ore. The cost of smelting on the basis of five furnaces in operation, treating 25 tons of ore per 24 hours, was approximately as follows:

1 foreman at $3	$ 3.00
15 smelters at $1.75	26.25
15 helpers at $1.55	23.25
Unloading 22.5 tons coal	1.50
Loading 14 tons lead	2.80
Loading 7 tons slag	1.40
Total labor	$58.20
22.5 tons coal at $2	$45.00
Fluxes and supplies	12.50
Repairs and renewals	10.00
Total	$125.70

This gives a cost of about $5 per ton of ore, exclusive of the cost of resmelting the gray slag, which would come to $1.50–$2 additional per ton of raw ore.

In the smelting of ore containing 70% lead at Desloge, about 77% of the metal contents of the ore were obtained directly as pig lead. The production of gray slag, assaying 38% lead, was approximately in the ratio of 0.25 ton per ton of ore smelted. In the reduction of this slag in the blast furnace, 95% of the lead could be recovered, giving a total extraction of about 91% of the lead of the original ore. This percentage might have been considerably increased by the provision of means for collecting the dust and fume from the furnaces, in which the major part of the loss was suffered.

In the Scotch hearth practice of 1901 the furnaces were 30×22 in., with four one-inch tuyeres. The blast was supplied by a Sturtevant fan, at about 5 oz. pressure. With three shifts of two men each, such a furnace would smelt 10,500 lb. of ore per 24 hours. In treating ore containing 70% lead, the production of gray slag is about the same as in the reverberatory furnace, but the direct yield of pig lead is rather less, the loss of metal in dust and fume being greater, the loss in fume amounting to 12 to 15%.

The cost of operating a plant of five hearths, smelting 25 tons of ore per day, was approximately as follows:

1 superintendent at $4	$ 4.00
2 foremen at $2.50	5.00
2 engineers at $2.00	4.00
15 smelters at $1.75	26.25
15 helpers at $1.50	22.50
5 charge wheelers at $1.50	7.50
4 yard men at $1.50	6.00
Total labor	$75.25
2250 lb. charcoal at $0.03	6.75
1.5 ton steam coal at $1.10	1.65
Supplies	1.50
Repairs and renewals	5.00
Total	$90.15

This gives a cost of about $3.60 per ton of ore, exclusive of the cost of resmelting the gray slag, dust, and fume. Estimating the proportion of slag, dust, and fume at 25%, 10%, and 20% respectively, the total cost of treatment was approximately as follows:

Smelting in hearth	$3.60
Collection of fume	.25
Briquetting 0.1 ton dust	.05
Smelting 0.45 ton slag, dust and fume at $6.00	2.70
Total	$6.60

The comparative cost of smelting and the recovery of lead by the different methods was approximately as follows:

Method	*Cost per ton*	*Extraction*
Reverberatory	$7.00	91–92%
Scotch hearth	6.60	98%
Cupola	6.00	90%

The smelting results at the Petræus smelting works at Galena, Kan., in 1907, were reported as follows:[1]

The equipment of the plant consists of four single jumbo Scotch fur-

[1] D. Brittain, *Engineering and Mining Journal*, Nov. 9, 1907.

naces, a blast furnace, bag room (100×68 ft.), containing 680 bags 30 ft. long and 6 ft. in circumference, made of cotton cloth of 44 threads to the inch both ways. The charge for a hearth includes: 7000 lb. galena ore, one bushel stone coal (Kansas), one bushel lime. The ore assays from 77 to 82%. A charge is smelted by two men in seven hours, three shifts per day being worked. The blast furnace takes galena, carbonate ore, gray slag from the hearths, and blue fume.

Fifteen charges of the blast furnace include: Galena, 45,000 lb.; coke, 2100; gray slag, 6000; blue fume, 7500; carbonates, 500; "ashes," 1500: black slag, 15,000; cast iron, 600; soft iron, 600; iron cinders, 300; and tin cans, 600 lb. The "ashes" entering into the charge are the coarser particles of blue fume which settle in the dust flue before reaching the suction fan. The black slag comes from the blast furnace. The blast furnace operates eight hours per day.

The average proportions of lead in the materials smelted are as follows: Galena, 77 to 82%; carbonates, 72; gray slag, 35; blue fume, 72 to 75; "ashes," 56; and black slag, 0.7%.

The smelters are required to produce on the hearths pig lead amounting to 60% of the ore and from the 15 charges of the blast furnace 11,810 lb. of pig lead, or 25.7%.

The black slag contains: Silica, 22 to 28%; lime, 20 to 24; iron, 24; zinc, 7; lead, 0.7; and other constituents, 16.3 to 26.3 %. The gray slag contains: Lead, 35%; iron, 1.67%.

The men required at each hearth are: two smelters, paid $2.20 per 7000 lb. of ores smelted; one yard man and one moulder, each receiving $1.65 per 7000 lb. of ore. The blast furnace requires one feeder, at $2.50; one tapper, $2.25; and four yard men, $1.90 per eight hours.

The lead from the hearths and blast furnace is moulded into pigs and remelted in a refining kettle of 9000 lb. capacity in which it is refined by poling. The smoke from the hearths and blast furnace is drawn by a 90-in. fan through a flue 800 ft. long, 6×4 ft. in the clear, into the bag room where the fume accumulates. It is periodically ignited after being shaken from the bags to the floor.

About 1870–1873 there were five silver smelting and refining works in and near the city of Chicago at which a good deal of ore from the Emma mine in Utah and small quantities of Colorado ore were smelted. The Emma ore was a ferruginous mixture of carbonate and oxide of lead, with nodules of galena, and silicious gangue. Its composition was approximately 41% silica, 34% lead, 3.5% iron, and 2 to 3% sulphur. It was smelted in reverberatory furnaces, with admixture of lime and fluorspar as fluxes and iron borings to decompose the lead sulphide. A furnace charge, described by Joseph L. Jernegan,[1] comprised in 24 hours

[1] Trans. Am. Inst. of Min. Eng., II, p. 279.

6380 lb. of Emma ore, 1500 of dross and 646 of litharge, a total of 8526 ol lead-bearing material, with 300 lb. of lime, 900 of fluorspar, and 900 of iron borings. This was treated in six charges.

The slag was fused so that it could be tapped off from the furnace in liquid state, separation from the lead being effected outside of the furnace. Rich slags were resmelted in a slag hearth.

This method of smelting was inefficient both in respect to operating cost and extraction of metal, and about 1873 the reverberatories were displaced by blast furnaces at two of the works and soon afterward became obsolete in all of them.

IV

REFINING, MARKETING, AND USES

Although the refining of lead is technically a part of its metallurgy, its purpose is to put the crude metal into marketable form, and its methods are directed to the production of grades which the market requires. It is generally performed at market centers, rather than at the points of origin of the crude lead. It has appeared, therefore, most useful in this study to discuss the refining, marketing, and uses of the metal in one chapter.

Refining

The refining of lead comprises the removal of all other metals so far as is practicable. The process of separating gold and silver is technically known as "desilverizing," and in the refining of argentiferous lead the treatment is based especially upon the complete separation of the precious metals. Incidentally, the same means that are employed for the separation of the gold and silver remove deleterious impurities and afford a higher quality of lead than is ordinarily produced from non-argentiferous ore. In the refining of non-argentiferous lead only the removal of such impurities as arsenic, antimony, and copper has to be considered.

In the art of desilverizing argentiferous lead, the ancient process of cupellation had practically gone out of use and the Pattinson process was rapidly being displaced by the Parkes process at the time when silver-lead began to be produced in the United States. In 1871 there were two important refineries in the United States, viz., the Balbach works at Newark, which had been established in 1850, and the Selby works at San Francisco, which had been started about 1866. Both of these works employed the Parkes process, but at Newark it was modified so that the silver-zinc crust was not skimmed from the lead, but the latter was removed by liquation at a low temperature. The Pennsylvania Lead Co. had a refinery in operation at Pittsburg, Penn., while at Chicago there were five plants, belonging to the Chicago Smelting and Refining Co., Swansea Smelting and Refining Co., C. P. Lunton, and two others. The Silver Islet smeltery and refinery was erected at Wyandotte, Mich., in 1872, and in the same year the Germania works at Salt Lake City. In 1874 the Richmond Consolidated Mining Co. established a refinery at Eureka, Nev., where the Luce-Rozan process was introduced.

It may be remarked here that never in the history of lead smelting in the United States has there been any general tendency to establish refineries near the mines. The Germania and Richmond, and later the Pueblo and the Globe, are the only examples of such installations. With those exceptions, the refineries from the earliest time have been established in market centers of the East. They stand between the producer of crude metal and the consumer, and experience has shown that they are best placed at a good distributing point for the territory of consumption which they are to serve. The experience in copper refining has been the same.

Of the refineries in the United States, the oldest is that of the Balbach Smelting and Refining Co., on the Passaic River, in the city of Newark, N. J. This plant was established by Edward Balbach, who was born in Carlsruhe, Baden, in 1804. Mr. Balbach, who was a proficient chemist, early engaged in the refining of metals in his native city. Although in a measure successful there, his active mind clearly foresaw the impossibility of increasing the business beyond certain limits, and with that conviction, together with his firm belief in republican principles, he was led to visit the United States in 1848, with a view of transplanting his business to this country. He selected for location of his works the city of Newark, where the manufacture of jewelry was a leading industry. The waste and sweepings of these establishments were then purchased by speculators, and sent to Europe for treatment. Mr. Balbach returned to Europe, but in 1850 came back to the United States and laid the foundation of the works which subsequently became so important in the lead industry.

Skill and fair business methods soon secured for Mr. Balbach the confidence of the jewelry trade in his vicinity, and his establishment being the only one of its kind, the enterprise proved to be a profitable and constantly increasing one. The reputation thus acquired soon spread, and small shipments of ore began to find their way to the Newark works. In 1859 the output of a lead mine discovered in Orange County, New York, furnished considerable material for treatment. In 1860 the yield of an old lead mine in Pennsylvania went to the works. A little later it became possible to obtain ore from Guymard, N. Y. The fame of the Newark works now reached to remote parts of the United States, and even to Mexico, and when silver-lead bullion began to be produced in Nevada, naturally it went to the Balbach works at Newark, and to the Selby works at San Francisco, the latter having been established in 1866. As the supply of bullion increased, refineries were established at other places.

In 1870 the largest lead refinery of the United States was that of Selby & Naylor (later the Selby Smelting and Lead Co.) at San Francisco, Cal., which was originally established to supply their shot tower with lead.[1] For several years the enterprise was unsuccessful, but the completion of the Pacific railway and the opening of new mining districts in California, Nevada, and Utah furnished large supplies of raw material, and the business expanded to large proportions. In 1870 the firm was able to compete successfully with the Balbachs of Newark, N. J., for ores and base bullion, and the movement of refined lead from the Atlantic to the Pacific coast had not only been stopped, but shipments in the opposite direction had been begun. However, the prestige of San Francisco lasted only so long as Cerro Gordo and Eureka were large producers of pig lead. The largest market for lead being in the Eastern and Central States, the work-lead of Utah, and later of Colorado, naturally went eastward, and refineries were gradually erected at various places, including Denver and Pueblo, Colo., Kansas City, Kan., St. Louis, Mo., Chicago and Aurora, Ill., Pittsburg, Penn., and Perth Amboy, N. J., while on the Pacific coast a plant was erected at Everett, Wash.

At most of the places where important refineries have been established, they have continued in operation to the present time, but the sources of their supply of base lead have undergone radical change. In the time of the great lead production of Nevada, when Utah also was turning out much lead, the crude metal was refined chiefly at Newark, Chicago, and San Francisco. A little later a good deal of the Utah metal was shipped to Pittsburg, which is still a refining center on a small scale. Kansas City and St. Louis once refined large quantities of Colorado lead, and Kansas City both smelted and refined a great deal of Mexican lead. The Kansas City plant was dismantled a few years ago, as was also the St. Louis plant, but St. Louis continues to be a great market for non-argentiferous lead. Chicago has been an important refining center ever since 1871. As San Francisco and Newark lost their holds on the Utah and Colorado bullion, they found new sources of supply in foreign countries — San Francisco in British Columbia, and Newark in Mexico. The law permitting the refining of lead in bond, following the remarkable development of lead smelting in Mexico in 1890–1893, endowed the Newark plant with a new lease of life and made the neighborhood of New York a great lead-refining center, a great plant being built by the Guggenheim Smelting Co., at Perth Amboy, N. J. Work-lead could then be shipped from Monterey, Aguascalientes, San Luis Potosi, and Mapimi in Mexico by rail to Tampico, and thence by steamship to New York harbor, and by lighters directly to the refineries at Newark and Perth Amboy, while the steamships which brought the metal to New York were able to carry back coal and coke to Mexico. Moreover, these refineries were able to draw ores and base bullion from Chile and other

[1] Mineral Resources West of the Rocky Mountains, 1870, p. 458.

South American countries, and eventually this traffic attained such magnitude that the American Smelting and Refining Co. organized a subsidiary steamship company to handle its part of it.

The desilverization of lead by means of Parkes' process[1] had in the early seventies already been developed to a high degree of efficiency. In treating 20 tons of lead per 24 hours at Havre, France, there was required the labor of 20 men, or 1 man per ton of lead, while the consumption of coal was 10% of the weight of the lead, of zinc 1%, and the loss of lead in the process was only 1%. The cost was $0.75 for labor, $0.47 for coal, $1.05 for zinc, and $0.19 for muriatic acid, a total of $2.46, which was increased to $3.83 at the maximum after allowing for repairs, renewals and all other costs.[2] In the practice of that time, however, the method of eliminating arsenic and antimony had not become well established, being done sometimes before the desilverization and sometimes after it, while there was a good deal of variation in the treatment of zinc crusts and in the dezinkification of the desilverized lead.

The methods employed at the Germania works, Salt Lake City, Utah, in 1872, are illustrative of the American practice at that time. The base bullion was melted in a pot of 25 tons capacity, wherein 2.25 to 2.75% of zinc (costing 9 c. per lb.) was added in the case of bullion containing 150 to 200 oz. silver per ton, the zinc being added in three portions, giving three skimmings. The desilverized lead was run into a softening furnace, 15 ft. 6 in.×9 ft. 4 in., wherein the zinc and antimony were oxidized, partly escaping as fume and partly forming a scum on the surface of the lead bath, whence it was raked off. The refined lead was then run into a pot, from which it was tapped into moulds, yielding pigs of 140 lb. each. The skimmings from the softening furnace were treated in a liquating furnace for recovery of entrained lead. The rich zinc crust was smelted in a small shaft furnace, fluxed with iron ore and lead slag, yielding lead rich in gold and silver. The rich lead was finally cupeled, yielding doré bars, which were shipped. The works were of 40 tons per 24 hours capacity and employed 35 men. The cost of construction was $58,000.[3]

[1] In Parkes' process base silver-lead is first softened, *i. e.*, the hardening impurities such as arsenic and antimony are removed by oxidizing them and skimming off the dross. To the refined silver-lead zinc in proper quantity is added in a large kettle. The zinc robs the lead of gold and silver, forming gold-zinc and silver-zinc alloys, which rise to the surface of the lead as a scum, which can be skimmed off. The scum, or crust, is distilled in a retort for elimination of the zinc, leaving a residue from which the gold and silver are easily obtained. The desilverized lead after the zinc treatment contains about 1% of zinc, which is burned off in a suitable furnace, leaving refined lead, which has only to be cast into pigs to be marketable.

[2] August R. Meyer, Mineral Resources West of the Rocky Mountains, 1873, pp. 458, 486. Gruner, *Annales des Mines*, XIII, sér 6, 3 livr., 1868.

[3] Bentham Fabian, Salt Lake *Tribune*, Jan. 4, 1873; Mineral Resources West of the Rocky Mountains, 1872, p. 261.

At one of the works at Chicago the Cordurié modification of Parkes' process was used. At all of the others the practice was to soften the lead first in a reverberatory furnace, followed by a liquating furnace; then desilverize by addition of zinc in a kettle; separate the gold-silver-zinc-lead alloy by liquation in a special furnace; refine the desilverized lead by heating in a reverberatory furnace, drawing it off into a market-kettle and moulding in 100 lb. pigs; distilling the gold-silver-zinc-lead alloy in a tilting retort, invented by A. Faber du Faur, condensing about 50% of the zinc for further use and obtaining from the retort a rich gold-silver-lead bullion, which was cupeled. This was commonly known at that time as the Balbach process, having been developed at Newark, N. J., and it is the basis of the modern American practice.

The modifications have really been slight. The liquation furnaces have been dispensed with, and the introduction of the zinc and removal of the zinc crust are effected by the stirrer and press invented by W. H. Howard. This has been the greatest improvement in the American practice of lead refining. The stirrer effects a thorough incorporation of the zinc with the lead. The press squeezes all surplus lead out of the zinc crust. These machines are handled from an overhead crawl extending over the desilverizing kettles. They have greatly reduced both the labor and zinc required in the desilverizing process. For the rest, the improvements in silver-lead refining have consisted in the better construction of the furnaces, the general arrangement of the plant, mechanical means for the handling of material, and means for reducing the loss of lead in fume.

The cost of refining at the Horn Silver works at Chicago, Ill., in 1884, was $8 per ton.[1] At the Globe works, Denver, Colo., in the second half of 1895, it was $7.06 per ton, inclusive of parting and brokerage, but exclusive of interest and expressage.[2] In 1901 the cost at the Globe works was $5.25; at Omaha, Neb., $4.60; at Chicago, Ill., $4; at Perth Amboy, N. J., $6.32.[3] It would be inaccurate to attempt to draw precise conclusions from these figures, because in order to do that it would be necessary to analyze more fully the various conditions. However, they indicate that in 20 years, although the cost of refining has been materially reduced, the saving has been by no means so large in proportion as the saving in the cost of smelting ore. To the producer of ore, moreover, the saving in refining is relatively less important than the saving in smelting, because while the ability to smelt for $1 less per ton adds $1 per ton to the value of the ore, the ability to refine bullion $1 per ton cheaper adds only 25 c., 12½ c., etc., to the value of a ton of ore, according as the latter yields 25%, 12½%, etc., of its weight in bullion.

[1] From an official report of the company.

[2] M. W. Iles, *Engineering and Mining Journal*, Aug. 18, 1900.

[3] Averages of a single month in each case.

It has been the practice of the silver-lead smelters in purchasing ore for many years to allow for the refining charges by paying the miner for the lead in his ore at a rate less than the market price for pig lead, *e.g.*, 1 c. per lb. less. Then if the price of pig lead were 4.5 c. per lb. at New York, the price to be paid for lead in ore might be 3.5 c. per lb. In this connection it is interesting to note the actual cost to the smelter for delivering his base bullion and refining it at Perth Amboy, N. J. The data are for the year 1901.

Bullion from Pueblo, Colo.: The silver content realized the New York price for silver less 1 c. per oz.; gold, $20 per oz.; lead, 98% of the New York price, *i.e.*, 2% of the lead is assumed to be lost in the refining. The costs were as follows, per 2000 lb. of base bullion: Refining, $6.25; lighterage, $0.62½; freight from Pueblo to New York, $6.40; selling commission, $0.40; miscellaneous, $0.325; total, $14, or 0.7 c. per lb.

Bullion from Monterey, Mexico: The silver content realized the New York price less 1 c. per oz.; gold, $20 per oz.; lead, 98% of the London price. The costs were as follows, per 2000 lb.: Refining, $6.25; freight from Monterey to New York, $4; lighterage, $1.25; selling commission, $0.40; miscellaneous, $0.15; total, $12, or 0.6 c. per lb.

A noteworthy recent improvement in the refining of argentiferous lead is the electrolytic process invented by Anson G. Betts, which was installed first at the refinery of the Canadian Smelting Works at Trail, B. C., in 1902. Since then the process has been in successful use there, and in 1906 similar plants were installed at Grasselli, Ind. (near Chicago, Ill.) by the United States Metals Refining Co., and at Newcastle on Tyne, England. How important an improvement in the metallurgy of lead this process will be remains to be proved. At present it appears doubtful if it will be more economical in operating cost than the standard Parkes process, but on the other hand it offers improved means for the extraction of antimony and bismuth from base lead, and of course the danger of lead poisoning of the workmen is greatly reduced, which makes the process noteworthy from the humanitarian standpoint, and there are possibly other advantages.

The refining of non-argentiferous lead is much simpler than that of the silver-lead. In many cases, referring especially to the lead produced by Scotch hearth, air, and reverberatory furnaces no refining at all is required, the lead being drawn into kettles from which it is ladled directly into the moulds, the pigs from which are prepared for market only by shaving off the excrescences on their upper surface. Sometimes a few chips of wood and bark are stirred into the kettle, and a little dross skimmed off before ladling out the metal. The lead produced by these furnaces is reduced at a comparatively low temperature and from a high grade of ore, wherefore its purity as a crude metal. Such impurities as the ore may contain are largely concentrated in the gray slag, and in the subsequent smelting of that product in the blast furnace, necessarily at a higher temperature, a much less pure metal, is obtained

In smelting the same kind of galena in the blast furnace a lower grade of metal than from the Scotch hearth or reverberatory is inevitably obtained because of the higher temperature of the furnace, but its character will be largely dependent upon the nature and amount of the impurities originally present in the ore. A refining is generally necessary, but this may often be only a poling, or steaming of the crude metal in a kettle. In either case, the impurities are oxidized by the decomposition of aqueous vapor, and the oxides rising to the surface of the lead bath as a dross are removed by skimming. At Mine la Motte the crude lead was in 1893 refined in a 6 ft. hemispherical kettle, holding about 18 tons, into which a jet of steam was introduced near the bottom. At Herculaneum the crude lead was melted in a reverberatory furnace and poled with green wood.[1] There has been no general change from this practice, except at Herculaneum.

At Herculaneum, in 1901, the crude lead from the blast furnaces contained about 0.2% copper. The pigs were charged into a liquating furnace, having a cast iron, sloping hearth, with holes in the center. Beneath the hearth there was a cast-iron trough conducting the eliquated lead to a 30-ton kettle. In the kettle it was treated with steam for 1½ to 2 hours. The drosses are resmelted in the blast furnace. The refining process reduces the copper content of the lead to 0.02%, and is comparatively inexpensive, the labor of only nine men being required in the treatment of 56 tons of crude metal in 12 hours.

This refining process does not entirely effect the elimination of copper, which is necessary in preparing lead for corroding purposes. In desilverizing lead with zinc, however, any copper that may remain in the lead will alloy with the zinc and its removal can be thus effected. For this purpose, Missouri lead has been refined to some extent at St. Louis by the Parkes process, the small quantity of silver won and the increased value of the lead as a corroding grade about paying the higher cost of refining by this method. This practice was inaugurated about 1900. During the last two or three years a largely increased amount of lead has been thus refined, especially at Collinsville, Ill.

Marketing

Lead is marketed in three principal forms: (*a*) desilverized; (*b*) soft; (*c*) antimonial, or hard. The terms to distinguish between classes *a* and *b* are inexact, because, of course, desilverized lead is soft lead.

[1] Report of Missouri Geological Survey, VII, ii, pp. 492–493.

Desilverized lead itself is classified as "corroding," which is the highest grade, and ordinary "desilverized." Soft lead, referring to the Missouri product, may be either "ordinary" or "chemical hard." The latter is such lead as contains a small percentage of copper and antimony as impurities, which, without making it really hard, increase its resistance against the action of acids, and therefore render it especially suitable for the production of sheet to be used in sulphuric-acid chamber construction and like purposes. The production of chemical hard lead is a fortuitous matter, depending on the presence of the influencing impurities in the virgin ores. If present, these impurities go into the lead, and cannot be completely removed by the simple process of refining which is practised. Nobody knows just what proportions of copper and antimony are required to impart the desired property, and consequently no specifications are made. Some chemical engineers call for a particular brand, but this is really only a whim, since the same brand will not be uniformly the same; practically one brand is as good as another. Corroding lead is the very pure metal, which is suitable for white lead manufacture. It may be made either from desilverized or from the ordinary Missouri product; or the latter, if especially pure, may be classed as corroding without further refining. The difference between "desilverized" and "corroding" lead made from argentiferous work-lead is merely that in preparing the latter the metal is drossed a second time in the refining furnace, wherein the zinc is burned off. The lead refined by the Betts electrolytic process is of excellent corroding grade. Antimonial lead is really an alloy of lead with about 15 to 30% antimony, which is produced as a by-product by the desilverizers of base bullion. The antimony content is variable, it being possible for the smelter to run the percentage up to 60. Formerly it was the general custom to make antimonial lead with a content of 10 to 12% Sb; later, with 18 to 20%; while now, 25 to 30% Sb is best suited to the market.

The relative values of the various grades of lead fluctuate considerably, according to the market-place, and the demand and supply. The schedules of the American Smelting and Refining Co. make a regular differential of 10 c. per 100 lb. between corroding lead and desilverized lead in all markets. In the St. Louis market, desilverized lead used to command a premium of 5 c. to 10 c. per 100 lb. over ordinary Missouri; but often they sell on approximately equal terms. Chemical hard lead sells sometimes at a higher price, sometimes at a lower price, than ordinary Missouri lead, according to the demand and supply. There is no regular differential.

The case of antimonial lead is peculiar. Until within a few years it sold at a discount from the price of desilverized lead, being regarded as an undesirable but unavoidable by-product, which was useful only for inferior purposes, such as yacht ballast, coffin linings, etc. Although antimony and lead are the essential constituents of several important alloys, the antimonial lead of the desilverizing refiners was too irregular in composition to be in great demand among the manufacturers of alloys, who preferred to mix antimony and lead directly to obtain the desired composition.

In 1874 antimonial lead sold at a discount of $\frac{3}{8}$ to $\frac{1}{2}$ c. per lb. below the price of desilverized.[1] In 1896 it sold at a discount of about $\frac{1}{8}$ c. per lb., but appears at some time previous to have been at a premium, since it is stated in The Mineral Industry, vol. V, p. 384, that "formerly when it commanded a premium over soft lead it was designed to contain only 10 to 12% antimony, but now it is at a discount of about $\frac{1}{8}$ c. per lb. from the price of ordinary lead, and it is therefore an object to produce as little lead in this form as possible. Consequently, the greater part of the hard lead made at present is run up to from 18 to 20% antimony, and certain smelters make it as high as 35 or 40%. The antimonial lead contains generally about 6 oz. silver per ton, and sometimes as much as 10 oz., which it does not pay to separate." In 1902 antimonial lead containing 25 to 30% antimony was best suited to the market. By 1905 this grade of metal had come to command a premium of 1 to $1\frac{1}{2}$ c. per lb., this being due chiefly to the shortage in the supply of metallic antimony (the price of which, ordinary brands, rose from 8 c. per lb. at the beginning of the year to nearly 13 c. per lb. in the summer), and the supply of antimonial lead was eagerly sought by the manufacturers of alloys. By 1907 antimonial lead had come to sell as a lead-antimony alloy, fetching nearly the full antimony value for its content of that metal, the market price for the alloy being only $\frac{1}{4}$ to $\frac{1}{2}$ c. per lb. below the computed price of its constituents. Thus, with lead at 6 c. per lb. and antimony at 25 c., the value of antimonial lead containing 20% antimony would be $9.8-0.5=9.3$ c. per lb.

The total production of lead from ores mined in the United States in 1901 was 279,922 short tons, of which 211,368 tons were desilverized, 57,898 soft (meaning lead from Missouri and adjacent States) and 10,656 antimonial. These are the statistics of The Mineral Industry. The United States Geological Survey reported substantially the same quantities. In 1902 the production was 199,615 tons of desilverized, 70,424 tons of soft, and 10,485 tons of antimonial, a total of 280,524 tons. There is an annual production of 4000 to 5000 tons of white lead direct from ore at Joplin, Mo., which increases the total lead production of the United States by, say, 3500 tons per annum. The production of lead reported as "soft" does not represent the full output of Missouri and adjacent

[1] J. Y. Bergen, Jr., Mineral Resources West of the Rocky Mountains, 1874, pp. 424–430.

States, because a good deal of their ore, itself non-argentiferous, except to the extent of about 1 oz. per ton, in certain districts, is smelted with silver-bearing ores, going thus into an argentiferous lead; while in one case, at least, the almost non-argentiferous lead, obtained by smelting the ore unmixed, is desilverized for the sake of the extra refining.

Uses

By far the most important use for lead is in the manufacture of white lead. Among its other uses, the manufacture of sheet pipe, shot, and alloys, together with litharge, red lead, and orange mineral, are the most important.

The principal use of white lead is as a pigment. In this use it has to meet the competition of zinc oxide and barytes. The three pigments are now to a large extent employed in mixture.

Lead pipe is chiefly employed for the water supply in dwelling-houses. It is also used extensively in chemical works.

The use of lead for bullets and shot does not require especial mention. It was one of the earliest, if not the earliest, use for the metal in this country. The manufacture of shot was begun near St. Louis in 1809, and also was one of the earliest manufacturing industries in the Wisconsin lead region.

Sheet lead is used chiefly for linings to withstand acids, or acid vapors, as for example, in the construction of sulphuric-acid chambers and towers, the barrels for the extraction of gold from ore by chlorination, the lining of vats, etc. It was formerly employed extensively for roofing, but in that use has been displaced largely by other substances, as it has been displaced also in the glazing of windows. A comparatively recent and highly important use has been for covering electric cables. This has accounted for a large part of the increase in consumption in late years.

Among the lead alloys, type metal, babbitt metal, solder, organ pipe composition, and the fusible alloys used in electric lighting, fire-protection sprinklers, etc., are the most important. Litharge is used as a flux in assaying, as an ingredient in the compounding of rubber, and in the manufacture of glass. Red lead is used as a pigment, very extensively for that purpose in the protection of structural steel; as a pipe-joint cement; and in the manufacture of glass.

V

EASTERN AND SOUTHERN STATES

Lead ore occurs in many of the Eastern and Southern States, and in some of them it was mined at an early date. The existence of the mineral in New England was doubtless known within 30 years after the arrival of the Pilgrims at Plymouth. As early as 1651, Governor John Winthrop received his famous license to work any mines of "lead, copper, or tin," and "to enjoy forever said mines, with the lands, woods, timber and water within two or three miles of said mines." As he received also a special grant of mines and minerals in the neighborhood of Middletown, Conn., it is not unlikely that the old Middletown silver-lead mine, the date of the discovery of which is not precisely known, was opened by him or his successors.[1] This is the first extant record of lead mining in the United States. However, the Jesuits are supposed to have begun mining in Pima County, Ariz., in 1650, and there was some early work done by the French in the Wisconsin region.

In Colonial times some of the lead mines of the Atlantic coast were worked to obtain lead for local consumption. Especially during the Revolutionary War they supplied considerable lead for bullets. But the requirement for lead in the early history of the United States was not large, and the production of the mines of the Eastern and Southern States, with the exception of those of New York and Virginia, has been insignificant. In most cases no statistics of production appear to have been collected; at least they have not been preserved.[2] In the present chapter the attempts at lead mining in the Eastern States will be sketched briefly in chronological order, except for New York and Virginia, which contain the only mining districts worthy of separate treatment.

As previously stated, the earliest mining appears to have been done at Middletown, Conn., where there was a small vein of lead-bearing quartz,

[1] Abram S. Hewitt, Trans. Am. Inst. Min. Eng.

[2] Failure to find records of early mining, chiefly because they do not exist, is to be explained by the non-appreciation of their possible future importance, or interest. It is one of the drawbacks of present mining operations in many places that no records of comparatively recent work are available. For example, in the reopening of the Comstock lode in 1905 and 1906, how valuable would have been the maps and assay charts of only 20 years previous, before the mines were allowed to fill with water up to the Sutro Tunnel level.

traversing mica slate. There are no records of its early history or production. At Northeast, Dutchess County, N. Y., lead ore was found and worked as early as 1740, small quantities being shipped abroad. Attempts to obtain lead here were also made during the Revolutionary War, but the quantity available was too small to admit of profitable development.[1] The Wythe mines in Virginia were discovered in 1750. These are referred to more fully further on. In 1765 work was begun at Southampton, Mass., where there was a quartz vein of considerable width, but lean and irregular mineralization, in mica slate and granite. Operations were suspended by the Revolutionary War and were not resumed until 1809.

In 1778 a mine near Birmingham, Blair County, Penn., was worked on a small scale, smelting works being erected. It was again operated about 1795. After a long idleness the mine was reopened in 1864, and was worked until 1870, but for zinc ore rather than lead ore, the two ores occurring together.

This is the scanty record of lead mining in the East previous to the nineteenth century. No doubt, all over the country occupied by the American forces, there were small and desultory surface operations, furnishing lead for the use of the Army.[2] In the early part of the nineteenth century little or nothing appears to have been done, but a little after 1820 several mines were discovered and worked.

A mine at Ellenville, N. Y., was opened in 1820, but not with much success. In 1826 the Eaton mine, near Madison, Carroll County, N. H., was developed. In this vicinity there were many veins, containing galena and blende, but their mineralization was too small and too irregular to permit them to be worked profitably. Small veins of lead ore, occurring at the contact between trap rock and limestone, were discovered at Lubec, Maine, in 1832, but in spite of a good deal of work expended on them their production failed to amount to much. In 1835 the mines at Rossie, N. Y., were first worked, and in 1837 a vein of lead ore at Redbridge, N. Y., was opened. Somewhat extensive developments were made in 1846 and 1847 near Shelburne, Coos County, N. H., where there is a quartz vein, mineralized with blende, galena, and pyrite, in gneiss. In 1850 a group of mines, chief of which was the Whately, was opened on Pickering Creek, a few miles south of Phenixville, Chester County, Penn. A smelting furnace was erected in 1851, and some extensive developments were made in the mines. The latter are of considerable geological interest, but their production has been inconsequential. They were worked only a few years.

The second half of the nineteenth century was marked by a resump-

[1] Winslow, Lead and Zinc, I, 120; Report of Missouri Geological Survey, vol. VI.
[2] Abram S. Hewitt, Trans. Am. Inst. Min. Eng.

tion of mining, in 1852, at Rossie, N. Y., and in 1853 at Ancram, Columbia County, N. Y. In 1858 a rather important vein of lead ore was discovered at Guymard, N. Y. Work also was resumed in 1855 at the Washington mine, known later as the Silver Hill mine, in Davidson County, N. C., which was subsequently developed on a considerable scale. This deposit was discovered in 1836, and was worked almost uninterruptedly until 1852. The ore, which is a mixture of the sulphides of zinc, lead, copper, and iron, in a talcose gangue — and is argentiferous — occurs in a series of veins parallel to the stratification of the country rock (argillaceous schists). The two principal veins are about 30 ft. apart at the surface, but unite at a depth of 60 ft., and then separate again and remain about the same distance apart. The veins vary in thickness, sometimes being wide and at other times very narrow, but the ore is much mixed with horses of schist. The mine has been opened to a depth of 650 ft.

About five miles north of the Washington mine is the Silver Valley, which was discovered in 1880. This has a vein of 5 to 12 ft. in width, similar in character to the Washington.

The mines of Davidson County, North Carolina, were worked in a more or less desultory way during 1871–1880 and the early eighties. In 1887 a smelting works for the reduction of their ores was erected at Thomasville. The operation of these works, however, proved to be of very fitful character, the reason being that the ores of the district were zinc ores rather than lead ores. Their complex character caused them to be difficult to smelt, and a variety of processes, pyrometallurgical and hydrometallurgical, were tried at the works, the owners of which were not discouraged by repeated failures. Eventually, however, they gave up, and since the early nineties there has been little or no mining in this district.

In the Civil War time a little mining for lead was done at Lead Mine Bend in eastern Tennessee. Recently the same mine was reopened for the zinc ore which occurred in connection with the lead, but the exploitation has not yet proved to be of any consequence. Small lead mines have been worked at various other places in Tennessee, but although the prospects have been thought promising the developments have uniformly been unsatisfactory.

The most spectacular event in lead mining in the Eastern States was the discovery of the Merrimac mine, a vein of argentiferous galena, which was really rich both in lead and silver. This mine, which was near Newburyport, Mass., was discovered early in 1874. There were several parallel crevices. A shaft sunk on one of these disclosed a width of 3 ft. of ore at a depth of 10 ft., and a width of 6 ft. at 22 ft. The shaft was well equipped with machinery and in September, 1875, was producing regularly about seven tons of ore per day. The richness of the ore and the success of the operations inspired a considerable mining excitement in this portion of Essex County, and many pits were sunk in search for mineral. However, the excitement was short-lived, inasmuch as the Merrimac vein soon petered out. At about 60 ft. the lower limit of the rich ore was reached, it giving place to a quartz vein-filling dotted with a little galena. This was followed downward to a depth of 225 ft., when the courage of the owners gave out. This was the end of lead mining in Massachusetts.

With the exception of a few mines in New York and Virginia, which have made an output sufficiently large to be recorded statistically, the numerous lead mines in the Eastern States, worked in a desultory way at one time or another, are not to be regarded seriously. There have been, and are now, mineralized veins, which have been found to contain little pockets of ore, and have held out bright hopes to the discoverers, but after being worked a little and yielding perhaps a car-load of ore, they have been found to be unprofitable, and have been abandoned. I believe that at the present time even the smelters in the vicinity of New York receive an occasional car-load. Within the last ten years I have myself had occasion to examine a lead mine in Maine and shipped from it 15 tons or so of ore of fair grade. But as for there being a regular lead-mining industry there is no such thing and never has been.

Virginia

However, in Virginia there is, and has been for many years, an interesting little lead-mining industry, centered about the Wythe mines at Austinville, Wythe County, in the southwestern part of the State. It is unknown who was the original discoverer of lead ore at this place, but the mines appear to have been operated first by Colonel Chiswell, a native of Wales, who began in 1750 and continued work until shortly after the beginning of the Revolutionary War. The mineral (galena) was found at Austinville disseminated in decayed limestone which outcropped at the surface. Chiswell's operations consisted almost wholly of open work. However, he made an attempt to reach the "vein" at some depth by driving an adit level into the hill from the edge of the river under a high cliff below the mouth of Bald Hill Spring branch. This adit was driven a distance of about 20 ft. and then was abandoned. It is still pointed out as Chiswell's hole.[1]

The ores mined by Colonel Chiswell had to be dressed, which was done by washing at the Bald Hill Spring branch, near where they were mined. They were smelted at a plant on the hill southeast of the Long Hole shaft. The remains of the smeltery indicate that it was a common air furnace,

[1] Thos. L. Watson, Lead and Zinc Deposits of Virginia, p. 68.

the hearth and roof having been built of fire-brick, which probably came from England.[1] Among the remains was found the bottom of a small cupel furnace, indicating that an attempt had been made to extract silver from the lead, which possibly was the basis of the tradition prevalent in the vicinity that Chiswell had produced silver.

Chiswell is reported to have been a Tory and to have died in jail at Cumberland Courthouse, Virginia, about 1776, which doubtless brought the operation of his mines to a close. His property reverted to the State of Virginia. It is said to have been worked during the Revolutionary War, but of that there do not appear to be any definite records. At some time between 1780 and 1800 it was sold to Stephen and Moses Austin, who continued mining and smelting.[2] The date of the transfer to Austin must have been considerably earlier than 1800, or at least his operation of the mines, because he is known to have visited Missouri in 1797, and was at that time an expert miner and smelter of lead ore, so much so, indeed, that he established himself in Missouri in 1799 and introduced his own method of smelting, which was far advanced over that practised by the French. This implies a considerable previous experience in the business. Austin's furnace was a crude reverberatory, or "air furnace," and doubtless was based on the form originally introduced by Chiswell.

In 1836 Rogers describes the Wythe mines as being worked for lead ore, the zinc ore associated with it being rejected.[3] The product was hauled to Baltimore in wagons. In 1838 the Wythe Lead Mines Co. acquired the property and worked it until 1848, producing 3256 tons of pig lead. During this period Scotch hearths were installed for smelting. The manufacture of shot was begun in 1843. A little later furnaces were erected for smelting the accumulations of old slag, partly from the Scotch hearths, and partly no doubt from the older type of furnace. In 1848 the mines were taken over by the Wythe Union Lead Mining Co., which worked them until 1858, producing 3807 tons of pig lead, while outside mines produced 1300 tons more. The manufacture of shot was continued.

In 1858 there was another reorganization, the new concern being incorporated in 1860 as the Union Lead Mining Co. The production from February, 1858, to May, 1861, was 1288 tons; from May, 1861, to February, 1862, 616 tons; from February, 1862, to February, 1863, 421 tons; from February, 1863, to April, 1864, 312 tons; from April, 1864, to December, 1864, 293 tons. During the Civil War these mines were the principal source of supply of lead for bullets for the Confederate

[1] Watson, *op. cit.*, 69. [2] Watson, *op. cit.*, 69.

[3] A Reprint of Annual Reports and other Papers on the Geology of the Virginias. By William Barton Rogers, N. Y., 1884, p. 139.

government. On Dec. 17, 1864, the works were burned by Federal troops. Immediately after the war the works were rebuilt (in 1865) and operations were resumed on about the same scale as previously and continued to the present time. O. J. Heinrichs estimated that from 1838 to 1879 the Wythe mines had produced 12,167 tons of pig lead.[1]

The Union Lead Mining Co. was succeeded by the Wythe Lead and Zinc Co. In August, 1902, the latter company sold the property to the Bertha Mineral Co., which now operates it. These mines in their eventful history have been not only producers of lead ore, but also of considerable quantities of zinc ore.

There have been other lead mines operated in Virginia, but none of anything like the importance of the Wythe, and it is unnecessary to make special mention of them.

New York

Lead ore has been mined at several places in the State of New York. The operations near Northeast, in Dutchess County, have been previously referred to in this chapter. In Columbia County, the Ancram or Livingston mines were worked in the early part of the nineteenth century, and again about 1853. The vein was very narrow and never proved remunerative, although it was extensively prospected. There are two districts in New York, however, which have been the scenes of real mining. These may be called the Shawangunk and the Rossie districts. The former comprises the mines at Ellenville, Wurtzboro, and Guymard, which, although in different counties, are rather near together, in the southeastern part of the State, and are of similar character. Unfortunately, complete statistics of the output of these mines are unavailable.

In the western corner of St. Lawrence County, in the northern part of the State, a group of veins occurs in Archean gneiss, near Rossie. They were discovered in 1835 and were worked at intervals during the next 25 years. The principal vein was the Coal Hill, which had an average width of 2 ft., but in some places was 4 ft. wide. In position it was nearly vertical. The gangue was principally calcite, in which there were seams of galena, irregularly distributed. In 1837 it had been exposed for a length of 450 ft. Operations were conducted vigorously in the Coal Hill vein in 1837 to 1839, and again in 1852. During the first period about 1800 tons of lead were smelted in a furnace about a mile distant from the mine. The Victoria Lead Co. operated a similar, parallel vein in 1836 and 1837, producing 524 tons of lead. This vein also was reopened in 1852.[2] At that time the Great Northern Lead Co. leased the chief

[1] Trans. Am. Inst. Min. Eng., VIII, 344.

[2] Winslow, Lead and Zinc Deposits, vol. I, p. 120. Report of Missouri Geological Survey, vol. VI.

mines at Rossie, put in new machinery and planned work on a large scale, but success does not appear to have followed this venture. During the Civil War the mines were worked by the Mineral Point Lead Mining Co., which also had mines on the south shore of Black Lake. At that time the high price for lead had started up at least two other mines in the region, one near the village of Macomb and the other in the town of Gouverneur, near Beaver Creek.[1] Since 1865 nothing has been done in this district.

The mines of the southeastern part of New York are situated in the Shawangunk and adjacent mountains, which are spurs of the Catskills. At several places in this region there are fissure veins of similar character. They are nearly vertical, in hard sandstone or grit, and are from two to five feet in width, the ore being galena, with which are associated blende and pyrite (occasionally chalcopyrite also). As mined, the ore is low grade, concentration being necessary as a preliminary to smelting. There is a difference of opinion as to whether these are "gash veins" or profound fissures.

At Ellenville, Ulster County, a mine was worked first in 1820, and later again, but with little success. Several veins in this vicinity were worked about 1854, and two Scotch hearths were erected for smelting the ore. Near Redbridge, in the same county, a similar vein was worked in 1837.

At Guymard, near Port Jervis, in Orange County, a vein of lead ore, said to have been rich, was found about 1858. Mining was still being done there in 1868, and a large quantity of lead had been taken out.[2] According to Dr. Cook, this discovery caused a good deal of excitement in the neighborhood, and led to an extensive search for similar veins, which proved, however, to be profitless, although small occurrences of ore were found at various places.

The Guymard mine was operated by the Erie Lead Co. It was opened extensively, there having been several shafts sunk on the vein, one of them to a depth of 400 ft., while two adit levels were driven. The location of the mine was almost ideal, the vein being crossed by the tracks of the Erie railway. The buildings and other works still remaining, together with the magnitude of the waste dumps, are evidences that operations were conducted on a considerable scale. The vein did indeed possess considerable longitudinal extent. The ore was dressed at the mine, and the concentrate was partly smelted there, partly shipped to Newark, where the Balbach smeltery had been established a few years previously.

[1] C. H. Smyth, Jr., *School of Mines Quarterly*, July, 1903, pp. 428–429.

[2] George H. Cook, Geology of New Jersey, p. 147 (published in 1868).

VI

MISSOURI

LEAD ore was discovered in Missouri in 1700, and serious attempts at mining were made as early as 1720. For a century thereafter the chief production of lead in the territory that now comprises the United States was derived from Missouri; more precisely from southeastern Missouri. The existence of lead in southwestern Missouri did not become well known until about 1850; at least no extensive prospecting was done before that date; and save for a brief period of activity in the vicinity of Granby from 1855 to 1860, the production of the district did not begin to increase largely until after 1870. Mines have also been worked in the central portion of Missouri, but they are not now, and never have been, important.

The history of lead mining in Missouri has already been ably related by Arthur Winslow in his Report on Lead and Zinc, for the Missouri Geological Survey, and in the following pages I shall make free use of the records collected by him.

The first discovery of lead in Missouri was by Penicaut, one of Le Sueur's party, which ascended the Mississippi in 1700. He refers to a mine reached by the Meramec River, about 50 leagues west of the Mississippi, and west of Ste. Genevieve, whence the Indians got lead. It is to be inferred from this vague description that the locality may have been somewhere in Crawford County. The existence of lead in Missouri evidently attracted attention in France, since Louis XIV in 1712 granted the Crozat patent with special privileges as to the discovery and operation of mines in the then territory of Louisiana. Little or nothing was actually done, however, until the transfer, in 1717, of this patent to the Company of the West, known better as the Mississippi Company, promoted by John Law, which immediately prepared for active operations.

About the first effort was made near the Meramec, by Sieur de Lochon, in 1719. He found ore, but his attempts to smelt it were failures. A few other attempts made at about the same time were also unsuccessful. These early adventurers expected to find in Missouri not only lead but also silver. It is known now that none of the lead ore of Missouri contains more than an insignificant proportion of silver.

In 1719, according to Schoolcraft,[1] Philip Francis Renault was

[1] A View of the Lead Mines of Missouri, p. 19 (New York, 1819).

appointed director-general of the mines of the Company of the West, and proceeded to Louisiana with 200 artisans and miners, taking on at St. Domingo 500 slaves for working the mines. With Renault came, according to one account, a mineralogist by name of La Motte. Renault established himself near Kaskaskia in 1720, whence he sent out exploring parties, one of which discovered the deposits near Fredericktown, Madison County, now known as Mine la Motte, which name was acquired by their having been worked to a small extent under M. La Motte. According to another account, M. de la Motte Cadillac arrived in Louisiana in 1713 with commission as governor and conducted in 1715 an expedition for the search of silver mines into the country of the Illinois,[1] returning with fine specimens of lead ore; it is supposed that Mine la Motte was discovered on this expedition. La Motte resigned as governor in 1719, and returned to France. At all events, Mine la Motte was undoubtedly the first lead mine to be seriously exploited in Missouri. Old Mine and Mine Renault, near Potosi, were discovered between 1724 and 1726, and mining was begun at a number of places.

Renault was apparently the prime mover in early mining in Missouri. He had succeeded in building up a flourishing mining and smelting industry, the product being shipped naturally to France via New Orleans, when the failure of Law's company brought about a cession of its charter to the Crown in 1731. Renault, who had received as early as 1723 grants covering the Mine la Motte and other tracts, remained in Missouri until 1742, when he abandoned his work, returned to France and thus terminated the first period of mining in Missouri.

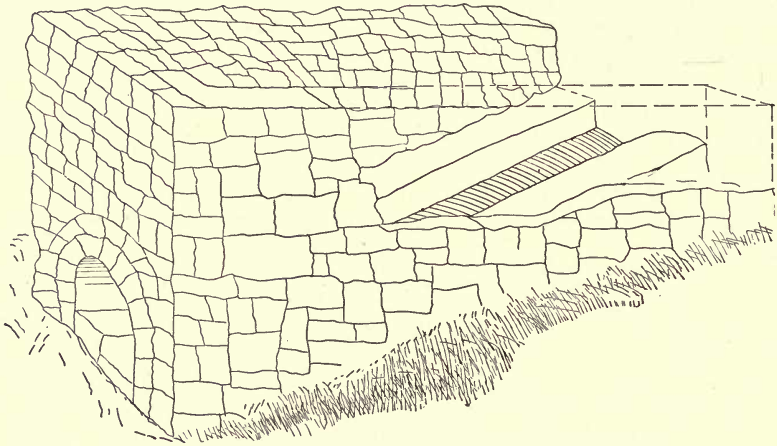
From 1742 to 1762 mining was feebly prosecuted by the French at Mine la Motte, Old Mines, and Mine á Gerbore, all of which had been discovered in Renault's time. In 1763 the Mine á Burton was discovered at Potosi by Francis Burton, and work was begun there at once. Other discoveries were made soon afterward in the same vicinity.

During the next 30 years lead mining was prosecuted on a small scale at various places in Missouri, chiefly those which have been previously mentioned. Shortly after 1795 some new discoveries were made. The Mines á Lanye, about 16 miles south-southeast of Potosi, were uncovered in 1795; the Mine á Maneto, or American mines, on Big River, about 12 miles southeast of Potosi, in 1799; and Mine á La Platte, near the southeastern corner of Washington County, also in 1799.

Up to this time the lead ore mined in Missouri was entirely galena, occurring as deposits in clay, the character of which has been previously described. Similar deposits have been worked in Washington County, in the vicinities of Palmer, Potosi, and elsewhere, within quite recent time, and occasionally are found and dug even at the present. The early open-

[1] William H. Pulsifer, Notes for a History of Lead, pp. 89–91.

ings were very shallow, being seldom over 10 ft. in depth. The ore, cleaned of clay by hand, was smelted either on log heaps or in a rude construction known as the log furnace. According to Schoolcraft[1] this furnace was built against the side of a hill sloping about 45°. Three large oak logs were rolled into the furnace transversely, resting on the ledges at the sides. Small split logs were set up vertically around the inside of the furnace, after which about 5000 lb. of ore in pieces averaging 15 lb. weight were piled up in the furnace, covered with logs, and the fire started. Metallurgically the method of smelting, which was lead smelting in almost the most primitive manner, is to be classed as a roast-



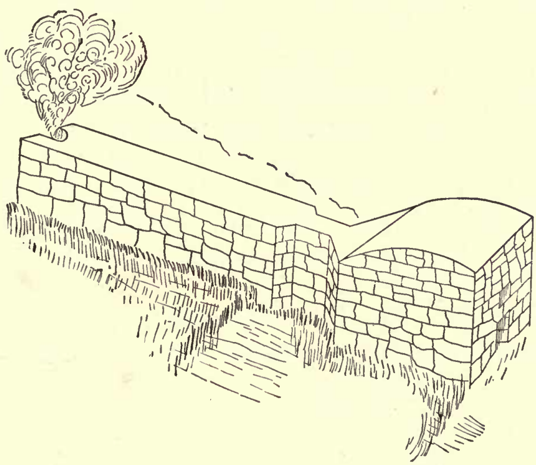
The Log Furnace.

reaction process. The fire was kept low for about 12 hours, during which the roasting took place. A stronger heat was then maintained for 12 hours more, to effect the reaction, during which period lead trickled out into a basin in front of the furnace. Sometimes the reaction period would have to be extended to 24 hours, this depending largely upon the skill of the smelter. As may be imagined, the extraction of lead by this crude process was very imperfect. If we may judge from the ore obtained nowadays from similar deposits, the grade of the mineral early won was likely upward of 80% lead, or 1600 lb. per ton. The yield of lead from a ton of ore smelted in the log furnace was only 700 to 800 lb., or less than 50% of the lead in the ore. By the methods of smelting now in use an extraction of 98% of the lead is attainable.

A noteworthy event in the history of lead mining in Missouri was the arrival, in 1799, of Moses Austin, who had formerly operated the mines at Wytheville, Va., and knew more about mining and smelting than did

[1] *Op. cit.*, p. 93.

the Missourians.[1] He obtained a grant of one league square at Potosi, in consideration of which he was to erect a furnace and other works; this he did in the following year. Austin introduced what was called the "ash" furnace, which was designed to supplement the log furnace. It was impossible to attain a good reaction from ore as coarse as that which was charged into the log furnace, and the loss of lead was largely due to its remaining unreduced in the cinders, or ashes, left in the furnace. Austin crushed these ashes moderately fine and charged them into the ash furnace, which was a rude reverberatory with a sloping hearth, wherein they were heated about two hours, extending the reaction



The Ash Furnace.

left incomplete in the log furnace. In this way an additional extraction of about 15% was effected. The furnace was built of limestone and lasted only 15 to 20 days of continuous work, but in view of its low first cost this was not a serious matter. At the time of Austin's advent there were about 20 log furnaces in operation near Potosi. They could not successfully compete with a smelter who could extract 15% more metal from the same ore, and in 1802 only one of the old furnaces was running. Austin also erected a shot tower in 1799, and a plant for the manufacture

[1] The following biographical sketch of Moses Austin has been kindly communicated to me by Mrs. Edward W. Parker, of Washington, D. C., one of his descendants:

Stephen Austin was born in November, 1747, and his brother Moses in October, 1761, both at Durham, Conn.; their father, Elias, having moved there from his birthplace, Suffield, of which place his grandfather, Anthony, was one of the original settlers. Anthony Austin came to America with his father, Richard, when a boy of thirteen, landing at Charlestown, Mass., in May, 1638.

Stephen Austin became an importer of English cloths in Philadelphia, and was of sheet lead, from which the arsenals of New Orleans and Havana were supplied.[1] To Austin, moreover, is due the credit of having inaugurated mining in the rock of the district, he having sunk a shaft to the depth of 80 ft. Previous to that all the mining had been done by open pits.

We are fortunate in having a report by Moses Austin himself, made in 1804, which is an excellent exposition of the condition of lead mining in Missouri during the five years immediately preceding the purchase from France. This report was entitled "A Summary Description of the Lead Mines in Upper Louisiana," and was prepared at the request of Capt. Amos Stoddard, first civil commandant of Upper Louisiana. Moses Austin evidently visited Missouri for the first time in 1797; at all events he states that it was in that year that he first knew the Mine á Burton. In 1798 he obtained a concession of "one league in superfice, comprehending about one-third part of the mine (on condition he should erect a smelting furnace, and establish a lead manufacture)." In June, 1799, Austin removed his family to the mine.

The mines known in Missouri in 1804, according to Austin, were Mine á Burton, Mine á Robuna, Old Mines, Mine Ranault, Mine á Maneto, Mine á la Plate, Mine á Joe, Mine á Lanye, Mine á la Mott, and Mine á Gerbore. Not all of these mines were being worked. The most productive was the Mine á Burton, after which the Mine á la Mott and Old Mines ranked in the order of mention. The produce of all the other mines together was insignificant.

Austin's description of the occurrence of the mineral was substantially

joined there in 1783 by Moses, who the next year established a branch house in Richmond, Va., under the firm name of Moses Austin & Co.

In Richmond he heard of the abandoned lead mines of Chiswell in Wythe County, and induced his brother, Stephen, to purchase them with him. Stephen Austin remained in Philadelphia and Moses worked the mines. He was there in the summer of 1789, perhaps earlier.

The failure of the Philadelphia house in 1796 or 1797 broke up Moses Austin's mining operations in Virginia and the properties there were sold. He had heard by chance, in 1796, of rich lead deposits in the French territory below St. Louis, and in 1797 set out to learn the truth of the reports. Being satisfied with the showing, he secured a grant of three miles square, returned to Virginia, and removed from there permanently with his family in 1799.

For twenty-one years he labored and built up a large fortune, which was lost in the failure of the Bank of St. Louis, of which he was a large stockholder. Again he saw his works and home sold, and, then a man of fifty-eight, thought of a new way to build up his fallen fortunes. He had heard of Texas from Zebulon Pike, and in 1819 struck out alone to cross another wilderness to the outpost of Spanish government in the southwest, San Antonio de Bexar. He returned after months, with a large land grant and permission to settle three hundred American families in Texas, but died June, 1820, as the result of the journey, before the setting out of his colonists. His plans were carried out by his son, Stephen F. Austin.

[1] Winslow, *op. cit.*, p. 271.

as we know it to be from recent observations of similar deposits mined at the present time. Also the method of mining the superficial deposits then was identical with that of the present time. Austin described two qualities of mineral, viz., gravel and fossil mineral. The gravel mineral was found immediately under the soil in pieces of 1 lb. to 50 lb. weight. After passing through the gravel, which is commonly from 3 to 4 ft., is found a sand rock, continuing 5 or 6 ft. more, and containing mineral nearly of the same quality as the gravel. Under the sand rock mineral of the first quality was found in a bed of red clay in pieces of 10 to 500 lb. weight. This last mineral produced 60% of its weight in lead when smelted in a common furnace, and 15% more when smelted again in a slag furnace. The gravel mineral would not produce more than 60% lead when cleanly smelted.

When Austin first knew the Mine á Burton, in 1797, the French smelted their mineral in stone furnaces, somewhat similar to lime-kilns. "At the bottom they put a floor of the largest logs to be found, setting smaller ones round the sides of the furnace. In a furnace thus arranged, is put from three to five thousand pounds' weight of mineral; and a fire, being lighted under the bottom of the furnace, is kept up until the mineral is entirely smelted, burnt or lost in the ashes. In this way, each miner smelted his own mineral, extracting about 350 lb. of lead from each 1000 lb. weight of mineral." In 1798 there were 20 French furnaces at Mine á Burton, but in 1802 only one was in use, the miners having found it more advantageous to sell their ore to Austin than to smelt it themselves.

The time for working the mines was from August to December. "After harvest the inhabitants of St. Genevieve and N. Burbon resort to the mines; the rich send their negroes, and the poor class depend on the mines to furnish them with lead to purchase all imported articles. From the middle of August to the fifteenth or twentieth of December there are from 40 to 50 men employed in digging mineral: the remainder of the year but little mineral is drawn from the mines, and but few hands employed. From 1798 to 1803 the average quantity of mineral may be stated at 550,000 to 600,000 lb., French weight, each year, procured in four months by not more than 50 men. The same number of hands employed the year round would produce at least fifteen to sixteen hundred thousand pounds, making proper allowance for spring rains."

Austin gives some additional information as to the methods of smelting. At the Mine á Maneto comparatively low grade ore was mined, the mineral occurring in thin flakes in a layer of soft gray limestone. The ore was pounded and washed, 1000 lb. yielding 300 to 400 lb. of mineral. This is interesting as an early example of ore-dressing practice. The process yielded but little profit to the operators, but Austin was of the opinion that experienced workmen could obtain a handsome profit. At the Mine á la Mott[1] the mineral was found in "regular veins, from two to four feet solid," found within four or five feet of the surface, "with a declination of 45°." Five of these veins had been opened and wrought. They could not be mined deeper than 25 ft., and to that depth only in the dry season. "Notwithstanding the French inhabitants of this country have followed the mining business upward of 80 years," said Austin, "yet they have not advanced in the art of smelting a step beyond their ancestors. The methods they pursue bespeak their surprising ignorance. As the Mine á la Mott differs from those already described, so does their mode of smelting. The first process is by depositing the mineral in a pile of logs, after the manner sea shells are burnt to lime; the piles being set on fire and consumed, the quantity of lead produced is 5%. It is then put into a furnace of stone, such as before described; from this process, if well attended, is produced 15% more. After this second burning, they consider the mineral in a proper state for smelting. Therefore, collecting it from the ashes, they again put it into the furnace, arranged with logs at bottom and sides, and make an end of smelting. From the last process they commonly obtain about 15%, making 35% the greatest quantity obtained.

"At the Mine á la Mott is also found, in beds, what the miners call gravel mineral. . . . This mineral, after an imperfect washing, is put into a furnace, where it is suffered to melt into a slag, no attempt being made to create a fluxility of the metal from the dross. It is then put into a furnace, not unlike a miller's hopper, with a grate at bottom; underneath a fire is lighted, and continued until the slags are all melted, and a partial fluxion effected. This mode of smelting produces about 250 lb. of lead to 1000 lb. of mineral. Notwithstanding the immense loss in smelting, the richness of the mines and the small expense in obtaining the mineral leaves an astonishing profit to the proprietors."

Austin estimated the average annual production of all the mines for the years 1801–1803 as follows: Mine á Burton, 550,000 lb. mineral, estimated to produce 366,667 lb. of lead, worth (at $5 per cwt.) $18,333; Old Mines, 200,000 lb. of mineral = 133,333 lb. of lead, worth $6,666.67; Mine á la Mott, 200,000 lb. lead, worth $10,000; all other mines, 30,000 lb. lead, worth $1500; total, $36,500. To this was added $3600 as the increased value of 120,000 lb. of lead manufactured into shot and sheet at Mine á Burton. The number of men engaged in the industry was about 150, of whom 120 worked about four months and the remainder the year round. Each man averaged $43 per month.

Austin was extremely optimistic as to the future of lead mining in this territory. He considered the time to be not far distant when it would

[1] Austin uniformly refers to the Mine la Motte in this way. Also he spells the name "Renault," "Ranault."

furnish lead sufficient "not only for the consumption of the United States, but all Europe, if moderate encouragement is given by government, and protection against the Osage Indians, who yearly plunder the inhabitants." However, as we know, the statistics for the next 20 years fell far short of bearing out this forecast.

Some of Austin's observations as to general conditions are of much historical value. The Spanish government had allowed the inhabitants to work on public lands free from any kind of tax. Austin recommended the payment of a small tax to the Government. He noted that surveys of all the lands worthy of notice had lately been made (Austin's report was dated Feb. 13, 1804), by order of the governor of St. Louis, with an intention to include every spot of land supposed to contain mineral, these surveys amounting to thirty or forty thousand acres. The Mine la Motte at this time was claimed as private property, as were also others of the early discoveries.

Americans began to move into Missouri about the end of the eighteenth century; after the purchase of the Louisiana territory, in 1803, the influx of the Americans became very large. This, together with the improvements in mining and smelting, led to an important development in the lead-mining industry, with the result that the output of pig lead during the first two decades of the nineteenth century is estimated to have averaged 1100 tons per annum. Of this, about 250 tons per annum were derived from the Mine á Burton, and approximately 250 tons from the Mine la Motte. Mills estimates that the latter produced 4000 tons from 1804 to 1819.[1] Just previous to 1804, however, the output was only about 100 tons per annum, a great falling off from what was done earlier, attributable to the fact that the mine was then claimed as private property and the residents were not allowed to mine ores thereon, whereas formerly it had been considered public property. At the Mine á Burton, which attained its maximum production between 1804 and 1808, about 200 men were employed. Among the new discoveries during this period were the Mine á Joe, later called the Bogy mine, near Desloge, St. François County, in 1801; the Mine á Martin, 4.5 miles east of Potosi, Washington County, in 1803; New Diggings, near Potosi, in 1806; the Hazel Run mines, about five miles northeast of Bonne Terre, St. François County, in 1806; the Shibboleth mines, near Cadet, Washington County, in 1811; the Fourche á Courtois mines, at Palmer, Washington County, in 1814; and others of less importance. The mines at Palmer and Cadet have been worked more or less continuously since their discovery, and are still productive. The Shibboleth mine is credited with a production of 2500 tons of ore, equivalent to 1563 tons of metal in its first year. Toward the end of the second decade of the nineteenth century mining in south-

[1] Geological Report on the Mine la Motte Estate, p. 46.

eastern Missouri had attained considerable importance. In 1819 Schoolcraft cited 45 mines worthy of note which were then working or had been worked; there were 27 in operation, giving employment to 1130 men for more or less portions of their time, that number including miners, smelters, smiths, teamsters, etc.

Technically there was little or no improvement. The work was of an intermittent character, being prosecuted chiefly during three or four months of the year when there was nothing to do on the farms. The method of mining continued to be primitive. Most of the ore was won from the superficial deposits in the clay. Few shafts were sunk into the rock, and none deeper than the 80 ft. which Austin sunk. The only tools used in 1811 appear to have been a pick, a wooden shovel, and a sledge-hammer to break the rock, but in 1819 Schoolcraft refers to the drill being used for blasting. In smelting, the log and ash furnaces continued to be used, without improvement, a practice which Schoolcraft condemned strongly and recommended the substitution of blast furnaces. The pig lead was carted to Ste. Genevieve during the early years, but after the establishment of Herculaneum about half of the product was taken there, where in 1818 three shot towers were erected on the river bluffs, the shot being made by letting it fall down the banks. From Ste. Genevieve and Herculaneum pig lead and shot were shipped to New Orleans, Philadelphia, and New York, the output being estimated by Schoolcraft in 1819 at about 1500 tons per annum.

The value of lead at Philadelphia in 1819 was 6 c. per lb.; at New Orleans, 5.5 c. At the mines in Missouri it was 4 c., which price appears to have been the standard basis of settlement during this period. The miner received about 2 c., and was obliged to pay a royalty of $3 to $4 per 1000 lb. of mineral.

The system of mining rights which came into vogue during the first decade of the American possession of the territory was of great importance in determining the subsequent mining practice, and its effects may be observed in Missouri at the present time. Under the Spanish dominion, four acres of land were granted to all discoverers of mineral. Elsewhere on public lands all were allowed to work, free from any tax. After the American purchase, little attention was paid at first to mining rights and naturally difficulties arose, to remedy which, and also to derive an income from the newly acquired territory, Congress in 1807 passed a law reserving all lead lands and authorizing the Governor of the territory to grant three-year leases to discoverers, who were required to pay a certain royalty. The reservations were made from reports of the Land Office surveyors, and because of defective surveys the results were necessarily imperfect. The Recorder of Land Titles at St. Louis made the leases. The royalty was generally one tenth of the ore raised. The periods of the leases varied from one year to two years and the royalties amounted to $3 or $4 per 1000 lb. of ore.[1] This system was ineffective in practice, few miners taking the trouble to procure leases, there being no special agent to oversee them. Rules were gradually established by custom, which were more regarded. According to these, a discoverer was allowed to claim ground within radius of 25 ft. of his discovery, while others were allowed 12 ft. square of the adjacent ground. These tracts could be held until work was abandoned. The practice of leasing small patches of land and disposing of lead ore by the 1000 lb. still prevails both in southeastern and southwestern Missouri.[2]

The same looseness regarding the leasing and supervising the lead lands continued up to 1824, in which year Lieut. Martin Thomas was appointed U. S. Superintendent of Mines for Missouri and the West generally, with authority to report land for reservation, enforce the conditions of leases, and protect the lessees. He appears to have entered energetically upon the discharge of his duties. In 1825 he reported that 34 new leases had been taken out at the regulation 10% royalty. At this time he estimated that the land under reservation, principally about Potosi, amounted to 150,000 acres, of which only 9000 was leased.

Lieutenant Thomas gave some data as to the mining and smelting results of that time (1825). He said[3] that the same old type of log furnace was used in smelting, and characterized the practice as crude and wasteful, consuming large quantities of fuel and yielding on an average only about 1240 lb. of lead to the ton of ore. The smelters paid the miners for 800 lb. of lead to the ton of ore. The cost of smelting was about $4 per ton of ore. With lead worth 4 c. per lb., a ton of ore would therefore bring $32 to the miner, and would afford a profit of about $12 to the smelter. Miners made at times as much as $15 per day, but only about $1 per day on the average. Schoolcraft, on the other hand, estimated $2.25 as a fair average of what a miner could earn throughout the year. The total number of men employed in 1825 was estimated by Thomas as 2000, half of their time being occupied in farming and half in mining and the accessory work. The number of mines had more than doubled since 1816, and was increasing rapidly. However, the Valle mines, about seven miles northeast of Bonne Terre, in St. François County, located in 1824, were the only important discovery during this period. The lead continued to be hauled to Herculaneum and Ste. Genevieve; after 1825 also to Selma. The hauls were long and the roads in bad condition. Lieutenant Thomas urged the construction of a Government road from Potosi to the Mississippi River.

[1] American State Papers, IV, 526,555.

[2] The leasing system introduced by the Federal Government is discussed more fully in the subsequent chapter on Wisconsin.

[3] American State Papers, IV, 557.

About 1825 there began to be a considerable increase in the lead production of Missouri, which appears to have been stimulated by the increase in the value of lead at about that time. The method of working the mines remained essentially the same. The lack of progress in the methods was attributed by Lieutenant Thomas to three principal causes: (1) the absence of capital and skilled labor; (2) the scarcity of labor; and (3) the ease with which ore could be obtained near the surface. In the light of modern knowledge it appears that the real cause was the character of the ore deposits. The small nests of ore in the superficial clay, which are even now found in the vicinities of Cadet, Potosi, and Palmer, are still extracted in substantially the same crude manner as in the early part of the nineteenth century, and it is the only manner in which they could be extracted profitably. Their location is too uncertain to induce systematic prospecting for them. When located, they are too small to make it worth while to install any considerable plant for working them, and they are so easily worked that no considerable plant is required. These conclusions are also substantially true as to the deposits in place in the limestone country-rock, at least down to the water-level. About the only practicable method of working them is through lessees operating in a primitive way, who will realize a profit where a company operating on its own account would fail. Below the water-level a different system must be pursued, means having to be provided to pump out the water and hoist from greater depth than is practicable by windlass or whim, but none of these mines has yet been worked below the water-level, and it remains to be proved whether a profitable modification of the present system will be developed.

In order to possess a thorough understanding of the economic history of lead mining in southeastern Missouri, explaining the wide-spread occurrence of the ores, the ease with which they were located and mined, and the long record of production from certain of the early discoveries, it is necessary to consider the nature of the ore deposits, and the method of exploitation. Inasmuch as the same kind of deposits are newly discovered and worked in a primitive manner at the present time we are able to picture accurately the early conditions. In this connection reference should be made to the description of the ore deposits and the methods of mining in Chapter II.

The smelting methods of 1801–1851 were obviously primitive, yet they were not so inefficient as would appear at first sight. The art of metallurgy is to make the most money out of the ore presented for reduction; not to achieve scientific perfection. The smelting cost of $4 per ton of ore reported by Lieutenant Thomas in 1825 is about as low as is accomplished with similar ores in the best practice in Missouri at the present time; it is lower if amortization and interest on plant be reckoned.

The loss of lead, amounting to approximately 25% of the content of the ore was high, but it was not much higher than would have been suffered in any other system of smelting available at that time; in fact it is not much higher than is suffered with the air furnaces used at Palmer and elsewhere at the present time. There was not then any market for the gray slag, which would have increased the yield of lead. Schoolcraft in 1819 recommended the use of blast furnaces, by which it is indefinite whether he meant Scotch hearth furnaces or shaft furnaces; if the former, their utility at that time would have been doubtful, and if the latter, it would have been still more doubtful.

Lieutenant Thomas defended the system of reserving and leasing lands as generous to the miners, and protecting the resources of the country. Nevertheless, the popular opinion continued to be different and the number of trespassers on the Government land increased. This led Thomas to recommend in September, 1826, that leases for larger tracts than 320 acres be given, which appears to have been the limit up to that time.[1] Up to 1827 only about 135 tons of lead had been collected as royalty during the previous three years. In 1827 attention was diverted from the lead mines of Missouri to those of Wisconsin, and the output of the former ceased to increase. This, together with the obvious failure of the system prescribed by Congress in the Act of 1807 induced Thomas to recommend the sale of the Missouri lands, arguing that they could be sold without danger of being monopolized while attention was concentrated on the rich deposits of the Upper Mississippi Valley. The proposed sale was favorably recommended by a Congressional committee in January, 1828, and it was urged in a memorial of the State legislature in January, 1829, but Congress was slow to act and it was not until 1847 that it was finally decided to offer the lands for sale. The law had then long been a dead-letter, since after 1834, according to Whitney,[2] in consequence of the immense number of illegal entries, the miners and smelters, both in Missouri and Wisconsin, refused to pay any more royalty and the Government was unable to collect. However, this statement was not quite correct, inasmuch as the Government did succeed in collecting some royalty, although it was done at large expense.

With about 1830 the great importance of the Missouri mines, which previously had been substantially the sole source of American lead, disappeared in the rise of the Wisconsin mines, and not until about 1871, when the Joplin district began to be really important and the disseminated deposits of the Southeast began to be exploited, did Missouri regain its early position of prominence in the lead industry.

This is not to say that the production of lead in Missouri fell off, save

[1] American State Papers, IV, 801.

[2] Metallic Wealth of the United States, p. 405.

in comparative importance. On the contrary, it increased rather steadily from 1831 to 1850. Numerous new discoveries were made at various points in the Southeast. Especially noteworthy is the Virginia mine, near St. Clair, Franklin County, which was a new class of deposit, different from what had previously been worked in Missouri. The deposits in the rock at Palmer, Potosi, and elsewhere were networks of small ore channels, lying approximately flat and near the surface. Consequently a large area of ground could be worked out through a series of shallow shafts. The Virginia mine was opened on a fissure vein cutting nearly vertically through the country-rock, and in order to open a large area of the vein it was necessary to sink deep shafts. Such veins are the characteristic of Franklin County. They have not been in the aggregate large producers of lead, although the Virginia mine, which was the most important of them, made a very respectable output, having yielded during its checkered career about 13,000 tons of lead ore, of which about 5000 tons were turned out previous to 1846, and 7500 tons from 1854 to 1873. The above explanation of the difference in character of the Virginia vein will make it clear why a shaft was early sunk on it to a depth of 264 ft. and equipped with a steam hoist, while elsewhere in Missouri there was nothing but shallow pits.

The old log and ash furnaces continued in sole use up to 1836, in which year a Scotch hearth was erected by Major Manning at Webster, Washington County.[1] Other furnaces of the same type were soon afterward erected elsewhere, but they do not seem to have immediately displaced the log and ash furnaces, which not only continued to be operated, but also new ones were built. At Higginbotham's smeltery, near the present Fertile post-office, they were retained for years subsequent to 1850, and they were in use at Mine la Motte in 1850.[2] This would indicate that the Scotch hearth did not give an overwhelming advantage over the older type of furnace. An interesting fact is the remark by J. T. Hodge, writing in 1842, that there were then in use at Mine la Motte nine Scotch hearths, two cupolas, and one reverberatory furnace.[3]

Previous to 1838 all of the lead ore worked in Missouri was galena. The presence of cerussite, lead carbonate, had early been noted, but its value as an ore does not appear to have been recognized until 1838, when new furnaces were erected to smelt it at Mine la Motte, leading to an increase of lead production.[4] However, this ore, commonly called "dry

[1] G. C. Swallow, First and Second Annual Reports of Geological Survey of Missouri, part ii, p. 59. This appears to be the first definite mention of the use of this type of furnace in Missouri, although Schoolcraft refers in 1819 to what was perhaps a Scotch hearth (A View of the Lead Mines of Missouri, p. 22).

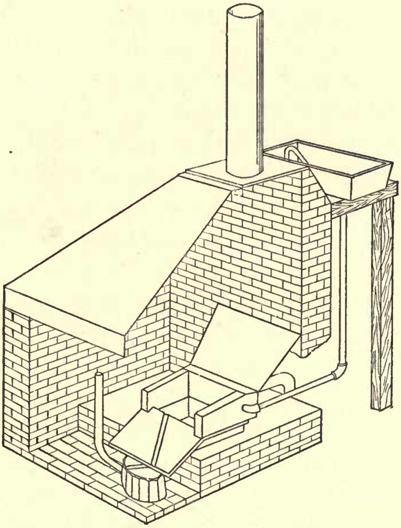
[2] Winslow, *op. cit.*, I, 283.

[3] On the Wisconsin and Missouri Lead Region, *American Journal of Science*, First Series, XLVII, 64.

[4] James E. Mills, Geological Report on the Mine la Motte Estate, p. 47.

bone" by the miners, was not abundant and therefore was never a very important source of lead in Missouri.

From 1831 to 1840 the production of lead in Missouri increased considerably, averaging about 3600 tons per annum, against about 1900 in the previous decade. In the ten years, 1841–1850, there was no material increase in the output, which was apparently checked by the low price of lead, the latter declining to about 3 c. per lb. during the early forties, and continuing low, on the whole, until nearly 1850. During the later years of this period shipments were made via Rush Tower, Plattim Rock, Salt Point, and St. Mary's, besides Ste. Genevieve, Herculaneum, and Selma. Both Missouri and Wisconsin were fortunate in having a water route to the Atlantic Seaboard from points comparatively near the mines. It was this that enabled so large an output of lead to be made at low prices before the advent of railway transportation.



Old form of American Scotch-hearth.

Reed & Hoffman erected a plant for the manufacture of white lead at St. Louis in 1837. Soon afterward it passed into the hands of Charles & Blow, and then into the hands of the Collier White Lead and Oil Co., which is now a part of the National Lead Co. Soon after 1840, William Glasgow, Jr., also erected works at St. Louis for the manufacture of white lead by the Dutch process, but operation continued only a few years, the works being destroyed by fire. Small works were also erected at St. Louis by Bacon & Hyde. The demand for white lead was small, however, and the annual product previous to 1850 did not exceed 500 tons.

The existence of lead ore in southwestern Missouri was known to the Osage Indians, and to the hunters from an early date, and it is certain that they used the ore as a source of metal for their bullets, inasmuch as remains of their crude furnaces have been found. About 1848 mining of lead ore was begun by William Tingle, two miles east of Joplin. In 1849 lead was discovered within the limits of Joplin by Daniel Campbell. This was the inception of mining in the Joplin district, the development of which was the predominant feature in Missouri mining during the next decade, although it was not for more than twenty years that the beginning of its great importance as a lead-producing district was to dawn. In 1851 mining was begun on Center Creek, near what was later called Minersville, and is now called Oronogo. In 1854 mines in operation on Turkey Creek were described by Swallow.[1] Discoveries were also made near Granby and Neosho, in Newton County, where the early developments were more important than in Jasper County. Up to 1854, however, the total production of both counties, according to Swallow, was only 862 tons of lead. This was produced chiefly from galena, though some carbonate ore was smelted. The zinc ore associated with the lead ore was thrown aside. By 1857 mining was actively in progress at Granby, and in 1858 Swallow estimated that probably 4000 tons of lead had been produced up to that date. From 1851 to 1860 it is reckoned that about 300 shafts were put down in and about Granby. The extensive developments of the mines accompanied by the provision of the necessary new smelting capacity led to a great increase in the production, the output of Granby rising to 4000 tons of lead per annum shortly after 1855 and causing the Southwest of Missouri to surpass the Southeast.

The decadence of the Southeast[2] was evidently due to exhaustion of the small, shallow deposits of Washington and St. François Counties, and the failure of the veins of Franklin County to become important producers. Prof. J. D. Whitney, writing in 1854, said:[3] "All these mines have now fallen off very much and most of them are completely exhausted. . . . The lead deposits of Missouri, on the whole, strikingly resemble those of the Upper Mississippi. . . . As they have been considerably longer worked in the former State, they are now nearer to exhaustion, and there is little reason to believe they will ever regain the importance which they once had."

The failure of this prediction, as shown by the statistics, has been remarked. Yet there was really no such failure. The conclusions of this very competent observer were undoubtedly warranted by the facts at that time and have been borne out substantially by the class of

[1] First and Second Annual Reports of the Missouri Geological Survey, part i, p. 160.

[2] G. C. Broadhead, Report on the Geological Survey of Missouri, p. 488.

[3] Metallic Wealth of the United States, pp. 418–419.

deposits to which he referred, namely, the shallow networks of Palmer, Potosi, etc. They have never since made an important production. The great increase in the lead production of southeastern Missouri since 1871 has been due to the disseminated deposits, which were unknown at the time of Whitney's visit; and between which and the shallow networks geologists have not yet been able to establish generally a connection.

The decline in the Southeastern production at this time was due partly to litigation which checked work at Mine la Motte. On the other hand, the Valle mine increased its output to over 500 tons of lead in 1858.

The first smelting furnaces erected in southwestern Missouri were the old log furnaces. They were soon superseded, however, by the Scotch hearths, the first of which was built in 1851, and started in 1852, by George W. and William S. Mosely, near the mouth of Cedar Creek, about six miles northwest of Neosho, in Newton County. The ore supply was obtained from mines near the works. The latter comprised two hearths of capacity for 3000 lb. of ore in 12 hours. The blast was produced by water power.

In order to encourage smelting at this early date, the Indian Agency gave the proprietors of this furnace a subsidy to build flatboats for transporting their product down Grand River from Gilstrap's Ferry to the Arkansas River, thence to the Mississippi River, and thence by steamboat to New Orleans, which was their market till 1854 when the firm failed. The old Moseley mines which were the ore supply for this early venture are still producing.[1]

The second smeltery to be erected in the Joplin district was that of Hartlerhodes in 1855. His furnace was situated on Hickory Creek, five miles southeast of Neosho, and consisted of two Scotch hearths. It is on record as having lost over half the metallic content of the ores smelted. In 1868, years after the abandonment of this smelter, its slag was hauled by John Kingston, now manager of the Granby Mining and Smelting Co's. plant at Granby, to Granby, Mo., where it was resmelted and much of the remaining metal extracted.[2]

In 1856 Kennett & Blow put up three Scotch hearths at Granby. This partnership continued to smelt lead until 1865 when the business passed into the hands of Henry T. Blow, who organized the Granby Mining and Smelting Co., which has been one of the most successful companies operating in the lead and zinc fields of the Southwest. During the year of organization the present smelting plant was built, with eight Scotch hearths capable of smelting 3000 lb. of ore in seven hours. These were succeeded by five water-back Scotch hearths of capacity for 7000 lb. of ore in seven hours, and these by five water-back

[1] D. Brittain, *Engineering and Mining Journal*, Nov. 9, 1907.

[2] D. Brittain, *loc. cit.*

jumbo Scotch hearths of capacity for 14,000 lb. of ore in seven hours, the last being the present equipment of the plant.

Also in 1856 William Tingle and his partner Fitzgerald operated a hearth (some say a log furnace) at the mouth of Leadville Hollow, two and a half miles northwest of Joplin. The blast was produced by two large bellows operated by water-power. This smelter continued in operation till 1861.

In 1858 Swallow gave a list of 34 furnaces, distributed as follows:[1] Washington County, 14; Franklin, 4; Jefferson, 3; Crawford, 1; Christian, 1; Newton, 9; Jasper, 2. Two of these are stated to have been log furnaces, 16 Scotch hearths, and 11 unclassified. Subsequent to 1851, at least, the Scotch hearth may be considered to have become the standard smelting furnace in Missouri.

About 1859 Tom Livingstone and one Parkinson operated two Scotch hearths at Oronogo. After the Civil War the bellows which supplied the blast was actuated by a treadwheel turned by a horse. While this smelter was in operation before the war Livingstone operated another plant at Livingstone's ford, on Center Creek. The place was then known as French Point on account of a colony of French smelters which Livingstone brought from southeastern Missouri. Lead ore for this furnace was obtained from Minersville and Duff's diggings, or Leadville, between Joplin and Minersville. The blast was furnished by water-power. This plant was destroyed during the war by Federal troops.

During the activity of Kennett & Blow at Granby and Tingle on Turkey Creek, E. St. George Noble and his brother John in 1859 erected a smelter four miles south of Granby on the site of the old Hartlerhodes smelter. After two years of operation this smelter was burned by the Federal troops in 1861. It consisted of four Scotch hearths and a blast furnace for smelting the flue dust and gray slag. There are some interesting and valuable records of the smelting operations at this works, which have been given in the previous chapter on "Metallurgy." It appears from these that the value of ore at that time was $32 per 2000 lb. The wages of smelters were $0.75 to $1 per day. Charcoal cost 7½ c. per bushel, and ordinary cordwood $1.50 per cord. The cost of conveying pig lead to St. Louis was 1.36 c. per lb. Including the freight the cost of the lead delivered at St. Louis was 4.125 c. per lb.

In the Southeast, the lead produced from 1851 to 1860 was carted during most of the period to the old points of shipment on the Mississippi River, but in 1853 the construction of the Iron Mountain railway was begun from St. Louis, and although it progressed but slowly, it reached Pilot Knob by 1858, and thus for several years preceding furnished an easier line of transportation to the Mississippi River, the railway running

[1] Geological Report Along the Line of the Southwestern Branch of the Pacific Railway, State of Missouri, pp. 65–66.

southward from St. Louis in such a way that it traversed the most important portion of the lead country, passing within 25 miles of nearly all the productive mines and much closer to most of them.

The Southwest was not so well favored in this respect, its lead having to be carted long distances to river points. Some went as far north as Boonville, on the Missouri River, and a large quantity was taken to Linn Creek, on the Osage River, while another large portion went to Fort Smith, on the Arkansas River. According to Swallow the usual cost of transportation from the furnaces in southwestern Missouri to St. Louis during 1851–1860 was $1.25 per 100 lb. This was a large deduction to make from the value of the product at St. Louis, but fortunately the price for lead ruled high during most of this period. The miners were paid generally $16 per 1000 lb. of ore, which may possibly have yielded about 650 lb. of lead, on which assumption the cost of lead in ore would have been about 2.5 c. per lb. Adding 0.5 c. per lb. for cost of smelting, and 1.25 c. for freight, the total cost at St. Louis would have been about 4.25 c. per lb. The market price ranged from 4.30 to 6.20 c. per lb. Out of the price received for his ore the miner had generally to pay a royalty of about $2 per ton.

Work was begun on the Southwestern Branch of the Pacific Railway, the present St. Louis & San Francisco, in 1855, but up to 1858 only 18 miles had been constructed, and in 1860 it was only as far as Rolla, so that it was not of much service to the mining interests of southwestern Missouri during this period.

Just when the production of lead in southwestern Missouri was beginning to attain large proportions, operations were checked by the Civil War. The district was contested territory, which caused mining to be stopped entirely at times. The Granby mines and furnaces were worked alternately on Federal and Confederate account. In southeastern Missouri there was not so much interruption to mining, its lead districts being outside the zone of active hostilities, though there were some raids in certain of them, and the Mine la Motte furnaces were destroyed by the United States Government in 1861. They were soon rebuilt, however, and were operated vigorously under the stimulus of the high price for lead, producing over 3500 tons of lead from 1861 to 1864. With the exception of Mine la Motte and the Valle mine there does not appear to have been much active operation in southeastern Missouri at this period. One of the effects of the Civil War on the lead industry was to cause a very high price for the metal, which rose to 12.8 c. per lb. in 1864, and in 1865 was 10 c. per lb., *loco* St. Louis. With the close of the war this naturally led to a vigorous resumption of mining.

The St. Joseph Lead Co. was organized in 1864 to purchase La Grave mines at Bonne Terre, St. François County, active operations upon which were begun during the following year. A mining, milling, and smelting plant was erected, but the production for several years was small. In 1865, Mr. Henry T. Blow, who was instrumental in founding the Collier White Lead and Oil Co., some 25 years earlier, obtained a lease of the Granby mines in Newton County, and immediately began energetic mining, his enterprise developing into the Granby Mining and Smelting Co. That company has ever since been the most important producer in southwestern Missouri, while the St. Joseph Lead Co. has been the most important in the Southeast.

The most important event in the entire history of lead mining in Missouri occurred in 1869 when the St. Joseph Lead Co. began prospecting at Bonne Terre with the diamond drill for deep deposits of ore.[1] It resulted almost immediately in the discovery of disseminated ore at a depth of about 120 ft., and led to the mining of those deposits, which although of low grade are of such magnitude that their aggregate lead content caused the shallow networks of Cadet, Palmer, Potosi, and elsewhere to fade into insignificance and raised Missouri to its present great importance as a lead-producing State. According to Mr. Francis La Grave, son of the former owner of the Bonne Terre lands, some prospecting with the churn drill before the war had showed the existence of disseminated ore at a depth of 80 ft., but apparently the importance of the discovery was not then appreciated. Ever since the discovery of the St. Joseph Lead Co., the diamond drill has played an important part in prospecting in this district, being more extensively used and more valuable as a means for prospecting than in any other metal-mining district of the United States outside of the Lake Superior copper region.

According to the statistics of the Ninth Census there were 42 producing mines in Missouri in 1870, which employed 539 men, and produced about 3500 tons of lead, but the largest single producer, namely the Mine la Motte, was omitted from the enumeration. Its output in 1870 was nearly 2600 tons, and the statisticians of the Missouri Geological Survey believe that the true total for the State was approximately 7000 tons. The Granby mines in Newton County gave employment to 300 men. In Jasper County there was only one mine in operation, it employing five men. According to Schmidt, there was not a single house standing on the present site of Joplin in 1870. However, there was soon to be an important change.

In August, 1870, J. B. Sargent and E. R. Moffett discovered lead ore in large quantity within what are now the city limits of Joplin. The Moon diggings, on East Joplin hill, were opened about the same time. The ore-bodies were rapidly developed, and by 1871 two smelting works were running. That of Riggin & Chapman had three or four air furnaces

[1] J. Wyman Jones, History of the St. Joseph Lead Co., p. 17.

and six or eight Scotch hearths, while that of Moffett & Sargent had three air furnaces. The lead was hauled to Baxter Springs, Kansas, and thence shipped by railway to St. Louis. In 1871 Patrick Murphy bought the land on which Joplin now stands, and the town, first called Murphysburg, was laid out. Discovery quickly succeeded discovery; the limits of the district were rapidly extended; miners flocked in from all directions. In 1874 the population of Joplin is said to have reached 5000, about 1000 miners being employed, while seven Scotch hearths and six reverberatory furnaces were in operation. In the same year, the Memphis, Carthage & Southwestern Railway, now a part of the St. Louis & San Francisco, was built. Mining was begun at Webb City in 1875, and at Carterville in 1876. The mines at Oronogo and along Turkey Creek had previously been discovered. From this time Joplin became a large producer of lead ore, but nevertheless it is essentially a zinc district, and the value of its lead output was soon surpassed by its zinc ore, of which the first shipments were made in 1872. The further history of this important and interesting district will therefore be treated in the division of this work relating to zinc.

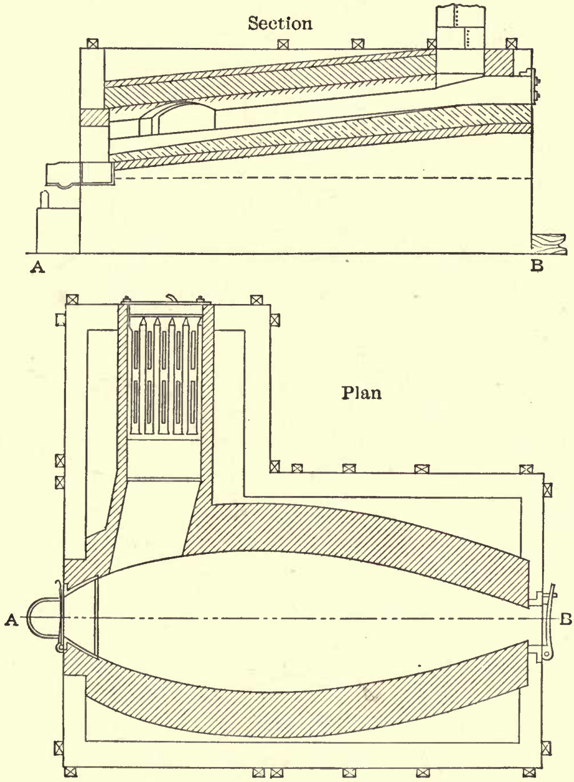
The later history of lead smelting in the Joplin district may be briefly summarized. In 1876 the Lone Elm Mining and Smelting Co., the successor of Moffett & Sargent, erected a new plant of 16 Scotch hearths at Joplin, at which the Bartlett process of making sublimed white lead was introduced in 1878. In 1886 the works passed successively into the hands of the Moffett Smelting Co. and Joplin Lead Co., and in the following year was sold to the Picher Lead Co., which has operated it ever since. The dates of other smelting enterprises were as follows: Davis & Murphy, Joplin, four air furnaces, 1872–1880. Corn & Thompson, 1872, Joplin, four air furnaces. P. Murphy, near Duenweg, two Scotch hearths, 1873–74. Jasper Lead and Mining Co., Joplin, four air furnaces, 1873–74. O. H. and W. H. Picher, Joplin, 1876–1880. Porter & Dorsey, Joplin, 1876–1880. Granby Mining and Smelting Co., Joplin, 1877–1878, the plant being removed to Granby in the latter year. Galena Lead and Zinc Co., Galena, Kan., 1879–1886, the plant passing into a succession of hands after 1880. West Joplin Lead and Zinc Co., Joplin, six Scotch hearths, 1880. Case & Serage Lead Co., Grand Falls, 1892–95. These and others of minor importance are referred to with considerable detail in an article by D. Brittain in the *Engineering and Mining Journal* of Nov. 9, 1907. The only smelters in operation in the Joplin district at present are those of the Picher Lead Co. at Joplin (1876); Granby Mining and Smelting Co., Granby, Mo. (1865); and C. V. Petraeus Smelting and Manufacturing Co., Galena, Kan. (1902).

Going back in the narrative to southeastern Missouri, developments were much less rapid than in southwestern because of the more elaborate mining and milling methods that it was necessary to install. It was early obvious that the low-grade disseminated ores could not be extracted and worked in the same simple manner as the small, but rich, shallow deposits, though it is doubtful if the kind of methods that would really be required was appreciated at all. The Mine la Motte, still working the old, superficial deposits, continued to be the largest producer in the Southeast during the early seventies, its output of pig lead having been 2564 tons in 1870, though the rate of production was reduced by a fire which destroyed 12 furnaces in 1872; in 1876, however, it rose to 2914 tons. In the meanwhile the output of the St. Joseph Lead Co. was steadily increasing; in 1869 it was about 22 tons of lead monthly; in 1874 about 122 tons; and in 1879 about 350 tons. In 1874 the construction of a railway to connect its mines with the Iron Mountain line at Riverside, on the Mississippi River, was begun. In 1878 the Desloge mill and smeltery adjacent to the St. Joseph works were put in operation, and in the same year the exploitation of the deeper-lying disseminated ores at Mine la Motte was begun in a systematic manner.

In 1881 there were three mines in southeastern Missouri opened on the disseminated ore, viz., the St. Joseph and Desloge at Bonne Terre, and the Mine la Motte. The mill and other works of the St. Joseph Lead Co. were destroyed by fire in 1883. They were immediately rebuilt on a grander scale and more in conformity with the requirements of the ores. The adjacent Desloge mill was burned in 1885, and the mine was purchased by the St. Joseph Lead Co. in 1886, which company has been continually adding to its holdings until it has become the largest owner of lead lands in this district. The Doe Run mine, near Farmington, was opened in 1887. The Flat River mines, a few miles south of Bonne Terre, were first opened in 1890.

The Mississippi River & Bonne Terre railway was completed from Riverside to Doe Run in 1890, whereupon the St. Joseph Lead Co. removed its smelting furnaces from Bonne Terre to Herculaneum, continuing, however, to roast the ore at Bonne Terre, whence it was shipped as slag. The Doe Run Lead Co., affiliated with the St. Joseph, adopted a similar policy, shipping its slag-roasted ore to the St. Joseph smeltery at Herculaneum.

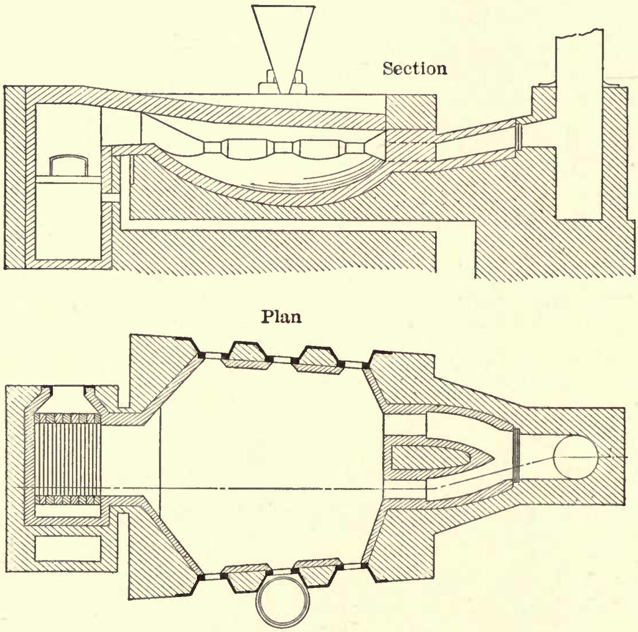
About 1871 there was a considerable change in the smelting practice in Missouri, a form of reverberatory furnace known as the Drummond, or air furnace, being extensively substituted for the Scotch hearths, which had been almost exclusively in use during the previous 20 years. A description of this furnace is to be found elsewhere in this work. It is uncertain where it first came into use, but it appears to have been employed at Bonne Terre and other points in southeastern Missouri a little before 1871. Form there it spread to the other districts of the State, and from its success no doubt certain smelters were led to construct Flintshire furnaces, which are a more highly developed form of reverberatory. A few blast furnaces also were erected, especially to reduce the gray slag, rich in lead, which is produced both by the Scotch hearths and the reverberatories. In 1876, according to Williams, there were in Missouri 52 reverberatory furnaces, 29 Scotch hearths, and seven blast furnaces. The St. Joseph Lead Co. began in 1878 to substitute blast furnaces for its reverberatories. From that time onward the major



The Air, or Drummond, Furnace.

portion of the galena concentrate produced in southeastern Missouri was smelted in blast furnaces, although the Desloge Consolidated Lead Co. has always stuck to the use of reverberatories, until early in the present century the Scotch hearth and bag-house method was adopted at two new, large plants. The development in the metallurgical practice of this district has been treated fully in an earlier chapter.

Since 1891 the history of the southeastern Missouri district has been simply a record of steady growth. The Doe Run mine, which occurred in an outlying, isolated territory, had become practically exhausted as early as 1895, but with that exception there has not yet been any failure of the great ore-bodies, and the known extent of the lead-bearing area of the district has been increased year by year. The development in 1890 of the mines at Flat River, where diamond drilling was begun in 1888, and their brilliant success, first directed attention to the probable wide-spread occurrence of the disseminated ore and stimulated prospecting beyond the limits of Bonne Terre, which previously had been the chief center of the mining. In this extension of interest, Mr. H. J. Cantwell



Flintshire Furnace formerly used at Frumet, Mo.

of St. Louis, who organized the Central Lead Co., operating at Flat River, was largely instrumental. In 1899 the producing companies of the district were the St. Joseph, Doe Run, Desloge, Central, Columbia, and Mine la Motte. The Catherine had developed an ore-body on land adjoining the Mine la Motte domain, and the St. Louis Smelting and Refining Co. (a subsidiary company of the National Lead Co.) was building a large mill at Flat River to dress the ore of mines it had acquired there. All of these companies were in a prosperous condition. It was the year of great industrial consolidations, and promoters in looking for new possibilities sought to acquire this group of profitable mines, but the terms asked for them were too high to afford an adequate margin for profit.

Their owners were so well satisfied with their investments, with the good returns the mines were yielding and with the strong prospect of their indefinite continuance, that there was no inducement to them to give them up.

That policy has since then been generally adhered to, the Central mine having been the only one to pass into a consolidation, although several others have changed hands. In 1900 the Guggenheims became interested in the district, buying the works of the Missouri Smelting Co. at St. Louis, and some partially developed mines at Flat River, which were organized as the Federal Lead Co. After some early mishaps, due partly to an attempt to introduce some novelties in the well-settled milling practice of the district, this company was put upon a profitable basis, and eventually became one of the important factors in the lead production of the district, especially after the construction of its large smelting works at Alton, Ill., the small plant at St. Louis having previously been abandoned. In 1905 the Federal Lead Co. purchased the Central mine, paying a large price for it. In the meanwhile, the St. Louis Smelting and Refining Co. had developed its mines at Flat River with great success, had constructed a large smelter at Collinsville, Ill., and had become one of the large producers of the district. In 1906 the Guggenheim interests acquired large holdings of the stock of the National Lead Co., and if not actually securing the control of that company, at least brought it into a community of interest. Consequently, at the present time the major part of the output of lead in southeastern Missouri is made by, and the largest areas of proved lead-bearing land are owned by, the Guggenheims and the St. Joseph-Doe Run companies. The only independent producers are the Desloge and several small mines in the vicinity of the Mine la Motte.

The most serious difficulty in lead mining in southeastern Missouri in recent years has been due to labor troubles. As early as 1899 it was troublesome to secure an adequate supply of miners, and the men at work in the district and available were comparatively inefficient. The results of their work were strikingly unsatisfactory when compared with those attained in zinc mining in southwestern Missouri. In the Southeast there were mines equipped with costly plants of the most modern design, opened in bodies of easily broken ore that often presented working faces 50 ft. and more in height, and of almost any width desired, operated through shafts of moderate depth, in many cases with only an insignificant amount of water to be pumped, and no timbering required anywhere in the stopes. In the Southwest there were mines equipped on almost a ridiculously petty scale, opened on bodies of the hardest kind of chert, affording a working face only 8 ft. high, operated at only a little less depth than in the Southeast. And yet mining and milling on the basis of only

200 tons per day was done for less per ton in the Southwest than on the basis of 1200 tons per day in the Southeast.[1] The only explanation of this is to be found in the lower efficiency of the labor in the Southeast, a conclusion which is borne out by an analysis of the mining costs.

Up to 1900 or 1901 the miners in southeastern Missouri, although inefficient, had been at least docile. There had never been any serious labor troubles. About that time, inspired perhaps by the great demand for labor and incited by agitators, the miners began to organize, and unionization having been effected, the companies were called upon to reduce the day's work from 10 hours to 8 hours with no change in pay. This resulted in strikes at certain mines, where the demand was refused, and some turbulence, there being a disgraceful disinclination to maintain order, or at least incompetency, on the part of the county and State officials. Victory was eventually gained by the miners, some of the companies having yielded without any fight, and as a result the cost of mining and milling in the district was materially increased. However, this happened at a time when the price of lead was high as compared with the averages of certain years in the previous decade, and the high level having been maintained up to 1907 the companies continued to make large profits and the statistics have shown a constant increase in production.

[1] This comparison is not, of course, strictly correct, because the company milling 1200 tons per day would be operating three shafts.

VII

WISCONSIN

In using the term "Wisconsin" in this chapter, it is to be understood that reference is made not merely to the political division of that name, but rather to the zinc- and lead-producing district which lies chiefly in the southwestern part of the State of Wisconsin, and extends into Illinois and Iowa. Back in the seventies and earlier this district was known as the "Galena district," from Galena, Ill., which was then its leading town. However, the largest mining areas and the most important mines, save at the outset, have been in Wisconsin proper, and now every one knows what "Wisconsin district" signifies, while "Galena district" would provoke an inquiry.

In the earliest days of this region little attention was paid to the line of latitude 42° 30,′ *i.e.* the boundary line between Wisconsin and Illinois. The Federal Government practically regarded the lead-mining district on the eastern side of the Mississippi as undivided, save that it recognized the rights of the Indians to the greater part of it. As did the Government, so did commerce. Neither could do otherwise, for as to industrial and social conditions the entire region was a unit, having Galena as its emporium. Indeed, for a time the inhabitants did not know whether they dwelt in Illinois or in then unnamed Wisconsin. The first election at Platteville, Wis., was held in the autumn of 1828, and state officers of Illinois were voted for. Even at an early day there was an effort to have the southern line of the new Territory of Wisconsin so placed as to include all of the mining district east of the Mississippi, and but for an act of Congress which was considered unjust that would have been done.[1] However, the district has been always a unit commercially and having its more important part in Wisconsin is properly referred to under that name.

The existence of lead ore in this district was doubtless known from the time of the earliest journeys of white men to the upper Mississippi Valley. The French exploration of the region began with Nicolet's voyage in 1634. The occurrence of lead ore was actually reported as early as 1658. Nicholas Perrot is credited with having discovered the mineral

[1] John N. Davidson, Proceedings of the State Historical Society of Wisconsin, 46th annual meeting, p. 190.

in 1682.[1] The location of mines was shown on Hennepin's map, 1687.[2] Joutel, who was in the country as early as 1687, says that "travelers who have been at the upper part of the Mississippi affirm that they have found mines of very good lead there." As early as 1690 lead was purchased from the Indians by traders at Peoria.[3] Nicholas Perrot in 1690 discovered lead ore that was "hard to work because it lay between rocks and required blasting," and established a trading-post opposite the present site of Dubuque, while Le Gueur in 1695 located on an island further up the river and at these posts lead was a regular article of commerce. In August, 1700, Le Sueur's expedition, which previously in the same year had discovered lead ore in Missouri, found it also near the southern boundary of Wisconsin.

Early notes as to the occurrence of lead in this region are multifold, but they chronicle only the discoveries at numerous places, and the petty transactions at the temporary posts of French traders. There was no systematic attempt at mining, although M. le Guis is said to have found 18 or 20 mines in operation along Fever River in 1743. In 1769 a concession for mining was granted to Martin Miloney Duralde, but he seems to have taken no advantage of it.

The first striking figure established permanently in the Wisconsin lead region was Julien Dubuque, a man of remarkable energy and singular popularity among the Indians, whose post was the site of the city in Iowa which now bears his name. According to Schoolcraft[4] lead ore was discovered there in 1780 by the wife of Peosta, a warrior of Kettle Chief's village. In 1788, at a council held at Prairie du Chien, the Sac and Fox Indians granted these lead-bearing lands to Dubuque, who in 1796 received a confirmation of the Indian grant from Baron de Carondelet, governor of Louisiana, in which they were designated the "Mines of Spain." Dubuque dug ore from surface pits, erected furnaces and constructed roads from the mines to the furnaces. Although his own lands were situated on the western side of the river, he seems to have carried on a trade in ore with the Indians east of the river. In 1805 Dubuque was visited by Lieutenant Pike, who reported that he found Dubuque "polite but evasive." Pike did not visit the mines, but he learned from Dubuque that the production of the furnaces was 20,000 to 40,000 lb. of lead per annum, that being a yield of 75% out of the ore smelted.

After Dubuque's death, in 1809 all of his works were destroyed by the Indians. However, they continued to dig lead ore intermittently, selling

[1] R. D. Irving, Mineral Resources of Wisconsin, Trans. Am. Inst. Min. Eng., VIII, 498.

[2] H. Foster Bain, Zinc and Lead Deposits of the Upper Mississippi Valley, Bulletin No. 294, United States Geological Survey, p. 2.

[3] Senate Document, No. 87, 29th Congress, 1st Session, 1846.

[4] Narrative Journal of Travels, etc., Albany, 1821, p. 348.

it to traders who had rude furnaces on islands in the river, and also smelting it themselves. In February, 1810, Nicholas Boilvain found that the Indians had mostly abandoned the chase, except to furnish themselves with meat, and turned their attention to lead mining, which they found more profitable than hunting. In 1810 they made 200 tons of pig lead. In 1811 George E. Jackson, a Missouri miner, had a rude log furnace on an island nearly opposite the mouth of Catfish Creek. He floated his lead to St. Louis by flatboat. He had much trouble with the Indians, who disliked Englishmen and Americans.[1] In 1812–13 John S. Miller joined fortunes with Jackson, but soon afterward they abandoned their furnace and returned down the river. Between 1815 and 1820 Capt. John Shaw made eight trips with a trading-boat between St. Louis and Prairie du Chien and several times visited the Fever River mines, at one time buying 70 tons of lead from the Indians working there. The first flatboat cargo of lead from these mines was brought to St. Louis by Col. George Davenport in 1816. John S. Miller revisited the lead region in 1818 and again in 1823 on trading expeditions. It is clearly evident that from the beginning of Dubuque's working up to the permanent American occupation of the region a considerable quantity of lead, amounting to as much as 200 tons in a year, was shipped from it to St. Louis. This represented a rather remarkable Indian industry. There were said to be about 20 Indian furnaces in operation near the present site of Galena, Ill., in 1815. Of course, these operations were of the most primitive character. A picturesque description of them was given by Schoolcraft,[2] who in 1820 went by canoe from Prairie du Chien to Kettle Chief's village (Dubuque), as follows:

"The district of country generally called Dubuque's lead mines embraces an area of about 21 square leagues, commencing at the mount of the Little Maquanquitons River, 60 miles below Prairie du Chien, and extending along the west bank of the Mississippi seven leagues in front by three in depth. The principal mines are situated on a tract of one square league, commencing immediately at the Fox village of the Kettle Chief and extending westward. This is the seat of the mining operations formerly carried on by Dubuque, and of what are called the Indian diggings. The ore found is the common sulphuret of lead, with a broad foliated structure and high metallic luster. It occurs massive and disseminated, in a reddish loam, resting upon limestone rock, and sometimes

[1] The whole of this territory was American domain at this time. Up to Nov. 3, 1762, France held possession of both sides of the Mississippi, but she then ceded the eastern half of the valley to Great Britain, which took possession April 21, 1764, and the western half to Spain, which allowed six years to elapse before she assumed charge. In 1803 France again took possession of Louisiana and almost immediately sold it to the United States, which took formal possession, March 9, 1804, at St. Louis.

[2] *Op. cit.*

is seen in small veins pervading the rock, but it has been chiefly explored in alluvial soil. It generally occurs in beds or veins which have no great width, and run in a certain direction 300 or 400 yards— then cease, or are traced into some crevice in the rock, having the appearance of a regular vein. At this stage of the pursuit most of the diggings have been abandoned and frequently with small veins of ore in view. No matrix is found with the ore which is dug out of the alluvial soil, but it is enveloped by the naked earth, and the lumps of ore are incrusted by an ocherous earth. Occasionally, however, some pieces of calcareous spar are thrown out of the earth in digging after lead, and I picked up a solitary specimen of the transparent sulphate of barytes, but these substances appear to be very rare. There is none of the radiated quartz, or white, opaque, heavy spar, which is so common at the Missouri mines. The calcareous rock upon which this alluvial formation, containing lead ore, rests, appears to be referable to the transition class. I have not ascertained its particular extent about the mines. The same formation is seen, overlaid by a distinct stratum of compact limestone, containing numerous petrifactions, at several places between the mines and Prairie du Chien. The lead ore at these mines is now exclusively dug by the Fox Indians, and, as is usual among savage tribes, the chief labor devolves upon the women. The old and superannuated men also partake in these labors, but the warriors and young men hold themselves above it. They employ the hoe, shovel, pickax, and crowbar, in taking up the ore. These things are supplied by the traders, but no shafts are sunk, not even of the simplest kind, and the windlass and buckets are unknown among them. They run drifts into the hills so far as they can conveniently go without the use of gunpowder, and if a trench caves in it is abandoned. They always dig down at such an angle that they walk in and out of the pits, and I descended into one of these which had probably been carried down for 40 ft. All this is the work of the Indian women and old men, who discover a degree of perseverance and industry which is deserving of commendation. When a quantity of ore has been gotten out it is carried in baskets by the women to the banks of the Mississippi, and then ferried over in canoes to the island, where it is purchased by the traders at the rate of $2 for 120 lb., payable in goods. At the profits at which these are usually sold it may be presumed to cost the traders 75 c. to $1, cash value, per hundred weight. The traders smelt the ore upon the island, in furnaces of the same construction used at the lead mines of Missouri, and observe that it yields the same per cent of metallic lead. Formerly the Indians were in the habit of smelting their ore themselves, upon log heaps, by which a great portion was converted into what are called lead ashes and thus lost. Now the traders induce them to search about the sites of the ancient fires, and carefully collect the lead ashes, for which they receive $1 per bushel delivered at the island, payable in merchandise."

It is supposed that the French first showed the Indians how to mine and smelt the ore, and thus obtain metal for bullets for the guns which they acquired through trade. There is no evidence that the American aborigines ever practised the art of smelting before the advent of the white men. The methods in vogue among the Indians were substantially the same as employed by the whites in the earlier days of lead mining, and are thus described by an eye-witness, writing in 1819:[1] "A hole was dug in the face of a piece of sloping ground, about 2 ft. deep, and as wide at the top. This hole was shaped like a mill-hopper and lined with flat stones. At the bottom or point of the hopper, which was 8 or 9 in. square, narrow stones were laid across, gratewise. A trench was dug, from the sloping ground inward to the bottom of the hopper. This channel was a foot in width and height, and was filled with dry wood and brush. The hopper being filled with the ore and the fuel ignited, in a few minutes the molten lead fell through the stone at the bottom of the hopper, and thence was discharged, through the trench, over the earth. The fluid mass was then poured into an awkward mould, and as it cooled was called a 'plat' weighing about 70 lb., very nearly the weight of a 'pig' of later days."[2]

As a rule the Indians did nothing but skim the surface, but occasionally they drifted into side-hills, and when they reached rock they continued by that universal form of primitive mining called "fire-setting," *i.e.*, building a fire against the rock and cracking it by dashing cold water upon the healted surface. Their tools in the earliest times were buckhorns, but in Dubuque's time they obtained hoes, shovels, and crowbars. The ore was dragged up to the surface in bags made of deerskin. Many of these Indian workings, abandoned when mining became too difficult for their primitive tools, were subsequently exploited by the whites and found to be among the best in the region.

Up to 1819 lead mining in Wisconsin was rather the primitive effort of the Indians and the spasmodic interest of traders than the prosecution of a real mining industry. In the meanwhile mining was being regularly conducted in Missouri, especially after the advent of Moses Austin and the purchase of Louisiana territory by the United States,

[1] Quoted by Reuben Gold Thwaites, Collections of the Wisconsin Historical Society, XIII, p. 281.

[2] This was an improvement over earlier days when the Indians reduced the mineral on top of large fires. "Large logs would be placed on the ground and smaller pieces of wood piled around and the ore heaped on. The fire would be set in the evening and in the morning shapeless pieces of lead would be found in cakes, or small holes scratched in the earth under the logs; or sometimes in shapeless masses. These pieces were sold to the traders." (Wisconsin Historical Collections, II, p. 228.)

and a skilful and energetic mining population had been developed. These began to be interested by the reports of the rich mines farther up the river and adventurous spirits migrated thither, not only from St. Louis, but also from along the Ohio and elsewhere. The influx of Americans into the Wisconsin region began in 1819 when Jesse W. Shull, later the founder of Shullsburg, Wis., established a trading-post in the neighborhood of Galena. Shull, who was ordered there by his principals, at first refused to go, from fear of the hostile Indians, who had lately murdered several American traders, but they were induced by promises and threats made by Col. James Johnson, commander of the Federal forces, not to molest Shull. A. P. Van Metre was at this time operating a small smelting furnace on the east side of the Fever River. Col. James Johnson, of Kentucky, came to the Fever River in 1819 or 1820 and did some mining and smelting. These appear to have been the first Americans to remain in the region for the purpose of mining and smelting as a continuous business. It was not, however, until 1821 that attention began to be widely attracted to the region, and not until 1823 does the lead production begin to figure in our statistics. In that year the output is said to have been 168 tons. However, the production in 1824 was only 87 tons, and in 1825 and 1826 only 332 and 479 tons, respectively. But the beginning had been made, and in 1827 the output was 2590 tons, considerably surpassing that of Missouri, and from that time until about 1871 Wisconsin was the leading producer of lead in the United States; indeed it was the chief source of supply.

The early history of the Wisconsin lead region — from 1634 to 1829 — is given with considerable detail, especially as to the reports of the French pioneers, Dubuque's operations, and the traders in the first two decades of the nineteenth century by Reuben Gold Thwaites in a paper "Notes on Early Lead Mining in the Fever River Region," in Collections of the Wisconsin Historical Society, vol. XIII, pp. 271–292. It is evident from the frequency and character of these reports that the Government of the United States must have been fully alive at an early date to the great possibilities of the region. That this was the case is manifest from the treaty concluded at St. Louis, Aug. 24, 1816, which granted to the Indians all lands lying north of a line drawn due west of the southern extremity of Lake Michigan to the Mississippi, except a tract five leagues square on the Mississippi River to be designated by the president. This reservation was intended to include the lead mines, the exact location of which was as yet undefined. By Act of Congress, March 3, 1807, all of the mineral lands of the territory of Louisiana were reserved from sale with the provision that they should be leased for terms of three to five years at an annual rental. The lands thus reserved amounted to 1,428,480 acres in Wisconsin, 345,600 in northern Illinois, and 184,320 in Iowa. A superintendent of mines, together with assistants, was appointed, and a royalty of 10% of the produce of the lands, payable either in cash or in the lead itself, was exacted.

Although the leasing system was early introduced in Missouri, in Wisconsin it did not obtain for many years and the pioneers operated there on their own account and without control. The first lease in the Fever River region was granted, Jan. 4, 1822, to T. D. Carneil and Benjamin Johnson and Messrs. Suggett and Payne, all of Kentucky. Lieut. C. Burdine, U. S. A., was ordered to aid them in selecting 160 acres each, and to protect them with an armed force,[1] but no result of the expedition, if it was undertaken, appears to have been published. Col. James Johnson, who had previously been operating in the region without a license, was granted a three-year lease, April 12, 1822. Encamping where Galena now stands, under strong military protection, Johnson commenced operations on the most extensive scale yet known in this region. Other leases were soon afterward taken out, but at this time and until the system was abandoned the unlicensed plants could be numbered by the score. As in Missouri, the system early provoked opposition and much friction resulted. Comparatively few leases were taken out either in Missouri or the Upper Mississippi, and when in 1846 the system was abolished it was shown that the total royalty collected between 1841 and 1845 was only $145,174.40, while the direct cost of collection was $68,464.50, besides which a considerable additional sum had been spent in litigation.[2]

It is worth while to pause here to consider this interesting trial by the United States of national ownership of developed mines. At the time of adoption of the policy the Republic was not 20 years old. It had no mining industry of consequence, and as a nation was inexperienced in the exploitation of mineral resources. In many of the old countries minerals were reserved by the crown which bestowed mining rights in consideration of royalties upon the produce. It was natural, therefore, that the United States upon acquiring an immense territory of little explored, practically unsettled land as the property of the nation should have aimed to secure for the direct benefit of the whole people a fair portion of its mineral yield. This policy was sound in theory, and was amply sanctioned by precedent in foreign countries. It found subsequently successful application in the United States, as we shall see, although not in so general a way as was contemplated by the Act of 1807.

However, the people who had but lately thrown off the yoke of Great Britain looked unkindly upon Government interference, and indeed upon

[1] History of Lafayette County, Wisconsin, p. 402.

[2] Senate Ex. Doc. No. 87, 29th Congress, 1st session, 1846.

anything that savored of landlordism. About the time when the Wisconsin lead region was being developed the country was experiencing a change from the old-fashioned Republicanism of Monroe and John Quincy Adams to the aggressive democracy of Andrew Jackson. The authority of the Government was exercised more and more feebly and more and more by unworthy men. There were many scandals and injustices in connection with the mining leases, and to the pioneers who were carving out the frontier, mining almost with rifle in hand, the system of taxing their single industry for the benefit of the rest of the people was utterly repugnant.

Yet we have seen later on in the Joplin district of Missouri the introduction and cheerful acceptance of a system precisely similar save that the royalty was paid to the private owner of the land; we have seen in the Rocky Mountains the eagerness with which the miners have adopted the tribute system; and we have seen several of the States reserve their mineral lands and lease them to private operators, as for example coal lands in Colorado and phosphate lands in South Caroliua, with entirely successful results. In 1906 President Roosevelt advocated that the Federal Government pursue a similar policy with respect to its remaining coal lands, and the conservation of our natural resources for the benefit of the whole people has been one of the distinguished policies of his administration.

Apparently the chief fault of the policy inaugurated in 1807 was that it was ahead of the times. Its abandonment in 1846 was undoubtedly wise. The development of the West has unquestionably been promoted by granting the prospectors a free hand. If the Nation has received little in direct returns from the sale of its lands, and nothing from royalties, it has benefited immensely in many other ways.

The early history of the lead region of Wisconsin has been written by Dr. Moses Meeker, himself one of the pioneers, who describes graphically the trials and tribulations of the initial development.[1] Dr. Meeker, who was born in New Jersey, settled in 1817 in Cincinnati, Ohio, he being then 17 years of age, where he engaged successfully in the manufacture of white lead until 1822, when he visited Galena. He went back to Cincinnati for his family and returned to Galena in 1823, and remained permanently in the lead region. Immediately upon his arrival he commenced the smelting business in which he continued for many years. Dr. Meeker first heard of the Wisconsin lead district during a visit to St. Louis, whither he had gone from Cincinnati to purchase pig lead. At that time lead smelted by Indian traders was coming from up the river by keel-boat to St. Louis, and Col. James Johnson of Kentucky was fitting out an expedition to work the mines on the Fever River (now Galena). About

[1] Collections of the State Historical Society of Wisconsin, vol. VI, pp. 271–296.

this time also an advertisement appeared that the Government would lease certain lead lands of the Upper Mississippi for a royalty of one tenth, the lessee being obliged to give a bond and security.

Col. James Johnson and others arrived on the Fever River about July 5, 1822. Anticipating opposition from the Indians he had procured an order from the Secretary of War to the local commanding officer to meet him with a force sufficient to overawe the Indians. The Sacs and Foxes had determined to resist the landing, but learning that this would be in vain had concluded, by virtue of necessity, to let the white men work with them.

During the summer of 1822 a great many notices were published in the papers of St. Louis concerning the richness of the mines of the Upper Mississippi. When Dr. Meeker arrived at Fever River, Nov. 12, 1822, he found about 30 white men there, and three log furnaces for smelting. When he went back to Fever River the next spring he took with him a party of 43 persons. The journey was made by keel-boat, down the Ohio, then up the Mississippi. This was the way in which the pioneers went to the Wisconsin lead region. Dr. Meeker's journey from St. Louis to Fever River occupied 31 days; from Cincinnati the time was 58 days.

The Government had stationed two officers of the Ordnance Department at Fever River as surveyors, but no agent had yet been sent out. At this time the Government had put the business of the lead mines under the Ordnance Department. Toward the close of the year (1823) Colonel Johnson, finding that he could not operate profitably, decided to leave the district and urged Dr. Meeker to do likewise, but the latter had a keener perception of its possibilities. In this year Colonel Johnson produced about 30 tons of pig lead, Dr. Meeker 85 tons, Thos. H. January 22½ tons, Bates and Barrel 25 tons; and David G. Bates and A. P. Van Metre, on an island in the Mississippi, opposite Dubuque, of mineral and ashes purchased of the Indians, 50 tons; making the total product of lead shipped for the year 212½ tons.

The pioneers suffered many hardships. Sanitary conditions were poorly attended to and there was much sickness from fever and ague and typhoid fever (whence evidently the name of the settlement). The product of pig lead was shipped down the river to St. Louis by keel-boats, and on the return trip the boats brought the necessary supplies, but the voyages were irregular and often delayed, and of course were impossible during the winter. Hence there was sometimes a shortage of supplies, and in subsisting on sour flour and condemned army pork the people suffered from scurvy.

In 1824 the mines at Hazel Green and New Diggings, which proved to be rich, were discovered. However, although mining went steadily on and new finds were made from time to time, there was not much immigration into the district either in 1824 or 1825. About this time, Colonel Bomford, the chief of the Ordnance Department, upon the recommendation of Dr. Meeker, made a change in the system of collecting the royalty, the smelters being given a license and being made responsible for the 10% of the lead due to the Government. In 1825 Lieut. Martin Thomas arrived at Fever River as superintendent of the mines claimed by the Government, both in the Upper Mississippi and in Missouri. It appears from the report of Lieutenant Thomas made to Congress in 1826[1] that there were in the Fever River diggings, July 1, 1825, about 100 persons engaged in mining; Dec. 31, 1825, about 151; March 31, 1826, about 194; and Aug. 31, 1826, about 453. In 1827 the name Galena was applied to the largest settlement on Fever River, six miles from its junction with the Mississippi. The heaviest immigration into the district began in 1826. In 1829, R. W. Chandler, of Galena, published in Cincinnati a map of the lead region on the eastern side of the Mississippi River, showing the location of all the diggings, trails, and Indian villages of that time.[2]

The method of smelting in vogue in Wisconsin at this time was exceedingly primitive, being indeed substantially the same as that practised in Missouri at a considerably earlier date. The smelting was done in log and ash furnaces. The log furnace was built upon a bank so as to have a slope of 45°. A strong wall was built parallel with the bank, with transverse walls back to the bank, 4 ft. apart. The hearth consisted of a flagstone laid so that the lead would flow down into the basin in front of the furnace. Side walls were placed on the hearth, 9 in. high and 9 to 12 in. wide. In the front wall there were stoke holes, 10 in. wide by 20 in. high. Logs about 3 ft. 10 in. long and 14 in. to 2 ft. in diameter were rolled in upon the side walls, which supported them above the hearth, leaving room for small wood beneath. After the logs were set sticks of wood were placed vertically around the walls (this being called the "barking"). The ore was then put in on the logs. Each furnace, or rather each division of the furnace (the division being called an "eye," the whole furnace comprising two or four eyes), received from 3000 to 4000 lb. of ore. After charging, a slow fire was kindled under the logs and allowed to burn until the ore arrived at dull red heat, when the fire was drawn from below. The logs and barking, together with the sulphur of the ore, would keep up a moderate combustion which continued about six hours. A brisk fire was then started under the logs, causing the lead to flow down from the ore into the basin, which was kept hot by a fire maintained upon it. The whole operation of charging and smelting occupied about 24 hours.

[1] House Ex. Docs., 19th Congress, 2d Sess., ii, No. 7.

[2] A reproduction of this map is to be found in Wisconsin Historical Collections, XI, p. 400.

When a sufficient quantity of ashes accumulated they were treated by first washing them clean and then smelting them in an ash furnace. The ash furnace was also constructed on a bank, but otherwise was quite different from the log furnace. There were walls raised about 3 ft. high and 18 in. apart and 5 ft. long for the ash-pit. The original mode of making the grate was by laying rocks transversely. The fireplace was so constructed that the blaze was thrown upon the basin. The basin was constructed in an oval shape, and so that it could be tapped on both sides, one side for slag and the other for lead and zane. (Zane was undecomposed ore, which had to be resmelted in the log furnace.) From the basin there was a flue, somewhat funnel-shaped, at an inclination of 45°, with a flat hearth, and at the top there was a place to put the ashes to be smelted, the charge being pushed into the flue as it melted, running thence down into the basin. The clean ashes smelted in these furnaces were a mixture of undecomposed ore and gray sulphate and oxide of lead. The ash furnaces were kept going day and night until the bottoms of the flue and basin were cut out "by the action of the sulphurate of lead combined with heat."[1] In 1823 it was considered a good ash furnace that would run 25 tons of lead, but subsequently they were improved so that they were good for a production of 80 tons. However, both the log and the ash furnaces were highly wasteful of lead. This method of smelting was practised up to 1830 or 1831.

Early mining in Wisconsin was greatly impeded by troubles with the Indians. The latter were possessors of the land, with certain rights that were recognized. "At that time," says John N. Davidson,[2] "it seems to have been the practically accepted understanding, as well as the legal theory, that, aside from the rights of Indians, the Government held absolute ownership of land and lead. Moreover, according to the treaty of 1816, which was supplementary to that made at St. Louis in 1804 by General Harrison, the Government possessed, free from all Indian claims whatsoever, as much land as would equal in area a tract five leagues square. As opposed to the view thus implied, the Winnebagoes may have thought that the land they ceded was not to consist of portions separate from each other; indeed some of the military authorities recognized the fact that there must be limits, even within the lead region, of the right conferred by this 'five league square' cession. Thus it is probable that until after the so-called Winnebago War, possibly until after the making of the Prairie du Chien treaty of 1829, special permission, as well as a lease of the usual kind, would have been — perhaps actually was — required of any one who wished to mine within the limits

[1] Dr. Meeker, *loc. cit.*

[2] Proceedings of the State Historical Society of Wisconsin, 46th annual meeting, p. 187

of what is now Wisconsin. But before 1829 the mining districts of the white men had such boundaries only as were set by their convenience, or their fears of the Indian scalping knife."

The miners trespassed on the lands of the Indians as far as they dared. There is reason to believe that in some cases they paid more or less to the Indians in the way of rental. At all events, when the Government sought to collect royalty from such smelters as were really trespassing on Indian land, reply was made that payment had already been made to the Indians. However, it is a fair supposition that most of the miners evaded all payments if they were able to do so. Of course under these conditions the friction was dangerous and troubles with the Indians were constant. These culminated in the Black Hawk War, when in the spring of 1832 the Sacs, Foxes, and Winnebagoes, under Black Hawk, a Sac chief, began to ravage the frontier, slaughtering families and destroying many settlements. Federal troops under Colonel Taylor and Illinois militia under General Atkinson were sent against them and finally defeated them August 2 at the mouth of the Iowa, taking Black Hawk a prisoner, and putting an end to the war. This paved the way for the final opening of the country, which took place in 1833. Dr. A. G. Leonard has summarized the circumstances as below:[1]

"At the close of the Black Hawk war the large tract known as the Black Hawk purchase, including one-third of the present area of Iowa, was ceded to the United States by the Sacs and Foxes. After the completion of the treaty negotiations the miners again crossed over into the coveted region, where they built cabins and commenced to take out much ore. But a second time they were forced to leave because the treaty had not been ratified. In June, 1833, the treaty went into effect and the way was at length clear for settlers to take possession of the land. During the next few years large numbers flocked in; prospecting was actively carried on and many mines were soon in operation. The first 'legislation' in Iowa dated from 1830. In June of that year a number of miners met on the banks of the Mississippi and enacted regulations to govern them in their relations to each other. One of the articles was that 'every man shall hold 200 yards square of ground by working said ground one day in six.' Much interesting history clusters around these mines."

Up to this time the mines on the western side of the Mississippi had been held to be private property, and prospectors generally had been warned off, although in 1830 certain miners from Galena, under the leadership of J. L. Langworthy, having previously obtained consent of the Indians and also of the heirs of Julien Dubuque, crossed the river and began work. It is said that the Langworthy crevice at Dubuque, still

[1] Iowa Geological Survey, vol. VI., 1896, p. 16.

occasionally worked, was located at this time.[1] The Government held, however, that the country was not yet open to settlements. In 1832 the United States war department asserted the claim of the Government to the tract granted by Spain to Dubuque, refusing to recognize the title of his heirs, and Lieut. Jefferson Davis was sent with a detail of infantry to eject all settlers upon it. There was much dispute as to the right of the Government in this matter, but it having taken possession proceeded to sell the lands. Many years later the case came up in the Supreme Court of the United States, and the appellants — the heirs of Auguste Chouteau and John Mullamphy, of St. Louis, who claimed to have bought a certain part of the tract in 1804, from Dubuque, were defeated. In 1833 mining commenced upon an extensive scale in Iowa, the Spanish and the Indian titles having been cleared and the Indians having been put out of the way by the defeat of Black Hawk as previously related.

The settlement of the Indian troubles was reflected quickly in the statistics of production. In 1833 the production of pig lead was 6796 tons; in 1834 it was 8622 tons; in 1835 it was 9485 tons; and in 1836 it rose to 12,756 tons. This increase of nearly 100% in the period of four years was fostered by a rather high price for pig lead, which in 1835 was at the highest point between 1826 and 1854. By this time the region may be considered to have become fairly well settled. According to the territorial census of 1836 there was in Wisconsin proper a population of 6 to 18 to the square mile, which was the densest of all parts of the Territory. The important mining towns — Platteville, Linden, Hardscrabble (Hazel Green), Shake Rag (Mineral Point), Snake Hollow (Potosi), Black Leg, etc. — had been settled as well as Dubuque and Galena, and both mining and smelting had graduated to a systematic basis. The great question of the time was the transportation problem.

At first the lead of the Wisconsin region was shipped naturally down the river to St. Louis and, as the production increased, also to New Orleans, where it was transhipped for conveyance to the Atlantic Coast and for export. However, as early as 1822 a 6-ton lot of lead was shipped directly eastward to Detroit, being transported by water the whole distance "with the exception of the short portage between the Fox and Ouisconsin rivers."[2] Also some of the shot made at the tower at Helena, established in 1831, was shipped east via the Wisconsin River and Green Bay, the tower being owned by Daniel Whitney, a merchant of Green Bay and of course interested in turning trade in that direction, while moreover the markets of the lower Mississippi were controlled by manufacturers in Missouri where the shot-making industry had been conducted thrivingly since 1809.

[1] H. Foster Bain, Zinc and Lead in the Upper Mississippi Valley, U. S. Geological Survey, Bulletin 294, p. 3.

[2] *National Gazette*, Philadelphia, Oct. 19, 1822.

With pig lead the case was quite different, St. Louis being the leading market for that metal, and consequently the bulk of the output was sent thither, at first in flat-boats, later in keel-boats, and finally in steamboats. As early as 1823 the steamboat "Virginia" made a trip to Galena.

In the development of the American lead-mining industry it was remarkable and fortunate that the two districts which furnished nearly the whole of the domestic supply up to 1871 were situated close to the great natural artery affording water transportation. The mines of Missouri were only a short distance west of the river, while some of the mines of Wisconsin, which were far more important than those of Missouri (until the disseminated ore of Bonne Terre began to be worked on an extensive scale), were situated almost on the banks of the river, as at Dubuque and Galena. Bearing in mind the long years of waiting for a railway that many districts west of the Rocky Mountains suffered, it may be appreciated how much the Wisconsin district was favored by the ability of a steamboat to go to its headquarters almost at the opening of the district. Although after a while its miners became dissatisfied with the natural water-way, for many years it was the dominating influence in the development of the district. The great river steamboats carried the lead to St. Louis and New Orleans and brought back the supplies of every-day necessity. The closeness of the business relations between the mining district and the South gave the former a southern character to a considerable extent. Its newspapers were southern in tone. Its social and intellectual ties were with the South. So deep was this influence that slavery took root for a while in this part of Wisconsin, introduced naturally by the circumstances. But together with this southern tone there was a display of the exuberance of spirit which has characterized many American mining regions, especially west of the Rocky Mountains in later years. S. M. Palmer, who wrote an account of a visit to the region in 1836, described the camp of Shake Rag (now Mineral Point) as a "few scattered log huts or shanties principally ranged along a deep gorge or ravine . . . through which the road wound its sinuous way." There was a "hotel" kept by Col. Abner Nichols, familiarly addressed as "Uncle Ab." A short distance from the main building was the "grocery." "Here was to be found, at all hours, music, dancing, singing, drinking, and gambling of every description. . . . Nor were these scenes confined to the grocery of 'Uncle Ab.', for they were openly and notoriously enacted in every other similar establishment in the town! Yet, with all this appearance of licentiousness, it was principally confined to a certain class of lawless adventurers."[1] Truly this description would have applied to many mining camps in California 20 years later, in Nevada 30 years later, and in Colorado 40 years later.

[1] Collections State Historical Society of Wisconsin, VI, 301.

As the district grew, dissatisfaction with the conditions of freighting on the Mississippi began to be felt more and more, although Lieut. Albert M. Lea, U. S. A., had expressed the opinion in 1836 that "the Mississippi is and must continue to be the main avenue of trade for this country."[1] The rapids at various places, but especially at the mouth of the Des Moines and at the head of Rock Island, about 70 miles apart, caused great trouble. Steamboats ascending or descending with freight at periods of low water were compelled to discharge their cargoes into flat-boats, which in descending floated down with the current, but in ascending had to be towed up by horses or oxen a distance of 12 miles at each rapid. It was estimated that this increased freight charges 150%. At times the lead trade had to be completely suspended. A correspondent of the St. Louis *Republican* wrote in its issue of Oct. 7, 1839, that large quantities of lead had accumulated at Galena, upon which many dealers had made large advances, awaiting a rise in the river. To add to the difficulties, the cost of the supplies for the mining country was materially increased by the high freight rates, and even the shippers who could afford to pay the latter could secure the transportation only of limited quantities over the rapids. This situation was so bad that a movement was early started to induce the Government to improve the channel of the river, but before much headway was made with that scheme relief came in a natural way.

As early as 1836 shipments of lead had been made by wagon to Milwaukee and thence by lake to eastern points. In the next few years it was a common thing to see ox-teams laden with lead appear at the Milwaukee wharves after a journey of eight to ten days. At about the same time strenuous efforts were made to develop the Fox-Wisconsin, or Green Bay route, *i.e.*, up the Wisconsin River to the portage at Fort Winnebago, and thence down the Fox River to Green Bay. It was estimated that lead could be transported by this route for $9 per ton from the Wisconsin River to Green Bay, and for $9 additional to New York via the lakes and the Erie Canal, while the cost via New Orleans was $30 per ton, to say nothing of the longer time required. This was in 1839. It is doubtful if the estimates of the promoters of this Green Bay line were ever realized. The shipment of lead by that route was thoroughly tried, but it proved too long, too roundabout, and involved too much handling of the freight to make it more than a pioneer route, and it was abandoned in favor of the shorter, more direct, overland route to Milwaukee. The movement over the latter was given a great impetus by the serious difficulties of navigation in the Mississippi in 1839–1840. The main roads were considerably improved, and this change of commercial routes from the natural water-ways to transportation over artificial

[1] Notes on Wisconsin Territory (Philadelphia, 1836), p. 16.

roads over the prairies, corduroyed through swampy places, was full of significance. With it is bound up the later development of the railway system.

In 1841 the cost of conveying lead from the mines to Milwaukee was \$18.50 to \$20 per ton; from Milwaukee to New York, \$10 per ton. The time from the furnaces to New York was as short as 20 days. By the New Orleans route the cost was at times as high as \$40 per ton, and the time was 90 days or more. Besides receiving better and quicker returns at Milwaukee the producers were able to procure their supplies there more cheaply, generally, than at Galena or other points on the river. By the diversion of this trade to the east the "lead schooners," drawn by six, eight, or more yoke of oxen, secured a return freight. Thus the movement was promoted by many who were interested in increasing the trade in this direction. In 1842, when the price of lead was extremely low, commanding only 3 c. per lb. at New York and sometimes was as low as 2.5 c., and was a drug in the market, it was seized as a favorable time to try whether a fair profit could not be made by corroding the lead in the State of New York, instead of shipping the pig to England. These enterprises were well repaid and white lead works were erected at various places, including Saugerties and Buffalo, which put the smelters shipping via Milwaukee in closer touch with their customers. It was called to the attention of the State of New York that business would be furthered if the tolls on the Erie canal were reduced, which was promptly done. In 1842 lead was carried from the mines to the lake for \$10 per ton, and from there to New York for \$9. At this rate the teamsters found it a profitable business, inasmuch as they had loads both ways, carried their own provisions and the prairies afforded all that their oxen required. In 1843 contracts were made for the carrying of lead from Milwaukee to Boston for \$7 per ton. By 1842 a continuous line of steam communication had been completed from Maine to Wisconsin, stopping short of the Mississippi only about 160 miles, and the construction of a railway from Milwaukee to Galena was being urged. In the *Northwestern Gazette* of Jan. 23, 1846, there was a statement of the comparative advantages of the Mississippi route and the lake route after a railroad should be constructed. Among other things it was shown that the distance by the two routes was 4000 and 1700 miles respectively; and by the river route the freight rate on lead was \$14 per ton and by the lake route it could be \$12.20.

In spite of the increasing competition of the overland and lake route, after 1840, the Mississippi steamboats did not yield their supremacy without a struggle. We have seen how in 1846 the cost of shipment by the two routes was not far apart, and it is to be inferred that some of the comparisons unfavorable to the river route which have been mentioned previously were based on conditions when river transportation was at the worst. Although the steamboats were able to enter the interior of the lead region by some of the branch rivers, like those which ascended the Wisconsin to Fort Winnebago as early as 1837, and took lead from there to St. Louis for $10 per ton, there were from the outset some inland points of production whence the lead could be hauled to Milwaukee for only a little more expense than to Galena. But the lead originating near Galena took its natural course down the river for a long time. This is manifest from the fact that the receipts of lead at St. Louis and New Orleans were at the maximum in 1846–47, and represented the bulk of the production of the Wisconsin region, but the great commercial change which the developments of the previous 10 years had been leading up to was then impending. In the Wisconsin *Herald* of May 7, 1847, it was remarked that "So nearly balanced is the cost of transportation now, by the lake and river routes, that if the lake route had the advantage of even 50 miles of railroad, which a comparatively small expenditure of money will give it, we should see all the lead, even from the wharves of Galena and Dubuque, moving off on wheels to New York and Boston."

This forecast was soon realized. From 1847 forward there was a steady decline in the receipts of lead at St. Louis and New Orleans. At the latter port the receipts sank to 256,000 pigs in 1852, to 74,000 in 1854, and to 18,000 in 1857 and thereafter were never more than one-tenth the amount in 1847, so that in 10 years the lead trade became practically extinct in that city. At St. Louis the loss was not proportionately so large, but it was none the less decided. In 1855 the shipments were less than half of those in 1847.[1] This period — 1846–47 — marks the beginning of the predominance of the overland route and the industrial changes which culminated a few years later with the beginnings of Chicago's railway system. Up to 1841 there was no railroad in Illinois, Iowa, Missouri, Minnesota, or Wisconsin. In 1841–50, about 97 miles were completed, but by the close of 1855 there were more than 2700 miles, and 4606 miles by the close of 1860. By 1852 it was said: "All lead from the upper Mississippi now goes east by the way of Milwaukee." So strenuous did the competition of the eastern trade centers become that steamboats used then to descend from the upper Mississippi, turn up the Illinois River, and discharge their cargoes at Peru for shipment to Chicago and New York, to the chagrin of the merchants of St. Louis and the older ports further down the Mississippi.

By 1840 the production of lead in the district had risen to 13,425 tons. According to the Federal census for that year the production of the Territory of Wisconsin proper was 7565 tons, most of which went to

[1] Hunt's *Merchants' Magazine*, xvi, 96, 97; *id.*, xxvl, 325; *id.*, xxix, 572; *id.*, xxxl, 476; *id.*, xxxi, 476; *id.*, xxxvii, 604; *id.*, xxxiv, 361; *id.*, xxvii, 431–432; *id.*, xxviii, 426.

Galena. There were 49 smelting houses, employing a capital of $664,600. One out of every 38 of the population of the Territory was engaged in mining. The next 10 years saw the lead-mining industry of Wisconsin at its zenith. In spite of a rather low range of prices for the metal in the early years of the decade the production rose to the maximum figures, and a large exportation of lead to foreign countries developed. It was a cheap production and when the price of lead was normal there was evidently a handsome profit in the industry. This is manifest from the fact that average prices of 3.81 c., 3.58 c., and 3.90 c., at New York, in 1842, 1843, and 1845 respectively, did not check production. The mining and smelting methods were crude, but the ores at that time were easily mined, were rich and were easily smelted. The wages for labor were almost ridiculously low. At the Helena shot tower in 1843, the men received $10 to $13 per month; the superintendent got $16. At the smelting works the rates were about the same.[1] In spite of all complaints, the cost of delivering the lead to New Orleans and New York was not excessive, being far less than what was paid by the miners west of the Rocky Mountains when, in 1871, they began to figure prominently in the markets. Supplies were costly, it is true, but except for the subsistence of the population the mining and smelting methods of the day required comparatively little of them. The Government exacted one-tenth of the output as its royalty, which was a burden upon those who paid it, but all did not pay it, and in 1846 the requirement was abolished by act of Congress. Understanding these conditions we can appreciate how Wisconsin lead was able to compete in the markets of the world with the development for a decade of a large export trade which the United States has experienced in pig lead at no other time, either previously or subsequently.

Lead mining in Wisconsin received a brief setback in 1846 when by the McKay bill the tariff on pig lead, which previously had been 3 c. per lb., was reduced to 20% *ad valorem.* This depressed the market temporarily by allowing British manufactures of lead to enter into competition with the American, and was felt very keenly in the lead regions. The *Weekly Northwestern Gazette,* published at Galena, said on Aug. 14, 1846, "But 30 days ago lead was worth in the City of New York $4.25 per 100 lb. It is now neglected at $3.50. Here it was worth $3.05 to $3.10; now it is worth $2.50. Mineral was worth $18 to $20; now it is worth $14 to $15 per 1000 lb. On Aug. 21, 1846, the same journal said, "Within the last 30 days no fewer than 16 furnaces on this side of the Mississippi and two on the other, in all 18 furnaces, running 20 hearths, have ceased operations; and this is not all, several of the smelters speak of stopping. To all appearances, there will be a greatly diminished product of lead this fall in comparison with that of last fall." These

[1] Collections of the State Historical Society of Wisconsin, XIII, pp. 357, 360.

pessimistic remarks read like the always repeated plaints and prognostications of disaster that follow the removal of "protection" from any industry, no matter how prosperous, and were not borne out by the statistics. The new tariff went into effect about the middle of the year, but the average price at New York for the whole year was 4.73 c. per lb., while for the four years following it was 4.37 c., 4.26 c., 4.78 c., and 4.80 c. respectively. In the St. Louis market the price rose, the average being 3.425 in 1846; 3.71 in 1847; 3.68 in 1848; 4.07 in 1849, and 4.60 in 1850. Certainly there was nothing in the market conditions, except perhaps temporarily, to check lead production in Missouri and Wisconsin. This is borne out by the fact that the production which was 26,334 tons in 1846 rose to 27,042 tons in 1847, the first full year under the new tariff. In 1845 it had been 27,247 tons. It is true that in 1848 we find a recession to 23,869 tons and after that a steady decline right down to recent years, but to account for this we must seek other causes.

The causes for the wane in lead mining in Wisconsin which began at this time were primarily the exhaustion of the easily worked portions of the veins near the surface; the increased expense of working them at greater depth, and indeed the impossibility of doing so at all after the water level was reached with the methods of mining that were then in vogue (and, indeed, continued in vogue for upward of 50 years later, no general attempt to introduce hoisting engines and pumps being made); and finally the emigration of a large part of the mining population to the gold fields of California, influenced both by the great attractions of the latter and the fact that lead mining in Wisconsin had ceased to be so lucrative as once it had been.

In the halcyon days of the Wisconsin lead region there came into it many Cornish miners, unlettered, shrewd, industrious, and above all things skilful in extracting ore. They would go to mines that had been abandoned by the less skilful and more careless American miners and would make them pay. They were not given to prospecting, lacking the imagination and gambling instinct that has made American miners preëminent in that work, but with ore found they would take it out so cleanly that it was of little use for any one else to try to get any more out of that place. When the resources of the lead region seemed to be failing and a more alluring field presented itself, these miners left it as they had come to it — in throngs. "No part of our State," says a local historian, "ever lost so large a proportion of its people as did the lead region at that time." Even then many parts of the region were honeycombed with abandoned holes, and the business of picking up mineral at old mines was already turned over to the farmers and children. The restoration of the high tariff on lead in the time of the Civil War failed utterly to stimulate lead mining in Wisconsin, because there was nothing much to stimulate. Many of the mines were mere shells down to the water level. Most of the miners had gone away. The few who remained were ignorant and without resources, content to eke out an existence by feeble and desultory operations which served to maintain a small output for the district. Even the development about 1860 of a market for the zinc ore, found in association with the lead, failed to stimulate activity although it aided in keeping the district alive. The history of lead mining in Wisconsin from 1851 to 1901 may be passed over briefly by the characterization of a rapid decline and then a long stagnation.

As late as 1901 there had been little or no improvement in the methods of mining over those of 50 to 60 years earlier. Nine-tenths of the mines were still worked by horse and man power. The bulk of the ore then produced, both lead and zinc ore, was cleaned by hand sorting. Certain companies had undertaken about 1891–1895 to operate on a more modern scale, but their inability to separate the associated blende and marcasite had put an end to their enterprises. The local mines had been assisted by a natural lowering of the water level in the mines by 10 to 15 ft. during the 30 or 40 years previous to 1901, exposing much more of the veins to attack by the old methods and thus helping materially to keep the district alive. The recent rejuvenation of the district which began in 1901 or 1902 pertains much more to the history of zinc than to that of lead. Indeed, since about 1881 Wisconsin has been more important as a zinc region than as a lead region, and while at the present time it is considered to have a bright future as a source of zinc ore, the geologists tell us that there is little or no hope that its production of lead ore will ever again be important.

The Wisconsin lead region presents highly interesting geological conditions, which were early investigated by scientists and formed the subject of radical differences of opinion and earnest discussion. A brief record of this work is given in "Zinc and Lead Deposits of the Upper Mississippi Valley,"[1] by H. Foster Bain, from which the following is quoted:

"A survey was ordered in 1839 and placed in charge of that pioneer geologist, D. D. Owen. This survey was in many particulars unique; Owen began field work in September and, with the aid of a large number of assistants, finished it before winter. A report, accompanied by maps, sections, figures, descriptions, and fossils, was submitted to the Land Office on April 2 following. This report was printed without illustrations[2] in June of the same year, and a revised edition, including the omitted plates, was printed in 1844.[3] In this survey a large area, including the whole of the mining section, was traversed township by township, and the character of the rocks

[1] U. S. Geological Survey, Bulletin No. 294.

[2] House Ex. Doc. No. 239, 26th Cong., 1st sess., 161 pp., Washington, 1840.

[3] Rept. Geol. Expl. Iowa, Wisconsin, and Illinois in 1839, Washington, 1844.

was noted. In 1847 Owen executed for the Treasury Department another survey of the Chippewa land district, and in his report on that region [1] gives certain additional details regarding the lead and zinc region.

"In the course of a still later survey he visited the region again, and in his well-known quarto report he briefly discusses the geological formations present.[2] Owen was accordingly the first geologist of note who studied the region in detail, and his conclusions, based as they were upon a long and intimate acquaintance with it, are worthy of the utmost respect. It is curious to note, however, that he entirely overlooked the Maquoketa shale and confused the Galena and Niagara; and it can be readily believed that in this, as well as in his opinions respecting the deep-seated origin of the ore deposits, he was misled by the ideas then currently accepted.

"In 1854 J. D. Whitney published his Metallic Wealth of the United States. Having made certain investigations in the region in the course of private professional work, he gave a very accurate though brief account of the mines. His ideas were later elaborated in the course of his work for the three States, Iowa, Wisconsin, and Illinois, for which he successively studied the field. In his reports he covered the whole ground excellently, and it is no disparagement to others to say that together they form the most complete account of the field yet published.[3] Professor Whitney visited the region in the years of the maximum importance of the lead mines, and his observations are accordingly particularly valuable. It was, however, after his work was finished that zinc became of value in the region. Industrial conditions have also largely changed, so that there is now much of interest to be added to his report.

"Aside from Whitney and Owen, the best known of the earlier investigators in this region was J. G. Percival, who made a study of the lead region for the State of Wisconsin in 1854 and 1855. Accuracy of observation is everywhere characteristic of Percival's work, but his conclusions as to the origin of the ores and the best methods of working them seem to have been unfortunate.[4] Like Owen, he followed the current theory of the period.

"The later Wisconsin survey renewed the study of the region, and in the elaborate papers of Moses Strong [5] and T. C. Chamberlin [6] we have the most detailed study of the region extant, with, in the latter case, a notable addition to the discussion of the theoretic considerations involved."

[1] Senate Ex. Doc. No. 57, 30th Cong., 1st sess., 134 pp., Washington, 1848.

[2] Rept. Geol. Survey, Wisconsin, Iowa, and Minnesota, 638 pp., Philadelphia, 1852.

[3] Geol. Survey Iowa (Hall), vol. I, Albany, 1858, pp. 286–295, 422–471. Geology of Wisconsin (Hall), vol. I, 1862, pp. 73–424. Geology of Illinois, vol. I, Springfield, 1866, pp. 153–207.

[4] Percival, J. G., Ann. Rept. Geol. Survey, Wisconsin, 101 pp., 1855. [Second] Ann. Rept. Geol. Survey, Wisconsin, 111 pp. 1856.

[5] Geology of Wisconsin, vol. II, 1877, pp. 643–752. [6] *Ibid.*, vol. IV, 1882, pp. 365–571.

VIII

ARIZONA AND NEW MEXICO

Arizona. — Arizona has never been an important lead-producing State, but comparatively small quantities of the metal, partly derived from ores smelted locally and partly from ores shipped to other States, especially California, have appeared in the market almost from the time of the first American occupation. Previous to that time lead ores were worked by the Spaniards and Mexicans, and some of the most promising of the lead mines of the Territory at the present time are of such ancient discovery. It is a well-authenticated fact that until the rising of the Apaches many of the silver-lead mines of southern Arizona were worked with remunerative results.

Next to the mining district south of Santa Fé, New Mexico, the portion of southern Arizona embraced in what are now Pima and Cochise Counties, originally all Pima County, adjoining the Mexican State of Sonora, is believed to be the earliest scene of mining in what is now the United States. It is generally believed that the Jesuits commenced mining in Pima County about 1650, and as early as 1700 many valuable mines had been opened in what are now known as the Oro Blanco, Patagonia, Santa Rita, and Arivaca districts, in all of which old shafts, adits, and other evidences indicate ancient and extensive workings. This is supposed to be the region from which came the Planchas de Plata, which contained about five tons of prime silver, mention of which is made in Mexican chronicles. These districts were worked until 1828, when the missions were finally abandoned because of raids by hostile Apaches, and but little mining was done subsequently until the Territory came into the possession of the United States.[1]

The southern part of Arizona, known as the Gadsden purchase, was the earliest part of the present Territory to be occupied by Americans, and up to 1870, or later, it continued to be the best known. Until the beginning of the Civil War it was a part of the favorite overland route to the Pacific Coast, the staging over it being the easiest. The Indian disturbances, lack of transportation facilities, high costs of material and labor, and other impediments were, however, for a long time a serious

[1] Production of Gold and Silver in the United States, 1881, p. 301.

check to the inauguration of mining, which was engaged in only in a fitful and spasmodic manner.

It is not known at precisely what date mining was first begun in southern Arizona by Americans, but probably it was about 1850, or soon afterward. The country came into the possession of the United States only in 1848. At all events, the Sopori silver mine, a few miles south of Tucson, was developed by a New England company about 1856. The Santa Rita mines, 10 miles east of Tubac and 50 miles south of Tucson, were reported on by engineers as early as 1859. Explorations were also early made in the Colorado, or Heintzelman mine, about 22 miles west of Tubac.

The most famous of the early mines of southern Arizona was the Mowry, situated in the Patagonia Mountains, just north of the Mexican border, 20 miles from Fort Buchanan. This was one of the first, possibly the first, of the silver-lead deposits of the country west of the Rocky Mountains to be worked by Americans. The date of its discovery is uncertain, but about 1855 its owners, Mexicans, sold it to Major Ewell, then in command at Fort Crittenden, Ariz., and associates. They sold it to Lieut. Sylvester Mowry, who operated it from 1858 to 1865, or a little later, on a considerable scale. He erected smelting furnaces, and at one time, it is said, employed as many as 400 men. During this period the mine was examined by several well-known engineers, who reported favorably concerning it. In 1862 a lot of 25 tons of the ore was exported to Europe.

The principal vein, which was 3 to 4 ft. in width, and at that time opened to a depth of 83 ft., carried argentiferous galena. Guido Küstel, well known as a mining engineer, reported in 1864 that the vein was then over 14 ft. in width, occurring between limestone and granite-like porphyry, with lead carbonate and sulphide ore. The mine had then been opened to a depth of 180 ft., with four galleries. The ore contained iron, manganese, and lead in such proportions as to be self-fluxing. Smelting was carried on at the mine, but in a crude and wasteful manner. Operations, moreover, were always endangered by the liability of Indian attacks, and finally were brought to a standstill by an incursion which resulted in the destruction of the works, the tall brick chimney of the smelter remaining as the only monument of the former enterprise and activity.

According to J. Ross Browne,[1] the reports as to the Mowry mine were all to some extent exaggerated. He visited the mine in 1864, and found that the average of the ore was between $35 and $40 per ton. The lode averaged about 4 ft. in thickness. He said, moreover, that the mine had never paid expenses, but might be made profitable under judi-

[1] Mineral Resources of the States and Territories West of the Rocky Mountains, for 1867, p. 447.

cious and economical management. Here we have, doubtless, the true reason why the mine remained idle so long after the termination of Mowry's operations. It was relocated in 1872, but it was in the heart of the country infested by Apaches, and nothing but desultory work was done on it until more than 30 years later.

Of the hostile Indians in Arizona, the Apaches were the most powerful and dangerous to the country. They had been persistent enemies of the Mexicans since their rising in 1828, and their raids into Mexico often extended as far south as Durango. Up to 1859, however, they lived at peace with the Americans, but beginning with that year they waged an unremitting and relentless war on all whites. It is the testimony of the early authorities in Arizona that these Indians did more to retard the settlement of the Territory and the development of its mines than all other causes put together. The subjugation of these Indians was one of the most difficult tasks that fell upon the United States Army after the Civil War. Finally, in 1875, after many years of tedious conflict, the Apaches and other hostile Indians were forced on reservations, and not until then was the Territory freely opened to the prosecution of mining, which previously had been at many points impeded and at some points absolutely prohibited. From 1875 to 1881 there were sporadic raids by the Apaches from their reservations, but these were gradually checked.

In the vicinity of the Mowry mines there were other veins of lead ore, which had been opened to a less extent. Other lead mines were known to exist, and were prospected to some extent, in the Baboquivori, Cababi, and Sierriti Mountains, to the west and northwest of Tubac. Along the Colorado River there were lead mines in the Eureka district, 40 miles above Arizona City, now Yuma, where there was a small mining excitement in 1862; and at Castle Dome, 50 miles above Arizona City, discovered in 1863, where galena rich in both silver and lead occurred. In central Arizona, in the vicinity of Prescott, occurrences of lead were also known, but nothing of great importance. The above notes indicate the general status of lead mining in Arizona in 1867.

About 1869 operations began to be conducted on a considerable scale, in the Castle Dome district, and small but steady shipments of rich galena were made to San Francisco. Some smelting was done in the district about 1874, but San Francisco continued to be the principal market for the ores. Most of the lead production of Arizona up to the time of operations at Tombstone was derived from Castle Dome and the neighboring district of Eureka.

In 1880 mining in southern Arizona received a great impetus through the completion of the Southern Pacific railway. About the same time the mines at Tombstone were becoming largely productive. These mines were discovered by Edward Schieffelin in the spring of 1878. The name of the first claim, and afterward of the town, was suggested by the prophecies of Schieffelin's friends, who advised him on starting out that he would find no mines, but only his tombstone, the region being still infested by hostile Apaches. The success of his discoveries attracted others, and in 1879 the town of Tombstone already numbered several thousand inhabitants. Tombstone was essentially a silver camp; its lead output was never very important, wherefore it will receive only brief mention here. The mines were worked profitably until 1886 when differences arose among the companies as to pumping the great volume of water that entered the mines, and the latter were allowed to fill. According to John A. Church, the product of the Tombstone mines up to their closing in 1886 was 163,000 oz. of gold, 21,500,000 oz. of silver, and 5000 tons of lead.[1] After nearly 20 years of idleness these mines are now being reopened by a company which has consolidated them.

Tombstone was never essentially a lead-producing district, its ores being chiefly valuable for their gold and silver, which were extractable by the pan amalgamation process. There were, however, in some portions of the district ores that were moderately rich in lead, and nearly all of the ores carried some lead, which was thrown away in the mill tailings. These tailings were also rather high in silver. In 1882 the experiment was tried of smelting these tailings for recovery of their lead and precious metals contents, using the black oxide of manganese of the district as flux instead of iron. This experiment was quite successful and lead-smelting furnaces were regularly operated from 1883 until the cessation of mining operations in 1886.

New Mexico. — New Mexico was considerably more backward than Arizona in the development of its mining industry, but as a producer of silver-lead ore it eventually became a good deal more important. The existence of lead ores was early known, but scarcely anything was done toward their exploitation until 1872 when the mines of carbonate ore in the Magdalena Mountains, about 24 miles from Socorro, were worked to some extent, and a few experiments were made to smelt the ores, reverberatory furnaces being first tried, and then blast furnaces blown with bellows. The mines at Silver City were also worked at about this time, several Mexican furnaces being in operation there for the reduction of rich silver-lead ores.

As in southern Arizona, there was an important Spanish mining industry in this Territory before its conquest by General Kearney in 1847 and subsequently cession to the United States. Mining had, however, been checked by the Indian risings, in some instances previous to 1680. Early mining by Americans was also impeded in New Mexico, as in Arizona, by the raids of the Apaches and other hostile Indians.

[1] Professional Report, Jan. 22, 1902.

No very active mining of silver-lead ores was undertaken in New Mexico until about 1881. In that year small furnaces were erected at various points, and a custom smelting plant was established at Socorro to draw ores from the mines near by and from the neighboring district in the Magdalena Mountains. Socorro County has always been the most important source of lead in New Mexico. In 1882 its output of base bullion was 1040 tons, besides which about 1000 tons of ore were shipped to outside smelters. In 1883 there was a considerable increase, and in 1884 the output of the Socorro smelter was 400 to 700 tons of base bullion per month. This was obtained from ores produced at Socorro and Magdalena, the latter district being very productive. Large bodies of lead carbonate ore were also developed in 1884 in the Victoria district, Grant County, whence shipments were made to Socorro, and at Cook's Peak, Grant County, whence shipments were made partly to Socorro and partly to Deming, where a smelter had been erected.

Shipments of ore were made in 1884 from Lake Valley, Sierra County, but the rich mines of that place were silver mines, rather than lead mines. The Organ district, Sierra County, was inactive.

The various lead-producing districts of New Mexico, especially Magdalena, Socorro, and Cook's Peak, maintained a small but rather steady output until about 1901, when mining fell to a low ebb. However, smelting continued to be done at Silver City. At Magdalena, where the Kelly and the Graphic were the most important mines, the lead ore had been practically exhausted, but large bodies of zinc ore remained, carbonate above the line of oxidation and mixed sulphides below. In 1903 these mines began to be worked as zinc mines, with the prospect that they would be as valuable for zinc as they had previously been for lead.

IX

CALIFORNIA

California now occupies a very minor place as a producer of lead, but in the early days of lead mining in the States and Territories west of the Rocky Mountains it held a very important position, it being indeed the first of those States wherein a regular production of lead in commercially significant quantity was begun, the inauguration of this industry a little antedating that of Eureka, Nevada. The lead production of California rapidly increased, and attained very respectable proportions even in comparison with the great production of Nevada and Utah.

The lead production of California was first derived from the mines of the Cerro Gordo district, in Inyo County, on the ridge of the Inyo Mountains, opposite Owens Lake. It was known as early as 1865, perhaps earlier, and like many mining districts in that part of the country was discovered by Mexicans. They worked the ores for some time in a primitive manner, smelting them in vasos, but the district did not attain importance until 1869, when some of its mines were taken in hand by Americans, especially V. Beaudry and M. W. Belshaw, who erected larger smelting furnaces, and after a great deal of experimenting succeeded in successfully fluxing the ores. The production of the district in 1869 was about 1000 tons of base bullion. During the seven years, 1869–1875, the production was as follows: 1869, 1000 tons; 1870, 1500 tons; 1871, 2000 tons; 1872, 3220 tons; 1873, 4000 tons; 1874, 5600 tons; 1875, 3600 tons.

The ore of Cerro Gordo was chiefly galena, averaging very high in silver and lead. It was found generally in contact veins of 8 ft. and more in width, occurring between formations of limestone and talcose slate. The veins were workable to considerable depths through adits, the ore was easily and cheaply mined, and save for the scarcity of water in the district and the high cost of transportation on material in and out the conditions of mining and smelting were favorable.

The district was reached by wagon road from Los Angeles, from which it was distant 286 miles in a northeasterly direction; or by stage from Reno on the Central Pacific Railway. The charges for freight out of the district, in 1869, were 6 c. per lb. to Los Angeles, and on inward freight from 3 to 6 c. per lb.

The smelting of the ore of the district early fell into the hands of V. Beaudry, the firm of Belshaw & Judson, and the Owens Lake Silver-Lead Co. The method adopted consisted in sorting the ore to a rather clean product of galena, slag-roasting in "galenadores," a Mexican form of reverberatory furnace with sloping hearth, and smelting in small blast furnaces, the last being gradually improved in dimensions and design. In 1874 Beaudry's furnace was remodeled to dimensions of 34×40 in. at the tuyeres, 48×52 in. above the bosh, and 9 ft. in height above the tuyeres. It had five 3½-inch tuyeres and was blown by a No. 6 Root's blower. The charge per 24 hours consisted of 7⅞ tons of charcoal, 25 tons of lead ore, 1¾ tons of silicious silver ore and 2 tons of slag, a total of about 27 tons of ore and 29 tons of charge. The cost of smelting was as follows:

7⅞ tons charcoal	$261.25
3 smelters at $4	12.00
3 helpers at $4	12.00
3 chargers at $4	12.00
2 enginemen at $4	8.00
2 foremen at $8	16.00
12 roustabouts at $4	48.00
Water	25.00
Repairs, supplies, etc.	75.00
Total	$469.25

On 27 tons of ore, this came to $17.38 per ton. The cost at Belshaw & Judson's works was about the same. Each furnace would turn out about 9.07 tons of pig lead per 24 hours, showing an extraction of about 36 units of lead per ton of ore, and indicating an average assay of 45 to 50% lead in the ore smelted. The bullion assayed about 140 oz. silver per ton. It was estimated that the lead value of the bullion would pay the cost of mining, smelting, and transportation to San Francisco, where the bullion was refined at cost of $25 per ton, the silver value in excess of $25 per ton being profit.

The two principal smelters, who entered into a species of combination, conducted a very successful business, both in mining and smelting, the purchase of ores from other miners being a prominent feature in the latter branch, and complaints were early made at the rates charged by the combination which much resembled the grumbling in other camps at a later period. From the historical standpoint the early work in the Cerro Gordo district, displaying intelligence and good business management, is particularly interesting in view of the bungling failures which were being experienced contemporaneously at so many other places in the West.

In 1875 the production of Cerro Gordo fell off because of litigation which closed the Union mine, one of the large producers, and the district never regained its previous importance. This was of course due not merely to the litigation, but rather to impoverishment of the mines and inability to work profitably the lower grade of ore under the existing conditions. The scarcity of water, distance from fuel, the altitude and extreme grade from the valley, all militated greatly against mining operations. By 1881 only three companies were operating and their production was small. All of the old furnaces, which previously had been so profitable, were idle. Great quantities of ore averaging in value from $25 to $30 per ton were said to have been left untouched, their value being barely sufficient to cover the cost of extraction and reduction. The real difficulty appears to have been, however, the character of the veins, which would in places swell into great ore-bodies such as those early opened in the Union mine, and further on would pinch out so as to be hardly traceable. In 1904, after a long period of idleness, steps were taken to reopen these mines.

In 1874 large deposits of argentiferous lead carbonate and sulphide ore were discovered in the Darwin district, Inyo County, and soon afterward several furnaces were erected. Other small lead-producing districts were subsequently found in various portions of Inyo County, but none of them has ever become an important source of lead, although some of them, including the Darwin district, have been worked in a desultory manner up to the present time.

X

COLORADO

Colorado was practically first explored in 1859, the year of the Pike's Peak excitement. No gold was then found in the vicinity of Pike's Peak itself, although it is interesting to note that more than 30 years later the mines of Cripple Creek, one of the greatest gold discoveries in America, were found within the shadow of the peak. The early pioneers penetrated the mountains in various directions, and among other less important camps located those of Georgetown, Central City, and Oro. The last was within the limits of what later became Leadville, but the original workings were for gold in the placers of California Gulch, and the existence of silver-lead ore did not become known until many years later.

The mines at Georgetown, in Clear Creek County, were discovered in 1859. During the next two years there was a rush to these mines from other parts of the State, and several smelting works were erected, but none of them was able to beneficiate the ore to advantage. Various processes were tried, among others the Scotch hearth, which had proved so successful in smelting the non-argentiferous galenas of Missouri. Their operation was not understood, and no lead could be produced until by the assistance of a colored man who had worked in Virginia the ore was made reluctantly to give up some of its lead, though not enough to encourage further work. The Scotch hearth was not of course adapted to the smelting of these galenas, rich in silver, under any circumstances, and the experiments at Georgetown were doubtless tried with ore too low in lead, and comparatively high in the zinc blende which characterizes the veins of Georgetown and Silver Plume. The silicious and zinky character of the Georgetown ores, together with their low content in iron, made them ill adapted to blast-furnace smelting, and although numerous furnaces were erected from 1861 to 1869, only one or two concerns achieved any success.

In 1869, ten years after the first immigration, Colorado west of the main range was still practically unknown. Some discoveries of nugget gold had been made in the gulches at the heads of Ten Mile Creek and Blue River, and some strong galena lodes had been discovered in Fletcher Mountain, which a Boston company was developing. A wagon road from Georgetown to Snake River was nearly finished and two or three concerns were erecting reverberatory furnaces. Numerous strong galena-bearing veins had been located, but few of them had been developed. A little smelting was done at Georgetown, but most of the rich galena ores produced in that vicinity were shipped to New Jersey for reduction.

The Comstock mine, at Saint John, near Montezuma, Summit County, was opened in 1870 by the Boston Silver Mining Association, and a few tons of its galena ore were smelted in a small blast furnace. A larger and better ore dressing and smelting plant was completed in 1872. These operations are of considerable interest since they may be considered the first serious attempt to conduct lead smelting in Colorado, and several engineers who subsequently became eminent in the profession received their training at these works. The ore was slag-roasted and smelted in a blast furnace with excellent results.

In 1873 the mines near Rosita in the Hardscrabble district, Fremont County, which had been discovered in 1870, began to attract considerable attention, and some attempts to smelt the ore were made, not however with success, the cause of the failure being the same as in so many of the early, abortive attempts, viz., defective construction and ignorance of the smelting process. About the same time, the Homestake mine in the Sawatch Range, near Homestake Peak, opposite the head of the Arkansas River, and not far from where Leadville was to be, had been opened, and in 1875 a smelter was built at Malta, at the mouth of California Gulch, to treat the ore from this mine and others which it was expected would be developed in that region. However, the smelter did not prove successful.

In 1874 lead ores were shipped from Colorado to Chicago, Ill., to Wyandotte, Mich., to Pittsburg, Penn., to Swansea, Wales, and to Germany. Experiments in smelting were made at Lincoln City, in French Gulch, near Breckenridge, where 216 tons of pig lead were produced in a four months' run. The ore was obtained from the Cincinnati (or Robley) lode, which had been developed so as to be capable of producing 10 tons daily of almost pure galena. The works were operated by Spears & Conant, who in the summer of 1873 put up a small reverberatory furnace, which did not prove successful. In 1874 a blast furnace was substituted, and this not proving satisfactory alone two Drummond furnaces were added. The bullion was shipped by pack train and wagon to Denver, whence it went by rail to Chicago. There were in Colorado in 1874, besides the Lincoln City works above mentioned, a plant at Hall Gulch (Park County) with three blast furnaces and nominal capacity of 40 tons of ore per day; a plant at Golden with one slag furnace and one blast furnace, nominal capacity of 12 tons per day; and one at Denver with two roasting furnaces, one blast furnace and a Balbach refining plant, nominal capacity 20 tons per day. None of these plants was in continuous operation throughout the year.[1] According to F. F. Chisholm the total production of lead in Colorado in 1874 was only 312 tons.[2] However, this estimate is too low, inasmuch as a large quantity of lead-bearing ore was shipped to eastern smelters. The status of lead smelting in Colorado at this time was quaintly put by T. F. Van Wagenen,[3] who said, "Whether Colorado ores are really as rebellious as in past times they have been supposed to be, or whether this Territory is supposed to be a legitimate and proper field for the trial of every new and outrageous idea that is hatched by would-be metallurgists, it is certainly true that the metallurgical industry here grows slowly, and does not show anything like the advance that is necessary to keep pace with the increasing ore product. This is evidenced by the quantity of high-grade ores that are shipped to the Eastern States and to Germany. . . . Even in the older towns and under the shadow of former failures can be found evidences of the same disregard of science and experience which nearly wrecked the young community in 1862–66." The Hall Valley Smelting and Mining Co. had erected a dressing works and smeltery regardless of expense. The mineral produced in the former was trucked to the furnace room. "Here the trouble commences," remarked Mr. Van Wagenen. However, Dr. Raymond, with his usual perception, expressed the belief that in a few years but little ore would go out of Colorado, except to Germany or to points in the East where fuel and labor are extraordinarily cheap. It required less than 10 years to fulfil this prophecy.

There was nothing particularly noteworthy in lead mining in Colorado until in 1876 and 1877 the discovery of carbonates at Leadville created an excitement which by 1878 attained a height superior to anything experienced in the United States since the early days of the Comstock lode. In comparison with this the rushes to Eureka, White Pine, Pioche and the Cottonwoods faded into insignificance. The idea was early grasped that here it was not a case of a single group of valuable mines, but rather that an extensive area of territory was mineralized with immense deposits of ore, rich in lead and silver, lying near the surface and easily mined. The experience of the next two or three years proved that in this idea there was no mistake.

The history of Leadville is one of the great romances of mining, but in a work of the present character it is impossible to dwell too long upon its many absorbing events not directly connected with the economics of the industry. In the midst of the ore deposits of Leadville there had been a mining camp, called Oro, since 1860, when some of the pioneers of the Pike's Peak excitement of 1859 pushed up the Arkansas Valley

[1] Mineral Resources West of the Rocky Mountains, for 1874, pp. 386–388.

[2] Mineral Resources of the United States, 1882, p. 310.

[3] Mineral Resources West of the Rocky Mountains, for 1874, pp. 358–388.

and found placer gold in California Gulch. The placers proved fairly productive, but the climax was soon reached and after the first year the population of the district began to dwindle and within three or four years there were only a few hundred remaining. In 1876 a few of the old placer miners were still at work, eking out an unsatisfactory existence.

However, the placers of California Gulch were the direct lead to the discovery of the carbonates. In April, 1874, Mr. A. B. Wood, of Detroit, Mich., an experienced mining engineer, went to California Gulch to work the Star placer.[1] In examining the gravel he noted the "heavy rock," so called by the miners, and identified it as lead ore. He immediately began searching for its source, and in June, 1874, found ore in place on the present Rock claim, on Dome Hill. He continued his prospecting, but made no locations, waiting for the titles to the abandoned placer claims, covering all the ground adjacent to California Gulch, to expire, which they would do in the next year. In the meanwhile he studied the geology, and in the spring of 1875 was able to point out to W. H. Stevens, of Detroit, and Prof. H. Beeger, of Alma, Colo., the outcrop of the vein in the Lime, Rock, and Dome claims. During the following summer these and other claims on Iron Hill were located by Wood and Stevens in the interest of Detroit parties; they formed the basis of the Iron Silver Mining Co., which it may be remarked in passing is one of the important mining companies of Leadville at the present time. The first ore was extracted from the Rock claim. In the summer of 1876 rich ore was found in the Iron and Bull's Eye claims.

In 1876 August R. Meyer was at Alma, just over the Mosquito range from Leadville, as agent for the St. Louis Smelting and Refining Company. He was naturally attracted by the reports of the new discoveries, and visited them for the purpose of buying ore. In the fall of 1876 he shipped 200 to 300 tons by wagon to Colorado Springs (at a cost of $25 per ton) and thence by rail to St. Louis. The ore, which assayed 60% lead and 7 oz. silver per ton, yielded a profit in spite of the high charges, and thus it having been proved that the mines could be operated successfully, prospecting was undertaken vigorously. Late in the fall of 1876 the Camp Bird mine on Iron Hill was discovered; in the winter the Long & Derry, on the hill of that name; in the following spring and summer, the Carbonate and Shamrock mines on Carbonate Hill. Then followed the Little Pittsburg and Chrysolite on Fryer Hill. These mines were far apart, indicating a great area of mineral district. Prospectors, miners, promoters, and all the camp followers rushed in. New discoveries multiplied rapidly. Immense amounts of ore were taken out from imme-

[1] It is worthy of note that the Comstock lode and the carbonate ore of Leadville were both discovered by educated mineralogists, the former by the Grosh brothers (see *Engineering and Mining Journal*, Feb. 27, 1892), and the latter by A. B. Wood.

diately under the surface. Mines were bought and sold at advancing prices with marvelous rapidity. The Leadville boom was inaugurated.

The natural conditions which stimulated the unparalleled excitement at Leadville were concisely expressed by a writer in the *Engineering and Mining Journal* of May 7, 1881, who said: "If the mineral deposits of Leadville were set upon edge like the fissures of Nevada, they would make a few mines equal in depth and richness to the famous Comstock lode, and there would be a few colossal fortunes, varying from $25,000,000 to $60,000,000, accumulated. As these deposits are, however, comparatively horizontal, the district embracing them is emphatically the people's mining district, and benefits a far greater number of individual operators and companies than any other camp yet discovered."

In the spring of 1877 a petition was made for a post-office. Mr. August R. Meyer proposed the names Cerussite and Agassiz, which were objected to as being too scientific. Mr. A. B. Wood proposed Lead City, which was rejected because of possible confusion with the town of the same name in the Black Hills. The name Leadville was finally adopted as a compromise. In the fall of 1877 the population of Leadville was 200. In the spring of 1878 it was incorporated as a city. In 1880 it had a population of 15,000, a full equipment of municipal improvements, together with schools, churches, and hospitals, 30 producing mines, and 14 smelteries with an aggregate of 37 blast furnaces, of which 24 were in active operation. The first smelter had been built by the St. Louis Smelting and Refining Co., under the direction of August R. Meyer. It was known as the Harrison Reduction Works, in honor of Edwin Harrison of St. Louis, stood on the side of California Gulch, at the foot of Harrison Avenue, and was one of the successful plants of the camp, continuing in operation into the nineties. The Grant smelter was next erected. (This was burned in 1882, after which Grant, Eddy & James rebuilt at Denver, their works there becoming one of the great metallurgical establishments of the United States.) The third plant at Leadville was that of Berdell & Witherill, subsequently known as La Plata. After that the number of works increased rapidly.

According to the statistics of the Tenth Census, the production of the mines of Leadville in the year ended May 31, 1880, was 152,241 tons, which averaged a little less than 70 oz. silver per ton. The smelters treated 140,623 tons of ore and produced 28,283 tons of work-lead, which contained an average of 285 oz. silver per ton. Data obtained from eight of the principal smelters, in operation at that time, showed that the average yield of a ton of ore was 65.64 oz. silver and 19.94% of lead.[1]

The statistics of Leadville's production of lead to the end of 1905

[1] S. F. Emmons, Geology and Mining Industry of Leadville, p. 17.

may as well be given here as later. For comparison the figures for the State of Colorado are added. The output is stated in tons of 2000 lb.:

Year	Leadville	Colorado	Year	Leadville	Colorado
1877	835	897	1892	22,211	61,500
1878	6,000	6,669	1893	[a]20,000	43,698
1879	22,500	23,674	1894	22,367	50,613
1880	34,000	35,674	1895	[a]17,380	46,984
1881	37,200	40,547	1896	[a]12,150	44,803
1882	48,020	55,000	1897	11,850	40,400
1883	[a]60,000	70,557	1898	17,973	56,708
1884	46,814	63,165	1899	24,299	69,024
1885	36,100	55,000	1900	31,300	82,137
1886	48,500	59,000	1901	28,180	74,056
1887	47,000	63,000	1902	19,725	53,152
1888	45,500	[a]65,500	1903	18,177	50,757
1889	50,500	68,000	1904	23,590	53,773
1890	[a]35,000	[a]52,500	1905	26,424	57,856
1891	[a]32,000	64,000	1906	23,918	52,992

[a] Estimated.

The statistics for the years 1877–1893 are from The Mineral Industry, vol. II, pp. 389–390, wherein the method of their compilation is described, except that the Leadville figures for 1881, 1882, and 1884 have been revised as per the Mint Reports for those years. While these statistics are probably not absolutely correct, they may be accepted as reasonably close approximations. The statistics for Leadville's production in 1895 and 1896 are estimated from reports in the "Production of Gold and Silver" (Director of the Mint) for those years, while the statistics for Colorado's production in 1894–1896 are from the reports of the U. S. Geological Survey. The statistics for 1897 and subsequent years are those of the Commissioner of Mines of Colorado.

The production of Leadville was checked for a few weeks in June, 1880, by a strike of the miners, which closed practically all of the mines of the camp, but nevertheless the output for the year showed a large increase over the previous year, amounting to 238,000 tons of ore, which yielded 34,000 tons of lead. At the end of the year there were 32 furnaces in the camp, of which 27 were in blast. The mines of Fryer Hill, made famous by the Little Pittsburg, Chrysolite, and Little Chief, were already decidedly on the wane, and this year suffered from a serious underground fire. The Little Pittsburg, which had produced over $4,000,000 in 1879 (of which $1,050,000 was profit), produced hardly anything in 1880.

Outside of Leadville the lead production of Colorado was still insignificant. In Custer County the Bassick and Bull-Domingo mines were producing, while lead ore was mined in small quantities at Kokomo, Red Cliff, Aspen, and in the Gunnison and San Juan countries. At certain of these points little smelteries were operated.

Reference may be made here to the extensive litigation over titles which proved costly and troublesome in the early history of Leadville. This was in connection with the pernicious law of the apex, which had previously been a prolific source of trouble in the mining camps of the West, especially at Eureka, but was worse in its effects at Leadville than elsewhere. Wood and Stevens had carefully located the outcrop of the blanket vein on Iron Hill, expecting to hold the deeper levels behind their claims. Litigation naturally arose over this, in which the Iron Silver Mining Co. was especially involved. The cases began to be decided in 1880 and 1881 and generally went against the Iron Silver company. The result was to make Leadville an unqualified side-line camp, *i.e.*, one in which by tacit consent the law of the apex was disregarded and mineral rights were held only within vertical planes projected downward from the surface lines of each piece of property.

In the silver-lead industry Leadville historically holds a high place, not only for the great magnitude of its production, but also because it put the finishing touches, so to speak, on the metallurgical industry, which had its first development at Eureka and Salt Lake 10 years previous. As we look back it is marvelous to consider how much was achieved in the 15 years from 1870 to 1885. The works of 1870 were petty affairs, even at Eureka. Those at Leadville in 1885 were already big plants that would compare not unfavorably with any of the works in operation in 1900. Subsequent to 1885 the improvements were mostly in details.

Eureka was the birthplace of the silver-lead smelting industry, but the work there was the smelting of ores of single mines. The Salt Lake Valley was the birth-place of the custom smelting business, *i.e.*, the purchase and treatment of miscellaneous ores. But it was at Leadville that custom-smelting received its great impetus. The ores were produced by many mining companies, few of which had any incentive to erect private smelteries; such as did so were quite unjustified in the undertaking. The ores were of varied character, affording ample opportunity to compound good smelting mixtures. The field was a superb one for shrewd buyers aided by expert smelter managers. Many of the early smelters failed after a few years of operation, but a considerable number achieved great success and laid the foundations of fortunes which continued to be employed for many years as capital in the lead smelting and refining business.

In the chapter on metallurgy the important features in the metallurgical practice in the early days of smelting at Leadville are described. This subject is exhaustively treated in the report of Antony Guyard, incorporated in Emmons' monograph on the "Geology and Mining Industry of Leadville." This report was made in August, 1880. At that time six of the 16 smelting works of the district had already ceased running. The first cost of the plants ranged generally from \$20,000 to \$95,000. One only had cost upward of \$100,000, its figure being \$160,000. The rate generally paid for ores was 95% of the New York price for silver, 20 to 25 c. per unit (20 lb.) for lead, and \$18 per oz. for gold (but only when its amount exceeded 0.1 oz.), minus \$16 to \$25 per ton. The dolomite flux then employed cost \$3.50 to \$4 per ton; charcoal, 10 and 18 c. per bushel; coke \$25 to \$30 per ton. The smelting of a ton of ore required 0.125 part of dolomite, 0.065 part of iron flux, and 0.32 part of fuel. On the basis of the furnace charge the fuel was 23.3%. The average percentage of lead extracted in smelting was 88; of silver, 96.5. The average cost of smelting was \$15.25 per ton. The general wages were \$4 per 12 hours for head smelters, \$3.50 per 12 hours for feeders, \$3 per 12 hours for slag wheelers, and \$2.50 per 10 hours for laborers. The freight on base bullion to the East was \$35 per ton.

The following estimate of the economic conditions in smelting at a plant of two furnaces is given as illustrative of the conditions in July, 1880. The quantity of ore smelted per 24 hours was 48 tons. The details of operating expense were as follows:

3.25 cords wood for steam raising at \$4.75	\$15.44
2 foremen at \$6 and \$4	10.00
8 smelters at \$4	32.00
26 helpers at \$3	78.00
65 laborers at \$2.50	162.50
17 tons of dolomite at \$3.50	59.50
2.75 tons of iron flux at \$9.50	26.12
9.25 tons charcoal at \$18.57	171.77
7 tons coke at \$37.50	262.50
Repairs and renewals	116.27
Total	\$980.60
or \$20.43 per ton.	

The cost of 48 tons of ore containing 34% lead and 41.5 oz. silver per ton at 95% of the price of silver (\$1.14 per oz.) and 15 c. per unit for the lead, less \$20 per ton, was \$1461.06. The product was 14 tons of bullion, containing 136 oz. silver per ton, which was worth (after deducting the refiner's charge of \$14.50 per ton) \$3226.44. There was therefore a profit of \$784.78, or \$16.35 per ton.[1]

I think, however, that the above estimate somewhat overstates the profit, inasmuch as the value of the lead in the bullion is reckoned at 4.5 c. per lb., while the bullion is reckoned at 100% lead, and no allowance

[1] Emmons, Geology and Mining Industry of Leadville, p. 669.

appears to be made either for freight on bullion to the refiner, or the refiner's discount on silver and lead. It is stated on p. 692 of the same report that the price of lead in bullion at Leadville during the year ending June 1, 1880, varied from \$30 to \$78 per ton, the average being \$60 to \$72. The freight to the East was \$35 per ton. The refiners paid for the silver at the New York price less 3 c. per oz., and in some cases deducted 100 lb. of lead per ton of bullion, besides which there was a refining charge of \$14 to \$15 per ton.

After 1880 the improvement in smelting methods was very rapid. The grade of the ore smelted declined both in silver and lead. Competition among the smelters reduced the margin in the purchase of ores, and consequently the profits in smelting, the price to the miners being correspondingly increased. The plants of inferior design, construction, and management were eliminated and smelting came down to an even and orderly basis. In April, 1881, the total number of furnaces in operation was 31, which treated 650 to 700 tons of ore per day. In 1885 the only plants in operation were the Arkansas Valley, American, La Plata, Harrison, Elgin, and Cummings & Finn. In 1886 the last had gone out of operation and had been dismantled. A few years later La Plata was abandoned. The remainder continued in operation until 1893, when all were closed down during the silver panic. After that the Elgin was operated fitfully for a little while, but the Arkansas Valley was the only one of the old works to be continued in regular operation. It resumed in January, 1894, with a reduction of 10 to 15% in the wage scale. This plant has been greatly developed and modernized and is now one of the most important of the American Smelting and Refining Co. The Union Smelting Co., a new concern, operated at Leadville in 1894, and for a few years subsequently.

The decline of Leadville as a smelting center, beginning in 1882 or 1883, was due largely to the competition of smelters at Denver, Pueblo, Kansas City, and St. Louis, which caused a bitter fight extending through several years. A plant had early been erected at Pueblo by Mather & Geist. In 1882 (May 24) the Grant smelter at Leadville was destroyed by fire, and its owners with a clear perception of future developments rebuilt at Denver. In 1883 the Colorado Smelting Co. erected works at Pueblo. The competition of the eastern and valley smelters, which the Leadville smelters were beginning to feel seriously in 1883, had become so strong in 1884 that out of the Leadville output of 46,814 tons of lead, they bought and produced 11,333 tons. They required the ferruginous ore of Leadville to flux the ores obtained from other districts, and to get it they bid up the price to a point where the Leadville smelters were forced to pay more than it was worth, *i.e.*, under their conditions. The valley smelters had the advantages of cheaper fuel and labor, and the command of a broader ore market, in fact the whole State of Colorado, while tributary to Leadville there were only a few camps, especially Red Cliff and Aspen. On the other hand, the ore that was shipped from Leadville to Pueblo and Denver had to pay $5 per ton railway freight, which the Leadville smelters escaped. But their bullion product was taxed $12 per ton, a disproportionately high rate, and with this and other railway discriminations against it, smelting at Leadville ceased to be very profitable. Only the excellent furnace work and strict economy of the Leadville smelters enabled them to survive.[1]

According to the report of La Plata Mining and Smelting Co., for the year ending June 30, 1885, as much as $40 per ton was paid for lead in ore when only $32 per ton could be obtained for lead in bars. For this reason, the furnaces were run only 77% of the time, and smelted 42,491 tons of ore at an average cost of $9.31 per ton, divided as follows: Labor, $2.64; supplies, $0.22; assaying, $0.04; transportation, $0.03; fuel, $5.11; flux, $0.72; water, $0.02; general expense, $0.63; total, $9.31. This figure was considerably higher than at some of the other works at Leadville at the same time. Out of the 24 furnaces in the six works at Leadville, only 15 were running in June, 1885. The shortage of lead was so great that some works were obliged to resmelt their bullion in order to provide sufficient collecting agent in the furnace charge.[2]

The lead ore originally smelted at Leadville was carbonate. Below the water level, however, the ore was sulphide and this was soon opened by the mines back of the outcrops. The comparatively small amount of sulphide ore at first produced was charged raw into the blast furnaces. None of the smelters at that time was provided with roasting furnaces. The output of sulphide ore increased rapidly and about 1883 the smelters began to erect roasting furnaces. By 1885 all of them were thus equipped.

The rise of the valley smelters was accompanied by a great increase in the production of lead in Colorado outside of Leadville. In 1881 there was a production of 1190 tons of bullion in the Ten Mile district (Robinson and Kokomo) and a little elsewhere in the State, but Leadville still furnished upward of 90% of the total. The next year saw a great increase in the outside production, Red Cliff and other camps beginning to yield considerable ore. In 1883 smelting was begun at Aspen, and the mines of the Monarch district began to be productive. From 1883 to 1890 a large quantity of lead in the aggregate was derived from Red Cliff, Aspen, and Monarch,[3] but their mines had nothing like the

[1] *Engineering and Mining Journal*, May 9, 1885.

[2] *Engineering and Mining Journal*, July 4, 1885.

[3] The Monarch district produced about 10,000 tons of lead in 1885, but after that its output gradually fell off, amounting to 7600 tons in 1887, 5700 tons in 1888, and less than 3000 tons in 1889.

magnitude of the great deposits at Leadville. More or less lead was obtained also in the San Juan, where there were smelters at Rico, Durango, Lake City, and elsewhere. After 1886 the mining industry of Colorado experienced a great expansion; by that time most of the important mining districts of the State had been reached by railways; the custom smelting business at Denver and Pueblo had been broadly developed; and ores carrying more or less lead, the amount of which was large in the aggregate, were received from many sources.

It was along with the establishment of the valley smelters that the important metallurgical and commercial difference, to which I have several times referred, began to be developed. Lead ore came to be no longer valuable only for its own metallic contents, but acquired an additional value because its lead was useful as collector for the gold and silver in smelting silicious and other ores which contained no lead, the so-called "dry ores." As the supply of those ores increased more rapidly than the supply of lead ores, the smelters were no longer able to run furnace charges containing 20% or more of lead as in the early days at Leadville; but as the extraction of the precious metals suffered when the percentage of lead in the charge went below 12%, there was created a strong competition for lead ore to bring up the average of the charge and a higher price was paid for it than its own metallic contents would justify. We shall see, later on, that this became an important question in connection with the importation of lead ores from foreign countries and the tariff on them.

As early as 1885 the shortage in the supply of lead ore in Colorado, from the standpoint of the silver-lead smelters, was acute. The situation which arose in that year is well summarized by P. S. Wilson in the report of the director of the mint on the "Production of Gold and Silver in the United States," for 1885, pp. 133–134, who says:

"The method of smelting has been changed considerably during the year, owing to the fact that the supply of lead has fallen below the demand. The smelters have been forced to use less lead, and to give preliminary roasting to rebellious ores, instead of charging them raw, in small quantities, as heretofore. They have also contracted for the entire output of heavy lead producers, or purchased outright mines of this character, to procure the amount absolutely necessary for their furnaces. . . . The cupellation of base bullion has become necessary in Leadville through the scarcity of lead ores and the excessive quantity of dry ores that the mines have been yielding of late. The competition for the purchase of lead ores has been so great that the prices paid have had the effect to greatly reduce the smelters' profits, and in instances to cause loss instead of profit. For the first six months of the year the quoted price of lead averaged 3⅝ c. per lb., but the price paid the miner was higher than the quotations justified. The last six months the quoted price ruled from 4 c. to 4⅞ c., and the smelters paid proportionately higher rates to the miner. During the entire year the price paid was higher than the average of market quotations."

This serious condition was somewhat ameliorated in 1886 when carbonate ore, rich in lead, began to be imported from Sierra Mojada, Mexico, but the stringency continued nevertheless, and at certain times was acute, the smelters being obliged to run charges as low as 7% in lead, which was far too little to insure a proper extraction of the precious metals. The letting of the contracts for the large outputs of good carbonate ore remaining at Leadville was an interesting event of each year, and ordinarily these ores fetched full market values for their silver and lead without any deduction for smelting, a loss to the smelters which they were obliged to make good out of other ores. After the passage of the McKinley bill in 1890, which led to the establishment of smelters in Mexico and the cutting off of that supply of lead ore, the situation became very bad, especially as at about this time the last of the big bodies of carbonate ore at Leadville was worked out. It was not until 1896–1900, when the production of the Cœur d'Alene increased largely, that the supply of lead ore became ample. We have seen two times since 1900 when it was too large and restriction became necessary. During the last 10 years, and at the present time, the silver-lead smelting industry of the United States has been and is based on the Cœur d'Alene production. The control of that means practically the control of the entire industry.

The remainder of the history of lead in Colorado may be summarized very briefly. The output of Leadville attained its maximum in 1883, continued at high figures until 1890 and then declined rapidly owing to the exhaustion of its ore-bodies, although the tonnage of other kinds of ore increased, and at the present time Leadville ranks first among the mining districts of Colorado in that respect. The increase in the tonnage was directly stimulated by the improvements in mining and smelting practice and reductions in the freight rates, which enabled lower and lower grades of ore to be mined, while the decline in the production of lead occurred in the face of these improved conditions. By 1892 the bodies of high-grade carbonate ore had practically been exhausted. The cost of smelting at Leadville in 1880 was about $15.25 per ton. In 1900 it was only $4 per ton. The cost of mining in the large deposits of sulphide ore had come down to only a little more than $2 per ton, and a few years later was only $1.75. The freight and refining charges on bullion had also experienced great reductions. There were corresponding economies in the treatment of ore at Pueblo and Denver, which stimulated the mining of lead-bearing ores in many parts of the State, and thus maintained the total lead output at a high figure. Subsequent to 1890 there was no new discovery of lead in Colorado except the mines of Creede in 1891, and those were of no great importance, although they have been steady producers. The large decrease in the production of lead in Colorado in 1893 was due to the great fall in the price of silver, together with the low price for lead, which compelled many mines to suspend operations. The lead-mining industry of the State continued at a low ebb during the four years following, due chiefly to the low price prevailing for lead. In 1896 a strike of the miners for higher wages checked production at Leadville. From June 1 to September 20 (when a violent attack was made against the Coronado mine) every important property was idle. Operations were then resumed with the aid of imported miners, under the protection of the State militia, although the strike continued.

The next year, 1897, marked the depth of depression in lead mining in Colorado. The prices for silver and lead were low and labor troubles were prevalent in many mining districts. In explaining the decrease in production, The Mineral Industry for that year said: "The great deposits of silver-lead ore at Leadville are now practically exhausted, and the Arkansas Valley Smelting Company, at present the only concern with lead furnaces in blast at Leadville, was obliged last year (in 1897) to buy Cœur d'Alene lead. The old mines of Fryer, Carbonate, Iron, and Rock hills, which were formerly the chief sources of lead ore, are for the most part abandoned to lessees. The latter make a considerable production by working around the old stopes and occasionally come across a new pocket of ore, but no important discovery is to be expected since the ground has been so thoroughly prospected. . . . The miners of the district have been helped considerably by concessions from the railways with respect to freight rates to the valley. Early in October the freight rate on high-grade ore was reduced from $4.45 per ton to $3." It is interesting to compare the smelting rates on carbonate ore at this time (1897) with those which prevailed in 1880. Silver was paid for at 95% of the New York quotation and gold at $19 per oz. The payment for lead and the deduction for smelting were as follows:

5–10 % lead	35 c. per unit	$7 treatment
10–15 % lead	35 c. per unit	5 treatment
15–20 % lead	40 c. per unit	3 treatment
20–25 % lead	42 c. per unit	2 treatment
30–35 % lead	45 c. per unit	0 treatment
35–40 % lead	47 c. per unit	0 treatment
40–45 % lead	50 c. per unit	0 treatment
45–50 % lead	52 c. per unit	0 treatment
50–55 % lead	55 c. per unit	0 treatment

These prices were based on lead at 4 c. per lb. at New York.

In 1898 a revival in mining at Leadville and elsewhere in Colorado set in, and in 1900 the total lead production of the State attained a higher figure than ever before in its history. This was due to the rising tendency of the price for lead, to the introduction of economies in mining and smelting, to the settlement of the labor troubles and a general recognition that the bonanza days of mining in Colorado had passed, and that operations to be successful would have to be conducted in a close, careful, and scientific manner. An important factor was the improvement in the method of milling the sulphide ore of Leadville, largely a result of the introduction of the Wilfley table, which enabled several mines, previously idle, to be put again into operation. These mines, and likewise similar mines in other parts of the State, were further aided soon afterward by the development of a market for their zinc product, which previously had been a waste. This subject is discussed at length in the section of this work which treats of the history of zinc.

It is interesting to observe the distribution of the lead production of Colorado in 1905, as shown by the report of the Commissioner of Mines. This gives the output by counties, but as in the most important cases the county production corresponds practically with that of a mining district, Lake County for example, being precisely equivalent to Leadville, the figures are instructive. They are as follows:

Lake County (Leadville)	26,424 tons
Pitkin County (Aspen)	10,987 tons
Mineral County (Creede)	5,940 tons
Other counties	14,505 tons
Total	57,856 tons

After Leadville the mines of Aspen have been the largest producers of lead in Colorado, although they are commonly regarded as, and indeed are, silver mines rather than lead mines. Since 1883 these mines have been steady producers, although for a few years after the silver panic their output was small. Their production was 3200 tons in 1885; 6000 in 1887; 8000 in 1888; 7100 in 1889; 2228 in 1897; 7951 in 1898; 12,729 in 1899; 13,726 in 1900; 16,375 in 1901; 12,487 in 1902; 16,635 in 1903; 9441 in 1904; 10,987 in 1905; and 8781 in 1906. The figures since 1897 are for the whole of Pitkin County.

In view of the incompleteness of the statistics, it would be difficult to pronounce which of the other districts of Colorado ranks preëminent in point of aggregate production.

As for the future, mining conditions in Colorado may be expected to develop gradually on the lines which have now been established. In its mining history of nearly 50 years its gulches and mountain-sides have been carefully and skilfully prospected, more so than any other of the States to the west of the Rocky Mountains, and the chances for new discoveries are therefore much smaller than in those States which have more undeveloped territory.

XI

IDAHO AND MONTANA

Idaho. — As in Nevada, the first mining in Idaho was for free-milling gold and silver ores. The existence of silver-lead ores in comparatively small quantities was probably early known, but there was evidently nothing discovered that it was considered worth while to work until the development in 1871 of the South Mountain district, 25 miles due south of Silver City, where promising veins of ferruginous lead carbonate and sulphide ore were found to exist. A furnace to smelt these ores was erected in 1872, but the const uction was so faulty that the attempt at smelting was an utter failure. There appears to have been an earlier attempt to smelt the ores from some galena veins at Pioneer, in Boise County, but no good records as to this are to be found, and the effort was certainly no serious one. In 1874 the ownership of all the mines of the South Mountain district was acquired by the South Mountain Consolidated Mining Co., which erected a large shaft furnace and made one or two short campaigns, operations being interrupted by insufficiency of charcoal. The management of this enterprise was faulty, or the mines were less good than was thought, since in 1875 the company failed and all operations in the district came to a standstill.

The first efforts of consequence in lead mining in Idaho were made in the Wood River district, where operations were stimulated by the exceptional richness of the ore, which was a galena averaging 55% in lead and about 100 oz. per ton in silver. Veins of silver-bearing galena were known to exist in this district as early as 1873, and in 1874 the Callahan brothers located some in the lower valley and developed them to a small extent, but the Bannock Indians interfered with operations. Various prospecting parties went into the district in 1876 and 1877, but did little more than the staking out of claims. The Nez Percé and Bannock wars, from 1877 to 1879, put a stop to all prospecting and mining in the district.

In the fall of 1879 a party of prospectors returning from the Salmon River Valley discovered numerous veins at the head of Wood River, in the vicinity of the present town of Galena, but it was too late in the season to begin mining. The report of the discovery spread and early in 1880 hundreds of miners rushed into the district, and soon located the principal lodes. In 1881 the output of the district was probably about 2000 tons. Furnaces were erected by the Wood River Smelting Co., near Hailey, these being the first in the district, and also at Ketchum and Galena. In smelting the average ore of the district there was required per ton of ore about 0.6 ton of iron flux, 0.2 ton of limestone, and 42 bushels of charcoal. The iron ore costing $6 per ton, the limestone $4 per ton, and the charcoal 14 c. per bushel, the cost of smelting in a plant of 40 tons daily capacity was estimated at $11.53 per ton, although the actual figures were probably somewhat higher. However, the district was favorably situated, having water for power and ample timber for making charcoal.

In 1882 there was great activity in the Wood River district and numerous smelters were erected, but that a Ketchum was the only one which developed into an important business. This furnished a market for about one fourth of the ore produced in the district, the remainder being sold to outside smelters. The production of the Wood River mines attained its maximum in 1886, when the output was estimated to contain about 8000 tons of lead. After that it declined along with the decline in the value of silver, which affected these mines very seriously because of the high proportion of the silver value in their ores, and finally the panic and great drop in price in 1893 practically brought operations to a standstill, from which there was no material revival until 1903.

Contemporaneously with the development of the Wood River district there was a prosecution of lead mining and smelting in Custer County, especially at Bay Horse, but while those mines became continuously productive, their output never attained great significance.

In 1883 the Viola mine, at Nicholia, in Lemhi County, 85 miles east of Salmon City, began to be productive, and from 1884 to 1889 it swelled the lead output of Idaho very largely. This famous mine was opened on a wide vein of carbonate and sulphide ore, assaying from 40 to 70% lead and 30 to 70 oz. silver per ton, but the life of the mine was short. At first its output was shipped outside the State for smelting. In 1884 the shipments to Denver, Omaha, and Kansas City amounted to about 2500 tons per month. Other lead-producing districts were opened in Lemhi County about the same time, including the Texas district, 65 miles east of Salmon City, and the Spring Mountain district, 75 miles east of Salmon City, both of which had rich lead carbonate and sulphide ores, but neither ever developed anything like the Viola bonanzas.

In 1883 the Cœur d'Alene district of northern Idaho began to attract attention because of the discovery of gold placers, and in that year and the year following there was a migration of prospectors thither. The placers did not prove to be of great value, but the acquaintance with the district which they inaugurated led to the discovery of many veins of silver-lead ore and in the course of time those veins became the most important source of lead in North America, a position which they still hold.

The mines at Wardner, on the South Fork of the Cœur d'Alene River, were discovered and developed in 1886. The mines were early appreciated to be of importance, a branch line from the Northern Pacific railway being built into the district almost immediately. In the "Production of Gold and Silver in the United States" for 1886, it was remarked: "This district promises to be one of the largest producers of lead bullion in the United States." The ores were of low grade from the outset, requiring concentration. A concentrating mill was erected at Wardner in 1886, and during that year an output of about 2300 tons of ore was reported. This ore was shipped outside the State for smelting, going largely to Montana. There was never any serious attempt to establish a local smelting industry in the Cœur d'Alene, in which respect its history differs greatly from the history of the earlier lead districts of the United States. It did not become productive, however, until after the custom smelting industry at central points had been well established, and the advantage of smelting in that way over smelting locally, except under unusually favorable conditions, was well recognized. The discovery and development of the Cœur d'Alene may indeed be considered to mark the termination of the epoch of discovery in the silver-lead industry of the Rocky Mountains. Since its date there have been no new discoveries of note, save Creede, Colo., and that was relatively of no great importance.

The development of the Cœur d'Alene district was rapid. In 1891 there were 40 developed mines, of which 26 were classed as producers.[1] There were 13 dressing works in operation, with an aggregate capacity of 2000 tons of ore per day. The largest works were those of the Bunker Hill & Sullivan company, which dressed 450 tons of ore per day, but in 1892 an addition to the mill was completed, giving a total capacity of 750 tons. At that time the concentrate produced in the Cœur d'Alene averaged 60% lead and 30 oz. silver per ton, about eight tons of ore being reduced to one ton of concentrate.[2] The cost of dressing was 44 c. per ton at the Bunker Hill & Sullivan mill; 45.6 c. at the Helena & Frisco. The cost of mining at the Bunker Hill & Sullivan was $4.10 per ton; at the Helena & Frisco, $2.45.[3] About 75% of the mineral of the crude ore was saved in the concentrates. The concentrates were shipped principally to Denver and Omaha. The freight rate to the principal smelting points, according to the schedule of March 20, 1892, was as follows:

[1] Production of Gold and Silver in the United States, 1891, p. 193.

[2] The Mineral Industry, II, 395.

[3] *Engineering and Mining Journal*, March 18, 1893.

Point	II	I	Point	II	I	Point	II	I
Omaha....	$12	$16	Denver....	$10.00	$14.00	Tacoma...	$7	$8
Kansas City	12	16	Pueblo ...	11.25	15.28	Helena....	6	8

I. First-class concentrate, containing more than 40 % lead. II. Second-class concentrate, containing less than 40 % lead.

The charges for smelting ranged from $9 to $12 per ton. In March, 1891, the total cost of freight and smelting to the Bunker Hill & Sullivan Co. was $28 per ton; in March, 1892, it was $25.50. A reduction in freight rates was made in September, 1893, but smelting charges were increased, so there was no net saving. At that time there was no great profit in the operation of these mines. The prices for silver and lead were low, the wages for labor were high, and the men were turbulent, while financial conditions had been upset by the silver panic. The production of lead in the district, which had jumped from 1500 tons in 1886 to 33,000 tons in 1891, declined in 1892 and 1893. It was not until 1896 that the output in 1891 was surpassed, and not until 1900 that it began to go upward by leaps and bounds.

The great drawbacks in the Cœur d'Alene up to 1893 were the high wages exacted by the miners, who had early been unionized; labor difficulties; and the high freight rates charged by the railways on ore shipments. Until the spring of 1892 miners were paid $3.50 per day, and trammers, shovelers, and surface-men received the same amount. A reduction to $3 per day was then made in the wages of all but the miners. A general strike followed, which was accompanied by many acts of lawlessness by the men. The striking miners eventually returned to work on the terms offered by the companies. The steady decline in the prices for silver and lead, however, reduced the profits of the mines very much, and when finally silver fell to 70 c. it became impossible to operate them longer under the then existing conditions. Every mine in the district was closed, while an offer was made to the men to reopen if a $2.50 per day wage rate would be accepted; this the men did not agree to. When the prices for silver and lead rose to 74 c. per oz. and 3.80 c. per lb., respectively, work was resumed in some of the mines at the old rate of wages ($3.50 per day).[1]

From 1892 to 1899 there was a continuance of labor troubles in the Cœur d'Alene, which greatly retarded the development of the district. In 1899 the production of lead was only 50,000 tons — less than double the output in 1890. In 1899 occurred the third great strike of the miners, and this time they were completely defeated, and the mines were reopened on a non-union basis. About the same time the price for lead rose to a

[1] The Mineral Industry, II, 396.

high figure, and this, together with the new freedom from the yoke of union labor, gave a great impetus to mining in the district. Its production jumped to 81,535 tons of lead in 1900.

It is extremely difficult to analyze the industrial conditions which have governed the production of lead in the Cœur d'Alene, chiefly because so large a part of the value of its ore is in silver. Consequently the operations are affected not only by the price for lead, but also by the price for silver. When both silver and lead are high the profits are, of course, high; similarly they are small when both metals are low; but, in between, a low price for silver may be offset by a high price for lead, and vice-versa.

There has been a decided reduction in the cost of production since 1891. Whereas at that time the average extraction of mineral from the crude ore was about 75%, at present it is perhaps as high as 80%. On the other hand, the cost of mining and milling has decreased. Whereas the cost of mining to the Helena & Frisco company in 1891 was $2.45 per ton, in 1902 the cost to the Bunker Hill & Sullivan was $2.09, and in 1903 only $1.75. According to Finlay the cost of mining and milling throughout the district in 1902 was $2.50 to $3.50 per ton.[1] Yet the wages for labor have not been materially decreased. Miners still receive (1907) $3.50 per eight hours, the same as in 1891, while muckers are paid $3, against $3.50 in 1891. However, the mine operators have gained the advantages of increased efficiency, elimination of strike expenses and the other benefits which result from release from the tyranny of an evil labor union. After the long record of lawlessness, labor conditions in 1904 were probably better than in any other mining district of the West. "Nearly 80% of all the men employed are native-born Americans."[2] Cheaper power had been secured by electric transmission from Spokane Falls, in Washington. Improved mining machinery, especially electrical, had been introduced. The lodes opened to great depth have been found to show as rich ore in the lowest levels as in any of the upper ones. In September, 1902, an important reduction in smelting and freight charges was made, an agreement having been entered into by the miners, railway companies, and the American Smelting and Refining Co., whereby the freight rates were reduced $2.50 to $3 per ton and the smelting company agreed to take 12,000 tons of concentrated ore per month.

In this account of the progress of mining in the Cœur d'Alene, attention has been confined heretofore to certain of the broad features of the industrial development of the district, the details of its history having been so adequately summarized by Mr. F. L. Ransome[3] that it is suffi-

[1] Trans. Am. Inst. Min. Eng., XXXIII, 250.

[2] Stanley A. Easton, The Mineral Industry, XIII, 266.

[3] "Ore Deposits of the Cœur d'Alene district, Idaho," in Contributions to Economic Geology (Bulletin No. 260, U. S. Geological Survey), 1904, pp. 285–289.

cient to quote in full his chapter on this subject, which is done in the following paragraphs:

The story of the opening of the Cœur d'Alene region to mining enterprise goes back to the year 1842, when a mission was established by the Jesuits in the beautiful valley of the St. Joseph River, a navigable stream which empties into the head of Cœur d'Alene Lake about five miles south of the embouchure of the Cœur d'Alene River. In 1846, however, the mission was moved to its present site on the latter stream, about 25 miles from the lake, and for many years Father J. Joset and the missionaries associated with him were the only white inhabitants in this whole region. The Cœur d'Alene Indians, about 300 in number, lived chiefly in the vicinity of the mission.

In 1854 Lieut. John Mullan, acting under instructions from the War Department, began explorations for a wagon road over the Cœur d'Alene Mountains to connect Fort Benton with Fort Walla Walla. These preparations aroused the hostility of the Indians, who, after defeating a small force of regular troops, were subjugated in 1858. In the following year work on the proposed road was begun under a Congressional appropriation, and the task seems to have been finished in 1861.[1] The new road crossed from the mouth of the St. Joseph River to the mission on the Cœur d'Alene River. Thence it followed the main stream and South Fork to a point about three miles east of the present town of Mullan. Here it turned south, crossed the divide through the Sohon, or St Regis Pass, and continued down the St. Regis de Borgia River, following the route later taken by the railroad to Missoula.

Roughly constructed as it was, this road, now familiarly known as the "Old Mullan Road," was for many years the only line of travel into the region to whose early development it substantially contributed. It traversed what afterward proved to be the most productive part of the district, but the discovery of the lead-silver deposits was reserved for a later date.

The first prospecting in the region appears to have been by Thomas Irwin, who in 1878 located a quartz claim near the Mullan road, apparently on Elk Creek. In the summer of 1879 a party, including A. J. Prichard, moving northward from the Mullan road over the Evolution trail, discovered Prichard Creek. In 1882 Gellett, another member of the party, found placer gold and located a claim on Prichard Creek. The first quartz claim on Prichard Creek was the Paymaster, near Littlefield, located by Patrick Flynn on Sept. 21, 1883.

The discoveries of Prichard and Gellett were followed by a rush of prospectors to the North Fork early in 1884, and in May Eagle City,

[1] Capt. John Mullan, U. S. Army, Report on the Construction of a Military Road from Fort Walla Walla to Fort Benton, Washington, 1863.

at the junction of Eagle and Prichard creeks, had become a bustling town connected by trail and telegraph with Belknap, 32 miles away, on the Northern Pacific Railway. It was soon found, however, that the richest placers lay higher up Prichard Creek, particularly in Dream, Buckskin, and Alder gulches, and the center of population soon shifted to the new town of Murray.

Although the chief excitement at this time centered in the rich gold placers near Murray, the lead-silver veins of the South Fork were beginning to attract attention. In 1884 Col. N. R. Wallace had a cabin and store in the dense grove of cedars that covered the future site of the town now bearing his name. His settlement was then known as Placer Center. At the same time W. B. Heyburn began work on the Polaris mine, in Polaris Gulch. The Tiger claim, on Canyon Creek, was also located in 1884 by John Carton and Almeda Seymour, who bonded it to John M. Burke. In 1885 the Tiger mine, in spite of its comparatively inaccessible position, had been opened by three tunnels, and had about 3000 tons of lead-silver ore on the dump. Other mines located in 1884 were the Gold Hunter, Morning, and You Like, near Mullan, and the Black Bear, San Francisco, and Gem of the Mountains (now comprised in the Helena-Frisco mine), near Gem.

In 1885 Murray, with a population of about 1500, became the permanent seat of Shoshone County. In spite of the promising character of the lead-silver deposits on the South Fork, the gold placers on Prichard and Beaver creeks were still the center of attraction, and considerable work was being done on the auriferous quartz veins between Murray and Littlefield.

Communication with the mines on the South Fork was at this time difficult. Small steamers plying across the lake ascended the Cœur d'Alene River to the Mission, where passengers and freight were transferred to wagons or horses and carried over the rough Mullan road. Murray was connected by an equally poor road with Thompson Falls, on the Northern Pacific Railway, by a road down the North Fork with the Mission, and by a road with Delta. Practically the only route from the county seat to the South Fork was by way of the Evolution trail, Evolution being a little settlement about two miles west of Osburn's ranch, then a well-known stopping point for travelers. It was impossible to mine and ship lead ores until better facilities for transportation were obtained.

The discovery of the Bunker Hill mine by Phil O'Rourke and N. S. Kellogg in 1885, of the Sullivan mine by Con Sullivan and Jacob Goetz, and the evident existence of large bodies of rich ore in the Tiger, Poorman, Granite, San Francisco, Morning, and other mines, removed all doubts of the future importance of the South Fork mines. The opening of the year 1886 was marked by a decided rush from the outside and from the waning placers of Murray into this new field, particularly to the settlements of Milo and Kentucky, now parts of Wardner and Kellogg. Triweekly stages ran from Mission to Wardner, and a stage road was built connecting Delta with the South Fork.

In 1886 ore from the Bunker Hill & Sullivan mines was hauled by wagons to Mission, carried by boat to the outlet of the lake, and thence shipped to Helena, Mont. The ore from Last Chance, Tyler, and Sierra Nevada mines was treated in a new smelter at Milo. This early attempt at local smelting was soon abandoned.

In the following year a narrow-gauge railroad was completed by the Cœur d'Alene Railway and Navigation Co. from Mission to Wardner Junction, at the mouth of Milo Creek. Wardner had now become a town of 1500 people, while the population of Murray had fallen to about 1000. There were about 500 inhabitants at Wallace, and Burke and Mullan were growing settlements. Probably 100,000 tons of ore were piled on the dumps of the Canyon Creek mines awaiting means of transportation. The Oregon Railway and Navigation Co. and the Northern Pacific Railway were both striving at this time to secure entrance to the district.

In April, 1887, the Bunker Hill & Sullivan mines were sold to S. G. Reed, and in August the Bunker Hill & Sullivan Mining and Concentrating Co. was organized, with a capital of $3,000,000. The Poorman, Granite, and Morning mines were also sold at about this time. The completion of the narrow-gauge railroad to Burke in this year enabled the Canyon Creek mines to ship their ore. Probably over 50,000 tons of lead-silver ore was mined in 1887, the principal producers being the Tiger, Bunker Hill & Sullivan, Tyler and Stemwinder, Last Chance, Sierra Nevada, Poorman, and Granite. The Mammoth and Standard veins were as yet merely good prospects.

In 1888 placer mining near Murray and Delta had greatly declined. A pipe line was constructed from Raven in 1890 to hydraulic, the bench gravels of the so-called Old Wash, near Murray, and some hydraulic mining is still occasionally carried on in Dream Gulch. A hydraulic elevator was operated for some time in the bed of Prichard Creek about a mile below Murray, and some dredges were working near Delta in 1904; but the scene of activity had definitely shifted by the year 1888 to the lead-silver mines of the South Fork.

The principal events in 1890 were the completion into the district of the tracks of the Northern Pacific Railway and Oregon Railway and Navigation Co., the partial destruction by fire of Wallace and Wardner, and the first shipment of rich ore from the Mammoth mine. The old narrow-gauge line was absorbed by the Oregon Railway and Navigation Co., and its tracks were replaced by those of standard gauge. Most of the larger mines were by this time equipped with concentrating mills.

At the beginning of 1892 most of the South Fork mines stopped work, ostensibly to secure better freight rates. Wages at this time were \$3.50 a day. In the following April a reduction was made in wages, followed by a strike of the union men. The Frisco, Gem, and Bunker Hill & Sullivan mines attempted to resume work with non-union men, and in July were attacked by armed strikers. Troops were called into the district and for a time order was partly restored. In July, 1894, a second attack was made upon the Gem mine, and in December, the Bunker Hill & Sullivan mine closed, rather than accede to union demands. In June, 1895, it resumed partial operations, paying \$3 a day to miners. The Tiger and Poorman mines consolidated in this year.

In May, 1898, the Empire State Mining and Development Co. was organized to control the Last Chance mine and to acquire additional territory west of Milo Gulch. This was the beginning of the process of consolidation that afterward resulted in the formation of the Federal Mining and Smelting Co. The county seat was this year moved from Murray to Wallace, now the largest town in the district.

The opening of the year 1899 found the miners' unions still determined to enforce their demands upon the mine owners, and in a particularly bitter mood against the Bunker Hill & Sullivan company, which maintained its right to employ non-union labor. On April 29 a force of several hundred men attacked the buildings of the company at Kellogg. The office of the mine was rifled and both office and mill were totally destroyed by dynamite.

After this episode, 500 regular troops were sent into the district and martial law was proclaimed. The mines were closed until June, when the Standard mine reopened with men brought from Missouri. The other mines resumed work one by one as they secured non-union miners. From that time to the present no man has been able to secure employment in the larger mines (with one exception) save through the employment bureau maintained by the principal mine owners.

In 1901 the Tiger-Poorman mine, previously acquired by the Buffalo Hump Mining Co., was consolidated with the holdings of the Empire State company, and in September, 1903, the Empire State, Standard, and Mammoth properties were all consolidated under the Federal Mining and Smelting Co. Other notable events of the past few years were the discovery in 1901 of the rich ore-body of the Hercules mine, which has produced ore of a gross value of about \$2,000,000 in less than three years, and the development of the Snowstorm mine in 1903. This is the only mine in the district that ships copper ore.

Montana. — The occurrence of lead ore in Montana was observed by many of the early explorers and travelers to Oregon. No great attention was bestowed on it, however, because of the impossibility of mining such ore at a profit under the then conditions. The first lead mining was done in the Argenta district, on Rattlesnake Creek, north of Bannock, where veins of silicious lead and iron ore, oxidized near the surface, were found in considerable number. The St. Louis & Montana Mining Co. erected a smelting plant at Argenta in 1865, and it is stated in Mineral Resources West of the Rocky Mountains for 1867 that from the metallurgical point of view its operations were eminently successful. This was the first lead-smelting plant in any of the States and Territories west of the Rocky Mountains, antedating that at Oreana, Nev. A second plant was built at Argenta in 1866, and a third and fourth in 1867. These plants consisted of one furnace each, except that of the St. Louis & Montana Mining Co., and cost about $8000, the furnaces having capacity for smelting six tons of ore per 24 hours. Operations could never have been very successful, since in 1870 only one furnace was running at Argenta. This failure was due partly to impoverishment of the veins as depth was gained, partly to the disadvantages of Argenta as a smelting point with respect to fuel, fluxes, and refractory material, and partly to the high cost of transportation. The bullion was shipped to Corinne, Utah, where it fetched 3.5 c. per lb. for its lead content, the cost of transportation to Corinne being 1 c. per lb. at the lowest.

In 1868 there were four small smelting plants at Argenta, one at Bannock, one at Jefferson City, and one near Virginia City. It does not appear that any of them was operated at a profit. Prof. A. K. Eaton, writing in Mineral Resources West of the Rocky Mountains for 1868, expressed the opinion that what was required to make smelting profitable in Montana was: (1) a separation of mine and furnace ownership, (2) a market for the lead, (3) cheap labor, and (4) the discovery of a coal capable of being coked, the only available fuels at that time being wood and charcoal. A small shipment of ore was made in that year from Philipsburg. The cost was $20 currency, per ton to Fort Benton, the head of steamboat navigation on the Missouri River, $20 per ton to St. Louis, and $10 to $15 per ton to the seaboard.

The development of the lead resources of Montana was retarded more than in most of the other States by the lack of transportation facilities, its mining districts being far from the transcontinental line of railway passing through Wyoming, Utah, and Nevada, the Northern Pacific line being uncompleted until 1883. However, there was a certain outlet for ores and base bullion, although a rather unsatisfactory one, in the steamboats which ascended the Missouri River to Carroll and Fort Benton. It was 150 miles from Helena to Fort Benton, and 225 miles to Carroll. On the other hand, it was 400 miles to Franklin, the terminus in 1874 of the Utah Northern railway, and 450 miles to Corinne. For those distances ore and bullion had to be conveyed by mule-teams and ox-teams. The quantity of products that could be transported under those conditions was small and there was therefore not much lead produced in Montana until about 1878, when the rich mines at Glendale, in Beaverhead County, became productive. There had previously been some smelting on a small scale in the districts just south of Helena. The old Argenta district had even then been practically deserted for a long while, its mines having failed to fulfil the expectations.

In 1881 the Hecla Consolidated Mining Co. had two 30-ton furnaces in operation at Glendale, using charcoal as fuel, which cost only 11 c. per bushel, and produced 2400 tons of lead, and was paying satisfactory dividends. Smelters were also erected at Wickes, where the Alta-Montana mines had been opened, at Gregory, and at Barker, a new district that had been discovered in 1879. The chief mines at Wickes were subsequently acquired by the Helena Mining and Reduction Co., and they, together with the Hecla mines at Glendale, were the principal producers of lead in Montana up to 1893, when the silver panic checked their output. Other important lead-producing districts were the Barker, in the Little Belt Mountains, about 60 miles south of Fort Benton, and the Neihart, a few miles north of Barker, which began to be prominent in 1884.

Eventually, Helena became the important lead-smelting center of Montana, a large plant being established there by the Montana Smelting Co., displacing the small local furnaces in the same way as had been the experience in other States. This plant from its central location drew the ores of Wickes, Barker, Neihart, and numerous smaller camps, and also obtained large supplies of ore from the Cœur d'Alene and elsewhere in Idaho. Montana has continued to be a fairly steady producer of lead, but its output has never attained large proportions.

XII

NEVADA AND UTAH

THE first lead mined and smelted in large quantity in the great country to the west of the Rocky Mountains came from Nevada. The opening of the deposits in Utah followed soon afterward. The existence of argentiferous lead ore in those Territories had been known for several years previous; to some extent since the Mormon occupation of Utah and the hegira overland to California soon after 1849; to a more extent since the movement to the Comstock lode in the years succeeding 1859; and to a still more extent since the march of General Conner's California volunteers in 1863, the members of which were enterprising prospectors, and devoted much time to looking for mineral in the country they traversed, which be it said was to the subsequent trouble of legitimate miners. The lack of transportation facilities, however, practically precluded the development of the deposits until the completion of the Pacific railway. In studying the history of the lead industry of the West, we have fortunately a minute and authoritative contemporaneous record in the annual volumes of the series entitled "Mineral Resources of the States and Territories West of the Rocky Mountains," edited first by J. Ross Browne, later by R. W. Raymond, and published by the Treasury Department.

In the first volume of the Mineral Resources, treating of the year 1866, such references to the known existence of lead ore as the following are to be found:

"In the Pueblo Mountains, Nevada, 60 miles northeast of Black Rock, many ledges were located five years ago. The ores are argentiferous galena, abounding in both silver and lead."

. . . .

"Utah is known to abound in many of the useful, and it is believed also in the precious metals. Both lead and iron have been produced for many years past by the Mormons living in the southern counties."

. . . .

"A number of large lodes heavily charged with argentiferous galena have been opened at Rush Valley, a short distance southwest of Salt Lake City, and being tested by the smelting process proved rich in both lead and silver. A number of furnaces were erected there two years ago, since which they have been kept part of the time in operation, and with suitable appliances it is thought a considerable amount of silver bullion might be produced from these mines."

. . . .

"Besides the precious metals, ores of copper, lead, iron, antimony and arsenic are abundant in southeastern Nevada, and when railroads traverse the country will be of great value."

In the report for 1867 it is said:

"Many of the ores in the Humboldt region, Nevada, are so mixed with lead, antimony, copper, and other refractory agents as to require smelting, for which purpose several establishments have already been erected and are in operation. Two of these, the one situated at Etna, and the other at Oreana, on the Humboldt River, have after many difficulties succeeded to such an extent that the business is now remunerative, the shipments of bullion from them amounting to $3000 per week. The crude metal turned out by smelting consists of lead, silver, and antimony, which is then passed through calcining and refining furnaces, whereby the silver is liberated from the base metals, coming out from 0.995 to 0.997 fine. Much of the crude metal is sent away, as it will not pay for refining here where the expenses are so high. The cost of smelting and refining ore at these establishments is $50 per ton, about double the cost of reduction here by ordinary mill process. The price of wood delivered at the mills varies from $6 to $14 per cord, depending on localities. The extraction of the ores costs about $10 per ton; hauling to mill from $3 to $8, according to distance."

. . . .

"Silver Hill district, situated in the mountains of the same name, Churchill County, Nevada, and organized in 1860, contains some large lodes heavily charged with auriferous and argentiferous galena, a number of which have been prospected."

. . . .

"The Hot Spring, Blind Spring and Montgomery districts, 30 to 50 miles southeast of Aurora, and lying partly in California, discovered in 1864, produce ores, of which most is an argentiferous galena, the large percentage of base and refractory metals rendering smelting necessary. Two small mills and a number of smelting furnaces have been put up, which considering their limited capacity have made a fair turnout of bullion."

. . . .

"The Eureka district, Lander County, Nevada, was organized in 1864. The geological formation is limestone, with veins or bodies of metal-bearing quartz. The chief characteristic of the ore is an argentiferous galena, which might be reduced by smelting."

. . . .

"Washington district, 28 miles south of Austin, in Nye County, organized in 1863, was the scene of busy operations in that and the subsequent year. The mineral is an argentiferous galena, abundant in quantity. The veins are from 4 to 16 ft. in width, and regular in formation. Attempts have been made to reduce the ores, but owing to want of skill on the part of the operators they have not been successful."

. . . .

"At Minersville, in the western part of Utah, are mines of lead and copper, which contain some gold and silver. One of the mines has been worked to a depth of 90 ft. At this point copper predominated, and the working of the mine for lead was suspended. The lead was smelted to supply the Territory. While lead prevailed working of the mine was remunerative. No effort was made to recover the silver, although in many countries this would have been profitable."

. . . .

"The Rush Valley district, Utah, abounds in veins containing argentiferous galena and copper. In 1865 there was considerable excitement about these mines. Companies were organized by officers of the army at Salt Lake City, and some developments were made. Smelting works were erected at the mines, but the smelting failed to extract the metal in a satisfactory manner."

. . . .

"Cottonwood Cañon, about 27 miles southeast from Salt Lake City, contains several silver mines. A Mr. Hirst is running two furnaces there at present. They are not on an extensive scale, but the results are satisfactory. This is a valuable lead-mining district."

The above extracts indicate clearly the character of the knowledge as to the silver-lead deposits of Nevada and Utah at the end of 1867, and outline the practice in exploitation of such of them as were worked. The prospectors of that time and the seven years immediately preceding were anxious to find lodes of gold and silver ore that could be beneficiated by the processes of plate or pan amalgamation. Lead-bearing ores were not wanted, being valuable only for their precious metal contents, which could only be extracted at greatly increased cost as compared with those ores that were amenable to amalgamation. The occurrence of such ores at numerous localities was known, however, and their future value, when the Pacific railway should be completed, was appreciated. Rich argentiferous galenas were smelted at several places, the metals being reduced to a base silver-lead bullion, from which the gold and silver were refined by cupellation. The furnaces were doubtless small and crude affairs, similar to what the Mexicans used to employ and still do. At Oreana, Nev., and Cottonwood Cañon, Utah, there were more important constructions. Of the lead-bearing localities mentioned in the Mineral Resources at the end of 1867 the more part failed to prove of any great importance, but certain of them became the greatest lead producers in the United States during the next decade. Thus both Eureka, Nev., and Cottonwood Cañon, Utah, had been discovered previous to the end of 1867, and at the latter smelting had already been begun. Bingham Cañon, Utah, also had been discovered previous to this time, although it does not appear to be mentioned in either of the first two volumes of the Mineral Resources.

The earliest knowledge of lead ore in Utah and Nevada was possessed by the Mormons, who settled at Salt Lake City in 1846. They produced such lead as they required for their purposes for many years previous to 1866, but the leaders of this people discouraged the searching for mineral, it being contrary to the policy of the church to have its disciples engage in mining pursuits, wherefore but little was known of the mineral resources of Utah until the soldiers stationed at Salt Lake began to unearth them. It is doubtful if the Mormons had any knowledge of the silver content of the galenas which they smelted; if they did, they did not regard it as worth while to separate, a process involving the conversion of the lead to litharge and a resmelting of the latter to regain metallic lead, which would have been profitable only with a bullion rich in silver. Certainly the ore at Minersville was smelted only for lead to supply the Territory, with no attempt to separate silver. Dr. R. W. Raymond, then special commissioner of mineral statistics for the Treasury Department, had an interview with Brigham Young and several leading members of his church. They expressed a willingness to have all the natural resources of Utah developed and utilized, and disclaimed any hostility to mining, but admitted that they had discouraged their own people from engaging in it because they thought that agriculture would be far more profitable. Mr. Young expressed the opinion that the ores of Utah had never yet been skilfully treated. "What we used to call lead," said he, "and dig and melt up into bullets, these fellows call silver now! But if anybody is fool enough to come and mine for it, he may do so, and welcome."

The birth of silver-lead smelting west of the Rocky Mountains is commonly credited to Oreana, Nev. However, lead was produced earlier at Argenta, Mont., for local consumption in Utah, and as a step toward the production of silver at other places, as has been elsewhere pointed out. But Oreana was certainly the place in Nevada whence lead was first sent to the outside market, which important development was the direct result of the arrival of the railway. The experience at Oreana just before and just after the advent of the railway is finely illustrative of the effect that the improvement in transportation facilities had upon the silver-lead mining industry of Nevada and Utah at this time. The development of Eureka, Nev., and the Cottonwoods, Utah, was a direct and immediate consequence.

Oreana was situated in the Trinity mining district, organized in June, 1863, in Humboldt County, 30 miles southwest of Unionville. The most important mine, and the only one actively worked in 1868, was the Montezuma, which had an antimonial lead carbonate ore averaging about $80 in silver value, silver being worth $1.30 per oz. at this time. The lead and antimony contents of the ore amounted to about 50%. The smeltery for the reduction of this ore was erected in 1867. The method of treatment was described in the Mineral Resources for 1868. The ore crushed to about egg-size by a Blake breaker was mixed with an equal weight of flux consisting of 20 parts soda and 80 parts lime, both gathered from the alkaline deposits of the valley and foot-hills. The fuel was charcoal, which cost 25 c. per bushel after the coming of the railway, whereas it had previously cost as high as 65 c. The furnace would smelt about 12 tons of ore per 24 hours, producing about 10,000 lb. of bullion, with a consumption of 12 bushels of charcoal, or 225 lb. per ton of ore. The bullion contained about 75 oz. silver per ton. The works comprised two blast furnaces, and four reverberatories for softening the antimonial lead and a cupellation furnace, the softening and cupellation furnaces being used when the silver was refined at the works previous to the arrival of the railway. The silver bullion was turned out 0.997 to 0.998 fine and realized $1.30 per oz. After the Pacific railway had reached Oreana, it passing close to the mine and works, the base bullion was shipped to Selby & Co., at San Francisco, who paid $100 per ton for the base metal and $1 per oz. for its silver contents. The balance sheet of the Montezuma Mining Co., on the basis of one furnace in operation, then stood approximately as follows:

Cr.	4.8 tons lead and antimony, at $100, San Francisco	$480
	360 oz. silver (the average contents) at $1	360
	Total	$840
Dr.	Mining 12 tons ore and carting to smeltery	$84
	4 smelters, two at $5 and two at $2.50	15
	2 enginemen at $4	8
	5 feeders, laborers, etc., at $3	15
	2 cords wood at $15	30
	144 bushels charcoal at $0.25	36
	Limestone, iron, horse feed, etc.	10
	Superintendence and office expense	25
	Transportation 4.8 tons metal to San Francisco at $30	144
	Total	$367

Accordingly there was a daily profit of $473. Unfortunately figures showing the result of previous operations were not given, but we may approximate them. The value of the silver bullion, at $1.30 per oz., would have been roughly about $468, not allowing for loss of silver in refining. The cost of mining and smelting would have been $223, as per the data previously given. The cost of refining may have been in the neighborhood of $60, on which assumption the daily profit would have been somewhat less than $185, allowing for loss of silver in refining. The railway apparently increased the daily profit of this enterprise at least 2.5 times. The Montezuma mine, however, was evidently not so good as it was thought, since a year or so later it became unprofitable.

The data given for the smelting practice at Oreana are not sufficiently full and precise to enable any valuable analysis of the technical results, but they also may be approximated. The recovery of lead and antimony was apparently about 80%; the consumption of charcoal was about 11% on the ore, and only half that on the charge, which appears extremely low, although the ore may have been easily reduced and the slag very fusible as would be expected from the use of soda flux; the cost of smelting was $9.50 per ton of ore, exclusive of superintendence and general expense. In some respects these would not be extravagant figures for smelting under unfavorable conditions even at the present time.

The year 1869 is especially noteworthy in the history of silver-lead mining west of the Rocky Mountains. The great event was the connection of the Central Pacific and Union Pacific railways, making an uninterrupted transcontinental line. The silver-bearing lead ores, which formerly had been ill-favored because of the greater cost and difficulty of extracting their precious metal value, could then be worked to advantage, inasmuch as it was possible to send the base bullion east or west for refining and marketing. The occurrence of lead-bearing ores was therefore not so much deplored as only a year or two previous, the erection of furnaces was talked of more nonchalantly, and a considerable number of furnaces were actually built during the year. It is to be remarked, however, that up to this time none of the great lead deposits of Nevada and Utah had been discovered. The abundant occurrences of lead ore which had been previously noted, and to a small extent exploited, were after all of trifling importance. It is true that mines had already been discovered at Eureka, Nev., and in the Cottonwood and Bingham cañons, in Utah, but the great ore-bodies which afterward made those places famous had not yet been uncovered.

The second great event of 1869 was the White Pine excitement, one of those wild "rushes" to newly discovered localities that were so frequent and picturesque in the early history of mining in the country west of the Rocky Mountains. The White Pine fever was one of the most violent of those epidemics, and prospectors from every part of Nevada rushed to the district, which had acquired the soubriquet of the "poor man's paradise," because of the richness of its ores and the ease with which they were mined. White Pine was essentially a silver-mining district, its rich horn-silver ores being free-milling. Its only importance to the lead industry was the fact that its deposits of silver ore occurred in a limestone formation. The early prospectors for gold and silver looked especially for quartz lodes. In those districts where rich ore had previously been found near the surface in limestone country-rock the results had been unfortunate, the ore "petering" out early. For this reason the rich deposits of White Pine, which bore a striking and ominous resemblance to other discoveries of fair prospect and rapid failure, were first regarded with distrust, and it was several months before much confidence was felt in their permanence. When, however, their value was demonstrated and knowledge had been gained as to their character and mode of occurrence, attention was directed to several of the old districts, which had been abandoned or disregarded on account of the limestone country-rock, and in the new light which White Pine had thrown upon this formation many discoveries were made, among them the great ore deposits of Eureka. White Pine may be considered, therefore, to have led directly to Eureka. As is well known, most of the great lead deposits of the world have been found in limestone formations.

The lead production of White Pine itself was insignificant. However, there was some lead ore in the "base range," which was discovered and worked two years before the excitement of 1869, and those ores being incapable of profitable beneficiation in any other way, two furnaces were erected in 1869, but they do not appear to have been successful. It may be remarked here that at the present time, nearly 40 years after the discovery of the district, some small lead mines are still being worked at White Pine.

The completion of the Pacific railway, which for several years had been looked forward to with such great expectations, was followed by a feeling of disappointment, the freight rates being much higher than was anticipated. When the railroad was first opened from Sacramento to Argenta, 396 miles, the freight rate was fixed at $50 (gold) per ton; from Sacramento to Elko, 468 miles, it was $60.75 per ton. These rates were reduced, Sept. 1, 1869, to $35 and $42 respectively, making the rate about 8.84 c. per ton mile to Argenta, and a trifle more than that to Elko. From Elko to Hamilton (the principal town of the White Pine district) the cost of transportation was 2.5 and 3 c. per lb., the distance being 128 miles. Even in 1869 it was argued that the railway freight rate ought to be reduced to 3 c. per ton mile at most.

The Eureka district, situated in the Diamond Range, about 40 miles west of White Pine, became the scene of renewed activity right after the rich discoveries at White Pine, a smelting furnace being erected by C. A. Stetefeldt, already an eminent metallurgist, in which he smelted ore from several of the mines. The process was not quite successful because of the large proportion of gangue in the ores delivered to the furnace, necessitating a proportionately large quantity of flux, while pecuniary embarrassments prevented even the completion of the works. Dr. Raymond in writing of Eureka in 1869 said: "The deposits are frequently large, but occur irregularly in limestone. They contain smelting ores, which, for cheap reduction, ought to be dressed before they reach the furnaces. The ores assay well and probably average better than those from the base range at White Pine."[1]

In Utah mining did not advance much in 1869, even the completion of the Union Pacific railway failing to stimulate general activity. Numerous veins had been located in the Cottonwood Cañon district, but not much mining was in progress there and the smelting experiment that had previously been undertaken had apparently been abandoned. In Bingham Cañon also nothing but trifling work was done. The Rush Valley mines were again attracting attention, and a furnace was erected there, with which exception there does not seem to have been any smelting done in Utah in 1869. Dr. Raymond in summarizing the results of the year wrote thus: "On the whole it may be said that, so far, Utah cannot be classed among the mining States and Territories. The developments made are all very slight and unimportant, and no shipments of any consequence of the precious metals have ever been made."[2]

In 1870 the mines of Eureka, Nev., came into great prominence. They had been discovered in 1864, and considerable money had been expended on them, some of them having been sold to a New York company, but they occurred in the despised limestone formation, and the ores contained too much lead to permit successful milling, so the district was virtually abandoned until 1868, when Major McCoy and associates determined to try to smelt the ore and employed Mr. Stetefeldt to erect the furnace, previously referred to, which was done in 1869. The results were at first rather unsuccessful, although not entirely discouraging. About this time a number of miners from White Pine came to Eureka and other valuable mines were discovered. In the autumn of 1869 Col. G. C. Robbins built a small furnace at Eureka and demonstrated that the ores could be successfully smelted. About the same time Col. David E. Buel and associates leased the McCoy furnace and bonded the Buckeye, Champion, and Sentinel mines. After Colonel Buel had satisfied himself of the smelting qualities of these ores, he resolved to build a large smeltery, and together with Messrs. Bateman, Allen, Ingoldsby, and Farren formed

[1] Mineral Resources West of the Rocky Mountains, 1869, p. 177.

[2] Mineral Resources West of the Rocky Mountains, 1869, p. 321.

The Main Street of Eureka, Nev., in 1907.

Surface Workings on Ruby Hill.

Surface Workings on Ruby Hill.

a company called the Bateman Association. A combination was soon afterward made with William Lent, who had acquired valuable property in the district, and the Eureka Consolidated Mining Co. was organized, beginning business with the Buckeye, Champion, Sentinel, Central, Roseland, and Mammoth mines, and the smelting works erected by Buel & Bateman.

The development of Eureka was very rapid. The ores were at first easily found, once the requisite knowledge was acquired, and were easily mined. A great ore-body in the Champion mine outcropped as a 3-inch crack in the limestone, filled with limonite. The limestone over the ore proved to be only six or eight inches thick. This and other deposits in the district were dug out in open cuts. The ore was an earthy lead carbonate and was so easily mined with pick and shovel alone that one man could take out 10 tons per day, and two miners actually supplied two smelting furnaces. The Eureka district began to be a regular producer in December, 1869. At that time only one furnace, McCoy's, was in operation. During the first six months of 1870 the production of the district was 858 tons of lead bullion. At the end of 1870 there were 14 furnaces, all in or close to the town of Eureka. According to Mr. Guido Kuestel, in an article in the *Scientific Press*, the ores smelted in the summer of 1870 averaged 40 to 48% lead, $60 to $80 in silver, and $15 to $20 in gold per ton. Three and a half tons of ore yielded one ton of pig lead or "bullion," as it was called.[1] The bullion averaged about $170 in silver and $80 in gold per ton. It was shipped to Newark, N. J., for refining. The actual yield of the Eureka mines in 1870 was not less than $1,200,000 in value.

A considerable quantity of lead was produced in 1870 by the mines of the base metal range at White Pine, where several furnaces were run, a new works with three furnaces being erected during the year, but these ores, although chiefly carbonates and rather rich in lead, were comparatively of low grade in silver, and were not so cheaply smelted as the ores of Eureka. The lead resources of the district were at that time, however, considered to be quite large.

According to a report of the State Mineralogist of Nevada, the shipments of ore from eastern Nevada to California in 1869 were 1473 tons; in 1870, exclusive of December, 6015 tons. Less than two tons of ore were shipped east during those years. In 1870 about 1900 tons of silver-lead

[1] The crude argentiferous pig lead, the "Werkblei" of the Germans, is still called "base bullion" by the Western smelters. The origin of this term is obviously due to the early silver miners of Nevada, who got bullion from their milling ores and chose to call bullion also the product which they got from their "cooking," or smelting, ores by the process which they at first regarded merely as a way of extracting silver with no consideration for the production of lead as a valuable metal.

was shipped westward and 2000 tons eastward. The ores shipped to California were partly smelted at San Francisco, and partly exported to England. According to A. D. Hodges, Jr., the receipts of ore at San Francisco from eastern Nevada and Utah in 1870 were 4537 tons, and of silver-lead, 1681 tons.

Making allowance for the lead content of ore shipped to San Francisco, it is probable that the lead production of Nevada in 1870, practically its first year as a producer of lead, was as much as 4500 tons.

From 1870 onward the history of lead production in Nevada is practically the history of Eureka, which from that time poured a constant stream of base bullion into the eastern refineries until the great deposits were exhausted. The Eureka Consolidated Mining Co. was always the largest producer of the district; the Richmond Consolidated was a good second. In the year ended Sept. 30, 1871, the former mined 18,847 tons of ore and smelted 18,825 tons, which produced 3468 tons of base bullion. The average cost of mining was $5.52 per ton of ore; of smelting, $19.60 per ton; these figures not including administration and general expenses. The works of the company comprised five furnaces, which had an aggregate capacity of 120 to 148 tons of ore per day. Charcoal was still the sole fuel for the furnaces, and wood for the steam-boilers, but the increasing scarcity and expense of both had already led to a consideration of the possible use of coal and coke. The consumption of charcoal was 30 to 45 bushels per ton of ore, averaging 35 bushels. It cost from 28 to 30 c. per bushel, or about $40 per ton. Wood cost $6 to $6.25 per cord. The cost of carting bullion to the Central Pacific railway was $12.50 to $17 per ton. The ores smelted had already become of lower grade in lead than in 1870, an average of 5.75 tons being required to make one ton of bullion in 1871. The total production of the Eureka district in 1871 was 5665 tons of bullion, valued at $2,035,588, of which the Eureka Consolidated produced 3172 tons, and the Richmond 1012 tons. The bullion averaged about $250 per ton in gold and silver and $90 to $100 per ton was paid for its lead.

The early mineral discoveries in Utah were chiefly of what was at that time called "base metal ores," *i.e.*, ores containing a comparatively large proportion of copper and lead. The difficulty experienced in the treatment of such ores, together with the high cost of transportation and the opposition of the Mormon authorities, caused the earlier mining enterprises to languish and fail. In 1868 and 1869 Dr. Raymond found no mines in productive operation except the placers of Bingham Cañon, which were worked on a small scale. In 1869, however, a few parties were preparing to take advantage of the railway, and experiments of a metallurgical character were in progress at Salt Lake City. In 1870 there was a sudden and extensive development of the mining industry in Utah.

This was due to several causes. The Pacific railway had been completed, furnishing greatly improved transportation facilities. The treatment of silver-lead ores had already been accomplished successfully on a large scale at Eureka, Nev. The opposition of the Mormon Church had been withdrawn, the market of an active mining population close at hand being welcomed to replace the lucrative traffic that the railway had practically put an end to, interrupting to a large extent the Mormon trading trains, carrying grain and vegetables far into the mining districts of other territories, and diverting the procession of wayfarers across the continent, who had previously paid great tribute to the farmers of the Salt Lake Valley. Finally, it was in 1870 that the famous Emma mine, in Little Cottonwood Cañon, was discovered, and the opening of its bonanza, "a lake of mineral of vast extent," which yielded a clear profit of nearly $120 per ton on shipments of ore to Swansea, Wales, "gave an impetus to mining in Utah that surpasses all other efforts made in that direction put together," these quotations being from a contemporaneous writer.[1]

The Emma mine became a large producer in the first year of its operation. One firm of brokers in Salt Lake City reported shipments during the six months ending Dec. 31, 1870, of 4200 tons of galena ores, of an average assay of 35% lead and $182 silver per ton, the average net value being $125 per ton. Almost all of this was from the Emma mine. The total shipments of the Emma mine for the year were 5293 tons of ore, of which 2968 went to the Atlantic coast and 2325 to the Pacific, and 8.5 tons of base bullion, the aggregate value being estimated at $967,000, reckoning the ore at $182 per ton and the bullion at $400. The cost of transportation (by team to Salt Lake City, 28 miles, and thence by rail to New Jersey), and the expense of treatment amounted to $90 per ton.

The prices paid in Salt Lake City by California buyers for Utah ores in January, 1871, were as follows: Ore containing 30% lead and 50 oz. silver per ton, $22; 40% lead, $30.60; 50% lead, $38; 60% lead, $45; 70% lead, $53; 80% lead, $61; for each 10 oz. of silver in excess of 50 oz., $10 per ton additional.

The costs of labor in Utah at this time were not high. In Bingham Cañon, first-class miners received $3 per day; second-class, $2.50; surface laborers, $2. Lumber cost $40 per M, mining timber $6 per cord, wood for fuel $4 per cord, common powder $5 per keg, quicksilver 80 c. per pound.

Outside of Little Cottonwood, prospecting was done in the adjacent cañons, Big Cottonwood and American Fork; at Stockton and in East Cañon, respectively 40 and 55 miles southwest of Salt Lake City; at

[1] Eli B. Kelsey, in Mineral Resources West of the Rocky Mountains, 1870, p. 219.

several places in the Tintic Valley, about 70 miles southwest of Salt Lake City, where some valuable discoveries of silver-lead ore were made; and in the West Mountain district, Bingham Cañon, about 25 miles southwest of Salt Lake City, where a large number of veins of argentiferous galena had already been discovered. All of these districts were naturally tributary to Salt Lake City, which was thus marked by its location as a logical point for smelting. Woodhull Bros. built a furnace there in 1870, and other works were projected. Dr. Raymond summarized the results of mining in Utah in 1870 in the statements that the most productive mines were deposits of argentiferous galena in limestone, that the business of mining and smelting required considerable capital, and that the abundance of supplies, cheapness of labor, and facility of transportation rendered it a highly inviting field for operations on a large scale, the accuracy of which forecast was borne out by the rapidity of the development during the next few years.

Even so soon as 1871 there was a great influx of prospectors, miners and speculators into Utah, and the remarkable increase in activity was manifested in the increased production of ore and bullion. The shipments of the year were estimated to be 2378 tons of base bullion and 10,806 tons of ore, of which 2185 tons of bullion and 8880 tons of ore were consigned eastward, the remainder westward. During the summer shipments of ore were restricted by an increase in the schedule of freights. The rates were subsequently reduced, though not to the former point. They were then $18 for ore and $20 for bullion per ton from Salt Lake to Omaha.

The Emma mine continued to be the principal producer. Up to August, 1871, it had yielded from 10,000 to 12,000 tons of ore, averaging about 160 oz. silver per ton, and from 45 to 50% lead. The total value of this ore, at the cash price paid for a large part of it in Liverpool, namely £36 per ton, was about $2,000,000. The mine had been sold to an English company for £1,000,000, a price which was contemporaneously criticised as unjustified by the appearance of the mine, and was subsequently proved to be greatly in excess of the actual value. The Flagstaff mine, near the Emma, also became a producer of rich lead ore during 1871.

Outside of Little Cottonwood Cañon, important developments were made in American Fork Cañon, where the Miller mine was worked; in Bingham Cañon; in the Tintic district, where rich smelting ores were mined in Eureka Hill; and in the Ophir and Rush Valley districts. Smelting furnaces were erected in all of these districts, their number in the latter part of the summer being reported as follows: Ophir, 5; Stockton, 2; Tintic, 2; Cottonwood, 3; Salt Lake, 4; Bingham, 2; American Fork, 2; Corinne, 1; total, 21. One plant was equipped with a reverberatory furnace for the treatment of galena ores, but the others had mostly small shaft furnaces, smelting chiefly oxidized ores and using charcoal as fuel. Most of the charcoal was brought into Utah by rail from Truckee, in the Sierra Nevada, though a considerable quantity was burned in the Wasatch Mountains, and in piñon districts further south. The Truckee charcoal was delivered at a cost of 25 c. per bushel. The Utah charcoal cost 22 to 30 c., but was apt to be inferior in quality, while, moreover, its supply was precarious.

The smelting practice was very bad, the furnaces being run for the most part in an ignorant manner, with the natural results of very brief and intermittent campaigns, frequent freeze-ups, high costs, and large losses of lead and silver. In many cases more than half of the lead contents of the ore were probably lost. Ores assaying 30 oz. silver per ton and 30% lead could hardly be treated at a profit, as appears from the following estimate by Mr. James Heffernan of the results at Corinne:

Cost of smelting 5 tons ore at $35	$175
Freight on 1 ton of bullion to Salt Lake	10
Total, not including interest, etc.	$185
Value of 2000 lb. bullion at 3.5c.	$70
Value of 120 oz. silver at $1.15	138
Total	$208

The percentage of lead recovery was estimated at $66\frac{2}{3}$; of silver at 80. According to the above figures there was a margin of only $23 to pay for five tons of ore.

The early history of lead mining in Utah and Nevada has been related with this detail in order to show clearly the causes and manner of its development. It will be observed that the great contributory cause was the completion of the Pacific railway, furnishing an outlet to the markets, east and west. Before the building of the railway, the cost of transportation was $250 and $300 per ton to the Pacific Coast, and $300 and $400 to the Atlantic,[1] which was a prohibitive charge on either ore or base bullion. By 1872 the cost of shipping bullion from Eureka, Nev., including the cost of refining and other charges, had come down to $78 per ton. With the possession of the transcontinental line, the determinative factor in the production of lead from these new sources was the opening of the great deposits of ore, which were previously known to a considerable extent, and were rich enough in silver, gold, and lead to stand the high cost of imperfect mining and smelting methods and local transportation. The prices for both lead and silver were high at that time, wherefore the ores were better able to meet the high costs,

[1] Mineral Resources West of the Rocky Mountains, 1870, p. 220.

which naturally were extremely variable in the different districts. In their subsequent history the dominating factors were the improvement in transportation facilities by the construction of branch lines of railway to the mining districts and the reductions in cost of mining and smelting by improvement in technical methods. The mines became thereby able to make an increased production though mining a lower and lower grade of ore, and in the face of a gradually declining price for silver and a generally downward tendency in the price for lead. Save for the exhaustion of some of the principal ore deposits there was no cause acting greatly to restrict production until prices fell very low during the monetary panic of 1893.

While Nevada and Utah became contemporaneously large producers of lead, the conditions in the two States were widely different. The large production of lead in Nevada was derived almost entirely from the mines of Eureka. These were the only really important lead mines ever discovered in Nevada, and when they were exhausted the lead production of the State dwindled to insignificance. The ores of Eureka were self-fluxing and could therefore be smelted at comparatively low cost, and being also mined easily and cheaply, they were exploited at great profit, the principal companies of the district being large dividend-payers from almost the beginning.

In Utah the principal mining districts are situated in the Wahsatch and Oquirrh ranges of mountains, lying respectively east and west of the valley south of Salt Lake, into which their gulches debouch. All of these districts are within a comparatively short distance of Salt Lake City, and within less distance of the points eight or ten miles south of the city which were early determined to be advantageous locations for smelteries. Lines radiating from that center reach Bingham, the Cottonwoods, Park City, and Tintic in comparatively short distances. In the first stage of mining in Utah the general idea was to smelt the ores at or near the mines where produced. Few or none of those mines, however, had ores of character that made them self-fluxing, and the cost of bringing in the necessary fluxes by the imperfect means of transportation of that time was high, and the cost of smelting was consequently high, on which account many of the early attempts proved failures. After the Utah Central railway was completed to Salt Lake City (in December, 1869) and extensions were continued to the various mining camps of that time, especially Alta, Bingham, and Tintic, it became possible to bring ores of different character together at a central point, near Salt Lake City, where smelting could be profitably conducted.

From the metallurgical standpoint Nevada never had but one lead-producing district, viz., Eureka. The operations in that district were chiefly in the hands of two large mining companies. Those companies smelted their ores directly at the mines. They were able to do so because the ores were self-fluxing. Moreover, the mines were rich and quickly became profitable and the companies were able to secure the best metallurgical services available at the time and construct the most improved works. For this reason, although silver-lead smelting had been previously tried elsewhere and was being tried elsewhere, more often with disastrous than with successful results, Eureka became the real birthplace of the industry in the United States. The technical developments that were due to the work at Eureka are described elsewhere in this history.

Utah, on the other hand, was a region of many lead-mining districts, none of which, until the development of the San Francisco or Horn Silver district, was in any way comparable industrially with Eureka. There was none of the early mines which in magnitude, richness, and ease of exploitation approached the Eureka and Richmond properties, and none which was so profitable. Many of the best mines, like the Emma and Flagstaff, were the subjects of inflated promotions, bad financiering, and eventual disaster, thus impeding industrial progress. The ores of the various districts were not self-fluxing and were incapable of successful reduction save at a suitable central point. When that was recognized and the construction of railways radiating from Salt Lake City made such practice possible, the production of lead in Utah was put on a sound basis and a great industry, lasting to the present time, was established upon it. Salt Lake City became the first point in the United States where a general smelting business of magnitude came to be conducted, and its practice was the prototype after which that of Denver, Pueblo, and El Paso was fashioned.

The production of Eureka increased rapidly. In 1872 it amounted to 6780 tons of base bullion, chiefly produced by the Eureka and Richmond companies, besides which there was a number of smaller concerns which had erected and were operating furnaces. However, the Eureka company alone furnished more than half of the output and its statistics for the year are important in illustrating the early conditions of mining and smelting. The cost of mining, and delivering the ore to the furnaces, was $7.84 per ton. One ton of bullion was produced from 8.42 tons of ore. The transportation and refining charges on the bullion aggregated about $78 per ton. The reason that there was not a larger increase in the production of the Eureka district in 1872 was litigation between the Eureka and Richmond companies, which checked the output of the latter.

Elsewhere in Nevada there was a little smelting done in the Railroad, Spruce Mountain, Robinson, and White Pine districts, but the aggregate output of those districts was insignificant.

In Utah also there was a noteworthy increase in the output of lead in 1872, the product of base bullion amounting to 8125 tons, while 10,347 tons of ore were shipped out of the State for smelting elsewhere. Estimating the yield of the ore shipped at 40%, the total lead product of the State in 1872 was 12,335 tons, which is probably an underestimate rather than an overestimate. The major part of this output was derived from the Cottonwoods. The Emma mine alone shipped 4000 tons of ore to England during the first eight months of the year and subsequently sold 6300 tons in the open market, a total of 10,300 tons which averaged 45% lead and 69 oz. silver per ton. The Flagstaff mine produced 3000 tons of base bullion, obtaining one ton of bullion from 3.5 tons of ore. The Miller mine produced 1536 tons of base bullion, smelted from very rich ore. The Winnemuck mine of the Bingham district produced 1232 tons of base bullion, smelted from an ore which averaged 38% lead and 56 oz. silver per ton. Smelting at the Winnemuck works was very expensive. Charcoal cost 30 c. per bushel; limestone, $7 per ton; iron flux, $22.50 and $25 per ton. The iron flux had to be obtained from Rawlins, Wyoming, and the fire-brick from Golden, Colo. The furnace charge consisted of 13 parts ore, 4 parts iron flux, 5 parts limestone, 2 parts old slag, and 6 parts charcoal. There were two furnaces, each smelting about 14 tons of ore per day. At the works of the Utah Silver Mining and Smelting Co., also in Bingham Cañon, the cost of smelting per ton of ore was $6.96 for fluxes, $15.80 for charcoal, $4.27 for labor, and $5.30 for roasting, a total of $32.33 per ton. The construction of the railroad up Bingham Cañon, which would enable the ores of that district to be taken to meet the ferruginous ores of the Cottonwoods, was eagerly awaited.

Both the miners and smelters of Utah in 1872 reaped great advantage from the fierce competition for ores and bullion among the eastern smelters and refiners, especially of St. Louis and Chicago, who bid up prices to a point which left dangerously small margins. The freight rate on ore from Salt Lake to Chicago at this time was $25 per ton; on bullion, $28.50 per ton. The Selby Smelting Co. of San Francisco was also a buyer in this market, and the refining of base bullion was begun at the Germania works at Salt Lake City, this being the first refinery in the Rocky Mountains. Altogether there were in Utah in 1872 smelting works to the number of 21, of which six had roasting furnaces, the total number of blast furnaces being 36, and of roasting furnaces seven. The Wahsatch works had begun with a Flintshire reverberatory furnace and a slag hearth, but those had been abandoned. The Wahsatch works which were situated just south of Salt Lake City were showing the advantage of a central location since they were able to mix the silicious lead ores of Bingham with the ferruginous lead ores of the Cottonwoods, and dispense with the use of costly iron flux. The cost of smelting in the blast furnace was $13 per ton of ore; of slag roasting in reverberatory furnaces,

$4 per ton, lignite being employed as fuel. Coke was used in the blast furnace instead of charcoal. It cost $30 per ton delivered, and as compared with charcoal at 30 c. per bushel was reckoned to be about $4 cheaper per ton of ore smelted. All the above values are currency. A comparison of these figures with those which have previously been given for smelting at Bingham will explain why the smelters in the Salt Lake Valley soon displaced those at the mines.

In 1873 Eureka, Nevada, showed a great increase in production, the base bullion product aggregating 12,052 tons, which was furnished by eight smelting works with a total of 17 furnaces. The statistics of the three principal companies are given in the following table, which is compiled from data in Mineral Resources West of the Rocky Mountains for 1876:

Company	Tons Ore Smelted	Tons Bullion Produced	Cost per Ton of Ore		
			Mining	Carting	Smelting
Richmond	30,262	5,010	$ 5.00	$ 2.00	$17.00
Eureka	25,692	3,227	$11.18		18.37
Ruby	13,102	1,930	7.25		17.50

The loss in smelting the Richmond ore was 19% of the lead and 15% of the gold and silver. The Ruby bullion was shipped to the Balbach refinery at Newark, N. J., which paid for the silver, less 5 oz. per ton, at the market value; for the gold at the assay value, less $2 per oz.; and for 88% of the lead at 5.5 c. per lb.; with a deduction of $20 per ton for refining. The usual receipt to the Ruby company was the assay value of the gold and silver, plus $15 to $20 per ton for the lead, after deducting freight and other charges.

Outside of the Eureka district the most important producer of lead in Nevada in 1873 was the Empire City Mining Co. of the Railroad district, which shipped 420 tons of base bullion.

In Utah the operation of many of the mines and smelting works was stopped by the panic, wherefore the lead output did not show any large increase over the previous year. The English companies suffered the worst and most of them fell into serious financial difficulties. Bingham and the Cottonwoods continued to be the chief lead-producing districts and in the latter the Emma mine was still the largest shipper, but at the end of the year it was practically exhausted and never afterward was it of importance except as a memory. It has been a hope in the Cottonwoods lasting to this day that some one would discover an ore deposit like the famous Emma bonanza. The Miller mine, of American Fork Cañon, was also exhausted this year.

Many new smelting works were erected in 1873, and the importance of the Salt Lake valley as a smelting center increased materially. A narrow-gauge railway was completed from Sandy on the Utah Southern railway, to the Winnemuck smelting works in Bingham Cañon, thus affording a cheaper outlet for the lead ores of that district. Dressing works were erected at Bingham Cañon, inaugurating a system of preliminary treatment of the ore that furnished to the smelters an improved class of smelting material. In general the smelting industry in Utah continued to be characterized by bad metallurgical practice, save at the Germania works, which were better managed than the others, and began to take a distinct place in the lead industry of Utah.

The production of lead in the Eureka district in 1874 showed a small falling off, as compared with the previous year, although conditions were improved by the completion of the railway from Palisade to a point only 30 miles distant from Eureka. The Richmond company, erected a refinery and began the desilverization of its bullion, and also made important improvements in its smelting plant, which gradually became the best plant of its kind in the West. The Eureka Consolidated Mining Co. continued to ship its base bullion to San Francisco, the transportation and other charges to that point aggregating $32.10 per ton.

The lead production of Nevada, outside of the Eureka district, continued to be insignificant.

In Utah there was a very considerable increase in the lead production in 1874, which was chiefly due to the Bingham district, then the most important lead-producing district of the Territory. A large output was still made, however, by the Cottonwoods, especially by the Flagstaff mine, which produced 14,767 tons of ore. There was a noteworthy increase in the number of dressing works in the Bingham district.

In 1875 there was little change in the output of the Eureka district, the Richmond and Eureka companies continuing to be the principal producers. The Ruby company made a considerable output, but in general there were restrictions in the undertakings of the smaller producers which for the most part gave up the scheme of smelting their own ores, and resorted to sale of the same to the Eureka and Richmond companies. The Eureka & Palisade railway was completed during the last quarter of the year, and the smelters were thereby enabled to avail themselves of coke as fuel, instead of charcoal, but very little coke was used at first, except by the Richmond company. The cost of the coke, delivered at its works, was $60 per ton.

The production of lead in Utah in 1875 also remained substantially at a standstill. This was apparently due, to a considerable extent, to the great competition among the smelters for ore which prevailed during the year, extinguishing their profits, and compelling many of them to shut down. The year was marked also by the completion of a narrow-gauge railway to Alta, in the Cottonwoods, reducing the freight from Alta to Sandy to $2.50 per ton. Coke from the San Pete district of Utah was also used this year by the smelters of Utah for the first time.

Subsequent to 1875, the mining and smelting industry of the Eureka district fell more and more into the hands of the two large companies which made increasing outputs up to about 1880, and paid large dividends. In the early eighties, however, the old bonanzas began to be exhausted, and the production of lead dwindled, falling to about 4000 tons in 1884. The reductions in mining and smelting costs were insufficient to compensate for the impoverishment of the ores, for although the cost of smelting was reduced somewhat, the cost of mining increased because of the necessity of operating at greater depth, and other unfavorable conditions. In 1883 the cost of mining to the Richmond company was $13.01 per ton, while smelting cost $11.66 per ton. In 1884 the figures were $15.83 and $11.72, respectively. Thus, there were no great differences between the cost of production at that time, and the cost 10 or 12 years earlier, in the first stages of mining in the Eureka district. By 1880 the workings in the principal mines had attained considerable depths, the Richmond having a shaft 1000 ft. deep. Up to that time the mines had been dry, but in 1881 the Eureka company encountered water in its new shaft at a depth of 756 ft. In the same year the great suit between the Eureka and Richmond companies was decided by the Supreme Court of the United States in favor of the former. This suit was brought in 1877 on account of the Richmond company having crossed its line and worked out the famous Potts Chamber, whereby the Eureka company claimed to have lost $2,000,000. In 1882 the deep shaft of the Eureka was drowned out, and henceforward pumping was a serious difficulty in the Eureka district.

From 1884 the mining industry at Eureka continued to fall off, the output dwindling to a comparatively low figure, being largely the product of lessees and tributers to whom portions of the mines had been given over. As early as 1885 most of the ore production of the Eureka Consolidated was from tributers. In 1889 the total lead production of the district was only 1489 tons. In the early nineties all operations came practically to a standstill. The feud that arose between the two great companies over early disputes, which became the subjects of bitter litigation, had never been forgotton, and prevented any possibility of harmonious action when such was needed. As the mines acquired more depth they had become wet and as early as 1882 had been drowned out in their lower levels, where the best prospects for ore existed. It was found that the water could be economically contended against only by united action, but under the circumstances that was hopeless. Consequently, the mines were practically abandoned to tributers, who gophered around in the upper levels. In 1890 the Richmond smeltery was closed and in 1891 the Eureka smeltery was also abandoned. Since that time the comparatively small production of the district has been shipped to outside smelters. In 1893 the production of the district was 14,515 tons of ore. The Diamond was then the only mine employing men on day's pay. In 1897 the output of the mines of the Eureka Consolidated was only 1121 tons of ore.

In 1905 there was a great increase in mining activity all over the United States, due to various causes, which need not be discussed here. The remarkable success of certain new gold mining camps in Nevada, especially Tonopah, Goldfield, and Bullfrog, attracted a large amount of attention to this famous old mining State, which previously had come to be regarded as almost dead. Among the many prospectors, miners, and engineers drawn to Nevada by the new discoveries, it was natural that the old bonanza mining camps, forgotten for many years, should be recalled to mind, and the idea suddenly occurred to various promoters and engineers that in all probability there were developments of ore in their mines, of too low grade to pay for working when they were abandoned, which would be profitable under the greatly improved methods of modern mining and metallurgical practice. In this way plans were made for reopening many of the old districts, among them Eureka. The Richmond-Eureka Mining Co. was organized in 1905, to take over the property of both the old companies, the stock of the Richmond Consolidated having been acquired by an American syndicate, and steps were inaugurated to unwater the mines, although that work has not yet (1907) been actually begun. In the meanwhile, however, shipments from the old stopes to Salt Lake City have been made on a large scale, it being possible to smelt profitably at that distant point in 1906 what had been valueless material on the spot 20 years earlier. The reopening of Eureka and some interesting points in its history were described in an article by me in the *Engineering and Mining Journal* of Dec. 7, 1907, from which the following paragraphs are reprinted:

"The first important mines of silver-lead ore in the United States were at Eureka, Nevada. It is now nearly 40 years since they were opened, nearly 25 years since they receded largely in production, and fully 15 years since anything worth mentioning has been heard of them until recently. But from 1869 to 1879, when their star paled under the superior brilliancy of Leadville, they were the largest domestic supply of pig lead and they are of peculiar interest because of their romantic history in the early days, because of the uniqueness of their geology and the famous litigation which arose respecting it, because of the richness and easy mining of the remarkable ore-bodies, and because at Eureka many mining engineers and metallurgists who subsequently became eminent received their first practical experience.

"There are some who think that these mines were abandoned prematurely and that well planned and persistently executed explorations will disclose new ore-bodies as rich as those which formerly were mined. There are others who think that the mineral-bearing formation of Ruby Hill was exhausted by the thorough exploitation of the old companies, that the mines were bottomed and have no further ore to yield, *i.e.*, silver-lead ore; of course, there is no question about the low-grade iron ore that was left behind in the old stopes.

"Up to the end of 1882 the production of the district, according to Curtis, was about 225,000 tons of lead, $40,000,000 worth of silver and $20,000,000 of gold. From the statistical records in Raymond's reports, and in Mineral Resources of the United States and elsewhere, I am unable to account for more than 178,000 tons of lead actually shipped from the State of Nevada, of which, of course, all but an insignificant amount came from Eureka. From 1882 to the end of 1890 the lead production was probably about 25,000 tons, and from 1891 to the end of 1900 I surmise it may have been about 12,000 tons. Probably the output of Eureka up to the end of 1900 was about 210,000 tons of lead, and doubtless 90% of that was derived from the two big mines.

"To go to Eureka, one leaves the main line of the Southern Pacific at Palisade. From that point the Eureka & Palisade runs almost due south to Eureka, a distance of about 80 miles. The country traversed is unfertile, unsettled, and uninteresting. There are occasional stations along the road, but nothing that can be called a village by any stretch of the imagination. At present there are two trains a day. One of them is exclusively a freight train. The other is chiefly a freight train, but by virtue of carrying a single combination car, with seats for 12 or 15 passengers, is by courtesy called a passenger train. This makes the journey of 80 miles in about six hours. Previous to the reopening of the mines there was only one train every other day.

"Descending from Garden pass the railway crosses Diamond valley and enters one of the gently sloping ravines, characteristic of eastern Nevada, in which — a short distance from the entrance — is situated the town of Eureka at an altitude of about 6500 ft. above sea-level. The terminus of the railway is below the town, a quarter of a mile or so. Just above the railway station was the smelter of the Eureka Consolidated, which company was always referred to as the 'Con.' Then comes the town and at the upper end of the town the Richmond smelter. There were smaller smelters near the 'Con' and near the Richmond, but with a single exception nothing remains of these save the slag-dumps, and indeed the same is true of the two big works.

"It is interesting to visit some of the old mining camps, which acquire a picturesqueness in their decay and dilapidation that savors of more years than they actually possess. But Eureka is not exactly dilapidated. On the contrary it exhibits rather a trim appearance in spite of the rows of shops with shutters closed on doors and windows since many years ago, bearing mute testimony to the fact that the 1000 inhabitants of to-day do not require so much as the 9000 of 30 years previous. Indeed, it is a mystery how the town has lived so well during the long years of stagnation in mining and has supported the many excellent retail stores, and two hotels — one particularly good — which it has to-day.

"Eureka is agreeably situated, its site being sufficiently roomy and the hills on either side being not very steep, and looking north there is a fine outlook over broad Diamond valley. There are some trees in the town and with the aforesaid shops and other conveniences it is not a bad place as mining camps go. In its various vicissitudes the town has been several times partially washed away by floods, once ravaged by smallpox, and twice almost completely destroyed by fire, but if not so prosperous as once it remains to-day a respectable shadow of its pristine self, with fond hopes that somewhat of its former activity may yet return.

"As early as 1878 the older workings of the Eureka mine contained considerable ore, which had failed to be extracted either through oversight or improper mining. Many small ore-bodies also had been passed over as too poor or insignificant to be worth mining, and there was reason, moreover, to believe that undiscovered ore-bodies of small size existed, as indeed turned out later to be the case. To make a clean sweep of the ground, in that year T. J. Read, then superintendent of the mine, introduced the tribute system, dividing up the ground into blocks. A little later the tribute system was introduced in the Richmond mine, and in that as well as in the Eureka, it was found to work very well. As the companies gradually finished their operations in the lower levels, tributers were put in them also, and eventually tributers were in possession of the whole mine in each case, especially after the influx of water had driven the companies out of the extreme lower levels. Subsequent to 1885 or 1886 the bulk of the production in the Eureka was made by tributers, and since about that time no maps were kept up by the companies.

"It is almost unnecessary to say that the tributers put the mines in wretched condition, because that is always what they do when they are not carefully supervised, and in almost all cases supervision which at first may be effective gradually becomes lax and eventually there is no supervision at all. The tributers in Ruby Hill burrowed, gouged, and gutted, filled up some old workings and allowed others to cave in. Probably it never will be known fully how and where they went. But the annoyance of present prospecting is that in discovering and following a promising leader of ore, it always is found to end not in a substantial and desirable nucleus, but invariably in a stope opened and exhausted by some tributer coming from a different direction. One cannot help admiring the industry of the former tributers, but it is to be remarked that in 30 years they had ample time to dig far and thoroughly.

"This leads to the question, What are the future prospects of the mines? In the first place, as to the upper wedge of limestone, it has evidently been nearly completely prospected. The ground in the Eureka mine has been prospected rather exhaustively clear to the bottom. However, in lower levels there are some blocks of 200 or 300 ft. square, which may be found to contain bodies of ore not yet discovered, although the chance for this does not appear to be extremely brilliant. In the Richmond mine the wedge of limestone is deeper and wider and the lower part of it has by no means been cut up so thoroughly as in the Eureka Consolidated. It is true that such exploratory work as has been done in the lower part of the Richmond mine has not resulted very successfully, but this may be due rather to bad luck than to the non-existence of ore-bodies. Nevertheless, it must be acknowledged that the mineral-bearing country in both these mines has been well prospected, and the production from any new ore-bodies that may be found in the upper wedge of limestone is unlikely to be more than a tithe of those which previously have been mined out. Recognizing this, it must be admitted that the chances are better for the Richmond mine than for the Eureka.

"As to the lower wedge of limestone the prospects are uncertain. They are the same to-day as when Curtis made his report, and consequently Curtis' views are important. He says in concluding his report: 'The probability of finding ore in the lower wedge of limestone depends in a great measure upon the validity of the theory of substitution. If this theory is the true one — and the proofs favoring it are strong — there seems to be no reason for doubting the presence of ore below, provided that the limestone was in a fit state to admit the ore-bearing solution during the period of deposition. That this was the case is indicated by what has been thus far observed in the lower limestone and by the fact that ore was found in the Ruby Hill fault-fissure when it was laid bare by the cross-cut from the 1200-ft. level of the Locan shaft. On the other hand, if the ore-body were dependent on the prior formation of caves they will not be found below the water level, as cave formation could not take place much below that plane.'

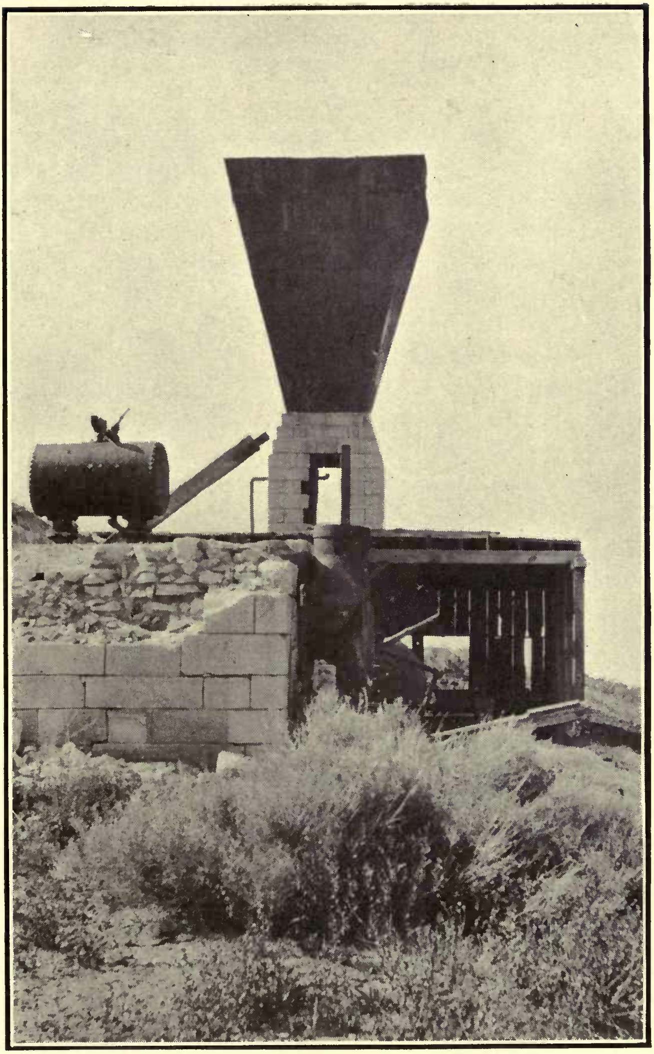
"It may be remarked here that Curtis himself rather strongly favored the theory of substitution. He continued as follows: 'Whether the extraction of the ore in the deeper workings will prove profitable will depend upon the flow of water, size of ore-body, value of ore, and facilities with which it can be reduced. Water may prove a serious impediment, but it is not necessarily one which should be fatal to the exploration of these mines. As to the size of the ore-bodies no satisfactory predictions can be made. No great change in the value of the ore as regards to silver need be feared, though it is possible that the contents in gold may be decreased.

"Whatever may be learned with respect to the lower wedge of limestone, its exploration is certain to prove one of the most interesting problems in mining geology. Up to the present time no active move has been made in this direction, although the equipment for bailing out the Locan shaft is already on the ground.

"The activity of the Richmond-Eureka Mining Co. so far has been confined to re-opening the old mine for the extraction of iron ore. This has been a costly, dangerous, troublesome, and tedious work, the old stopes having largely come in, so that it has been necessary to retimber them entirely with square sets. The shafts also had to be retimbered. As a preliminary to the present operations all of the leases in the mine were canceled.

"Operations are now going on in the surface workings on the western side of Ruby Hill, on the first, second, and ninth levels of the Eureka and on the sixth level and elsewhere of the Richmond. The operations are resulting in the production of about 130 tons of ore per day, which averages about 3½% lead, 30% excess of iron, 0.18 to 0.2 oz. of gold and from 2 to 3 oz. of silver per ton. The value of such ore is probably about $10 per ton at the mine. In its production 160 men are employed. Drill runners are paid $4 per day, miners, $3.50, muckers and trammers, $3. Timber is very expensive, costing $80 per thousand. It is probable that the requirements will be reduced later on by the introduction of the top-slice system of mining in certain portions of the mine. The reopening of the mines has not yet by any means been completed, and gradually without doubt the cost of mining will be reduced, but even under the most favorable circumstances it is difficult to see how there can be any great profit from $10 ore which has to stand transportation charges of 380 miles to the smelter at Salt Lake City. That there is any profit must be due to a favorable smelting contract with the United States Smelting, Refining and Mining Co., which owns a large interest in and manages the Richmond-Eureka. The ore from the latter furnishes a necessary and valuable flux to the smelter.

"Eureka was the real birthplace of silver-lead smelting in the United States. The two large smelters of Eureka were in operation for 20 years. The Richmond was closed in 1890; the 'Con' in 1891. When the Richmond was built, in 1871, it was the finest thing in American lead-smelting



Matamoras Smelter, Eureka, Nev., in 1907.

practice. Doubts were expressed as to the justification of so much perfection in view of the uncertain life of the mines. This is, of course, amusing, when we read the later history of the latter. Now, nothing much remains of the old works except the huge slag dumps. On the Richmond site there is standing a small cupola furnace and a few pieces of rusty dismantled machinery that it was not worth while to remove. On the 'Con' site there are a few dismantled sheds. The sites of the smaller works are stripped equally clean.

"However, there is at Eureka one good relic of the past. This is the Matamoras smelter, just above the 'Con,' which is shown in one of the engravings. Its stone furnace surmounted by a strange piece of iron-work is a prominent sight upon arriving at Eureka. The building in which it stood has fallen down and been carried away for lumber, but the furnace has withstood the action of wind, weather, and vandals, and remains to-day a fine example, and the only example, of how smelting used to be done at Eureka. The date of its erection I am unable to say, but it must have been early. The furnace is constructed of the 'firestone,' a refractory, easily cut standstone which was used in all of the early furnaces at Eureka. Indeed, the Eureka Consolidated did not abandon this construction and substitute water-jackets until 1884. The entire shaft of the Matamoras furnace is constructed of this stone. The breast is open — a sump-furnace. The curious structure on top of the furnace is a dust-catcher. It is of sheet-iron lined with brick. In the top there is a circular hole, about 18 in. in diameter, for escape of the gas. At the bottom a steam-pipe, bent upward, was evidently to promote the draft. The idea was that the dust carried upward from the charge would be checked in the inverted pyramid and would slide down the sides of the latter into the furnace again. To our modern eyes this is an amusing contrivance, but at that time, be it remembered, dust-collecting flues had not been introduced. Alongside of the furnace is the Sturtevant fan which furnished the blast, then the little engine which drove the fan, and finally the boilers, set also in firestone, which produced the steam. These are shown quite clearly in the engraving.

"The old metallurgists were fairly skilful and the ores were of easy smelting character. Consequently the slags are not very rich; certainly not rich enough to rework. They are said to contain from 2 to 3 oz. silver per ton and 1 to 2% lead. However, there are large accumulations of speiss, which may some day be a source of value. The formation of this compound, due to the arsenic in the ore, was always a great trouble to the Eureka metallurgists. They could not cleanly extract its gold, silver, and lead, and cast it aside in cones, which glisten brilliantly on the dumps to-day. I was informed by an official who had long been connected with the Eureka Consolidated that the amount of speiss in the Eureka and Richmond dumps is probably between 130,000 and 200,000 tons, and that it contains 30% arsenic, 3% lead, 2% copper, and 2 to 3 oz. silver and $3 to $4 gold per ton. If these figures are approximately correct, there is in these dumps a great resource of arsenic, enough to supply the domestic consumption for many years. The high percentage of arsenic noted in the bag-house fume at the United States smelter at Salt Lake undoubtedly comes from the smelting of the Eureka ore."

Subsequent to 1875, the lead production of the Cottonwood and Bingham districts of Utah fell off, but the decrease in the output from these sources was much more than compensated for by the great yield of the Horn Silver Mining Co., which began to come into prominence about 1878. The mines of this company were situated in the San Francisco mining district, near the town of Frisco, 240 miles from Salt Lake City. The output of the district was made almost entirely by two companies, the Horn Silver Mining Co., owning the Horn Silver mine, and the Frisco Milling and Smelting Co., owning the Cave and Carbonate mines. Both of these companies smelted their own ore. The Horn Silver Mining Co. originally had a plant at the mines, but that proving to be uneconomical, a new plant was erected at Francklyn, near Salt Lake City, and a refinery was also erected at Chicago, Ill. For about five years the production of the Horn Silver Mining Co. was very large, as appears in the following table:

Year	Ore Smelted Tons	Lead Assay	Bullion Produced Tons	Lead Sold Tons	Average Price per cwt.
1879				1,556	$4.07
1880	51,758	36.12%	16,915	3,900	4.53
1881				7,893	4.61
1882	48,551	37.79	16,127	14,568	4.60
1883	42,663	36.83	15,008	14,991	4.20
1884	39,185	30.91	11,603	10,976	3.50

The price for lead in the above table is what was realized at Chicago. Besides the ore smelted the company sold 6150 tons to other smelters. Previous to the sale of the property to the Horn Silver Mining Co. there had been smelted 16,299 tons of ore assaying an average of 38.49% lead, which produced 5180 tons of pig lead. The total output of this famous mine up to the end of 1884 was 204,607 tons of ore, which yielded 69,380 tons of base bullion and 7,260,566 oz. of fine silver.

The cost of mining in 1884 was $5.07 per ton of ore. Miners were paid $3.50 per day and laborers $3. The smeltery at Francklyn had five furnaces, which reduced 39,185 tons of ore at a cost of $13.29 per ton, but the total quantity of material smelted, including fluxes and fuel, was 103,079 tons. The cost of refining base bullion at Chicago was $8 per ton.[1]

In 1885 the Horn Silver production declined greatly, and in 1886 the mine became practically dead. Subsequent to this time, the chief lead-producing districts of Utah were Bingham Cañon and Park City, the latter, discovered in 1871, having attained prominence in 1873 when the famous Ontario mine was opened, but as a lead producer it did not become of great significance until about 1884 when the Crescent mine was a large producer. Subsequent to 1884 the lead production of Park City increased very largely, and at the present time, it is the most important lead-producing district of Utah. The mines at Tintic, Stockton, and Alta have been continuously worked, but during the last 20 years the major portion of the lead production of Utah has been derived from the mines of Bingham Cañon and Park City.

[1] Production of the Precious Metals in the United States, Report of the Director of the Mint, 1884.

XIII

STATISTICS OF PRODUCTION, CONSUMPTION, AND PRICES

The statistics of lead production in the United States are given in the following table, which is an original compilation from various authorities. The figures published in the Mineral Resources of the United States of the U. S. Geological Survey are those of Whitney, from 1825 to 1853; and of Mr. Edward A. Caswell, of New York, from 1854 to 1882. From 1873 to 1882 Mr. Caswell gathered annually the statistics of production with a painstaking care and an intimate knowledge of the business which caused his figures to be accepted as authoritative. Since 1882 statistics have been collected annually by the U. S. Geological Survey. About the same time the *Engineering and Mining Journal* began independent statistical investigations, the results of which were published annually in The Mineral Industry since 1892. Unfortunately, the statistics of The Mineral Industry and the Mineral Resources do not always agree. Moreover, none of the statistical reports are complete in showing the distribution of the production by States.

PRODUCTION OF LEAD IN THE UNITED STATES, 1830–1870
In tons of 2000 lb.

Year	Tons	Year	Tons	Year	Tons	Year	Tons	Year	Tons	Year	Tons
1830	8,000	1837	15,300	1844	26,000	1851	21,100	1858	19,500	1865	14,700
1831	9,500	1838	16,300	1845	31,000	1852	18,800	1859	21,000	1866	16,100
1832	9,750	1839	18,000	1846	30,000	1853	19,500	1860	20,200	1867	15,200
1833	10,500	1840	17,350	1847	31,000	1854	20,500	1861	14,100	1868	16,400
1834	12,000	1841	20,000	1848	28,000	1855	19,800	1862	14,200	1869	17,500
1835	13,000	1842	19,700	1849	26,200	1856	20,000	1863	14,800	1870	17,830
1836	16,500	1843	23,600	1850	24,000	1857	19,800	1864	15,300		

In my present compilation I have modified the figures of Whitney and Caswell in some cases where such appeared advisable from an examination of the later investigations of State geological surveys, and with respect to the production since 1882 I have adopted the figures which appear most probable, being aided in this by the reports of various State commissioners of mines, and the reports of the Director of the Mint on the "Production of Gold and Silver in the United States." No statistics

Production of Lead in the United States, 1871–1907

In tons of 2000 lb.

Year	Arizona	California	Colorado	Idaho	Mississippi Valley	Montana	New Mexico	Nevada	Utah	Other States[1]	Total
1871 ..	..	2,000	..	..	12,000	..	..	6,000	5,000	..	25,000
1872 ..	..	3,220	..	..	16,170	..	..	7,000	12,300	..	38,690
1873 ..	..	4,000	56	..	22,381	..	..	12,812	12,615	..	51,864
1874 ..	1,000	5,600	312	..	[2] 23,000	..	..	11,516	18,000	..	59,428
1875 ..	..	3,600	818	..	24,730	..	..	13,000	18,500	1,000	61,648
1876 ..	..	..	667	..	26,421	..	..	12,000	25,000	3,000	67,088
1877 ..	..	..	897	..	31,152	..	..	19,724	27,000	3,127	89,100
1878 ..	..	..	6,669	..	26,770	..	..	31,063	21,000	5,558	91,060
1879 ..	..	..	23,674	..	28,130	..	..	22,805	14,000	4,171	92,780
1880 ..	..	..	35,674	..	27,690	..	..	16,659	15,000	2,082	97,825
1881 ..	..	..	40,547	800	30,770	3,000	..	12,826	24,000	5,142	117,085
1882 ..	..	..	55,000	[2] 4,100	29,019	4,100	1,500	8,590	27,000	3,581	132,890
1883 ..	1,000	1,700	70,557	6,100	21,800	4,900	2,400	6,000	29,000	500	143,957
1884 ..	..	1,600	63,165	7,600	19,932	6,900	6,000	4,000	28,000	2,700	139,897
1885 ..	..	..	55,000	10,000	21,975	[2] 6,500	5,500	3,500	23,000	3,937	129,412
1806 ..	700	..	59,000	16,500	20,800	[2] 5,500	5,000	3,400	[2] 21,500	3,229	135,629
1887 ..	..	800	63,000	20,000	25,148	7,000	[2] 5,000	3,400	[2] 19,500	2,364	145,212
1888 ..	..	..	[2] 65,500	21,500	29,090	[2] 8,500	[2] 4,500	2,400	[2] 17,500	2,929	151,919
1889 ..	3,158	53	68,000	23,172	29,258	10,000	4,764	1,950	16,500	542	157,397
1890 ..	..	..	52,500	[2] 24,000	31,351	[2] 10,000	5,910	[2] 1,500	[2] 15,000	1,804	142,065
1891 ..	..	..	64,000	38,181	34,000	14,127	5,330	2,500	[2] 17,000	3,416	178,554
1892 ..	..	..	61,500	33,000	37,000	12,858	5,895	3,000	[2] 23,000	4,747	181,000
1893 ..	..	..	43,698	32,263	38,241	8,348	6,869	3,041	26,454	5,068	163,982
1894 ..	1,480	478	50,613	33,308	38,000	9,637	2,973	2,254	23,190	753	162,686
1895 ..	2,053	949	46,984	31,638	40,000	9,802	3,040	2,583	31,305	1,646	170,000
1896 ..	1,165	690	44,803	46,600	43,500	11,000	3,400	1,150	35,500	589	188,000
1897 ..	2,150	380	40,400	58,627	45,710	12,900	9,100	950	40,500	283	211,000
1898 ..	2,200	480	56,708	59,000	50,468	10,500	5,700	4,700	38,500	219	228,475
1899 ..	3,400	500	69,024	52,500	40,566	10,250	4,850	3,400	32,000	595	217,085
1900 ..	3,400	520	82,137	85,000	47,923	7,600	3,300	2,000	47,000	227	279,107
1901 ..	4,045	360	74,056	81,275	57,898	5,790	3,060	1,873	49,870	1,695	279,922
1902 ..	600	175	53,152	84,742	74,050	4,438	1,200	1,269	54,000	1,374	275,000
1903 ..	1,000	50	50,757	95,000	78,298	3,300	3,150	2,000	48,500	347	282,402
1904 ..	1,000	155	53,773	103,000	90,470	2,150	1,500	1,700	53,250	206	307,204
1905 .	2,090	120	57,856	104,500	102,500	2,280	1,200	2,200	44,500	298	319,744
1906 ..	2,900	432	52,992	121,584	115,103	2,485	1,100	1,800	56,268	645	355,309
1907 ..	1,760	811	47,332	111,697	128,193	2,005	1,927	3,373	54,738	401	352,237

[1] The statistics of "other States" include production that cannot be definitely assigned. For example, the lead production of California did not cease in 1875, but for several years it is comprised in "other States."

[2] Estimated.

of production can be absolutely correct in the case of industries which are so complex as the metal industries of the United States have recently become. As a general principle, honestly and intelligently collected statistics should fall somewhat short of the actual production, because there are always small outputs which escape enumeration. But under conditions where products in various stages are passed from one smelter to another, there is always the danger of a duplication of reports, two or more producers counting the same material, and the total will then be too high. The statistics in this chapter are presented, therefore, simply as those which in my opinion are the most probable.

The statistics of price of pig lead in the accompanying table are based on the following authorities: London, 1801–1893 inclusive, as reported by the Metallgesellschaft, Frankfurt am Main, converted into U. S. currency by Mr. John N. Judson (Report of the Missouri Geological Survey on Lead and Zinc, I, 261). As specie payments were suspended in Great Britain from 1797 until about 1844, the prices quoted between those dates were in bank paper, gold standing at a premium. The figures for the years subsequent to 1893 are also as reported by the Metallgesellschaft, but have been converted into U. S. currency by me on the basis of £1 = $4.87. The New York price, 1812–1869, both inclusive, is the wholesale value of pig lead, according to data collected by Wetherill & Brother of Philadelphia, and published in The Mineral Industry, III, 408–409. The figures for the years subsequent to 1869 are as given by The Mineral Industry. The price at St. Louis, 1844–1873, is as given by the Report of the Missouri Geological Survey on Lead and Zinc, II, 501. These data being compiled by so many different sources are not strictly comparable, but are presented as the best available. It is doubtful always to what extent such figures are thorough averages. However, it is probable that from 1870 onward the New York and London prices are fairly comparable, and that also may perhaps be said in general as to the data for St. Louis, but there are some discrepancies that are obviously improbable. The high prices at St. Louis from 1862 to 1876 are evidently in currency, gold being at a premium.

The figure given for the average price at St. Louis in 1888 is probably an error, inasmuch as the St. Louis price is normally lower than the New York price, and anyway there could be no such difference between the two markets. Since 1893, the St. Louis price has been from 0.10 to 0.20 c. per lb. below the New York price. Formerly, the St. Louis quotations represented chiefly the Missouri brands of lead, either the ordinary Missouri or the chemical hard, while the New York quotation is for ordinary desilverized. As compared with the latter, the Missouri brands often sold at a slight discount, but recently the two kinds of lead have sold substantially on a par.

Average Annual Price of Pig Lead

In cents per pound

Year	St. Louis	New York	London	Year	St. Louis	New York	London
1812	..	11.16	5.02	1860	5.25	5.65	4.83
1813	..	..	5.59	1861	5.25	5.25	4.78
1814	..	..	5.81	1862	6.50	6.10	4.52
1815	..	17.86	..	1863	8.625	6.25	4.52
1816	..	..	3.53	1864	12.80	7.10	4.69
1817	..	..	..	1865	10.00	6.60	4.37
1818	..	..	5.95	1866	10.00	6.90	4.45
1819	..	6.70	..	1867	9.00	6.50	4.25
1820	..	6.36	4.67	1868	9.00	6.50	4.20
1821	..	6.63	4.89	1869	8.75	6.45	4.25
1822	..	6.35	..	1870	7.25	6.25	4.05
1823	..	5.36	4.83	1871	7.00	6.08	3.95
1824	..	6.39	4.56	1872	6.875	6.30	4.34
1825	..	7.59	5.48	1873	6.875	6.32	5.06
1826	..	6.75	4.13	1874	6.34	6.01	4.80
1827	..	6.14	..	1875	6.70	5.85	4.88
1828	..	5.39	3.42	1876	6.60	6.13	4.70
1829	..	3.75	..	1877	5.15	5.49	4.46
1830	..	3.75	2.64	1878	3.40	3.61	3.63
1831	..	4.56–6.00	..	1879	4.00	4.14	3.22
1832	..	5.94	2.53	1880	4.75	5.04	3.56
1833	..	5.91	..	1881	4.10	4.81	3.25
1834	..	5.12½	..	1882	4.70	4.91	3.13
1835	..	6.50	3.69	1883	4.00	4.32	2.81
1836	..	6.37½	5.45	1884	3.50	3.74	2.59
1837	..	5.96	4.72	1885	3.80	3.95	2.51
1838	..	5.29	..	1886	4.50	4.63	2.87
1839	..	5.83	..	1887	4.30	4.50	2.80
1840	..	4.89	3.94	1888	5.00	4.42	3.02
1841	..	4.50	4.37	1889	3.60	3.93	2.84
1842	..	3.81	..	1890	4.20	4.48	2.91
1843	..	3.58	..	1891	4.15	4.35	2.70
1844	3.025	3.90	3.68	1892	3.90	4.09	2.34
1845	3.305	4.03	..	1893	3.50	3.73	2.07
1846	3.425	4.73	4.11	1894	..	3.29	2.05
1847	3.710	4.37	..	1895	..	3.23	2.34
1848	3.68	4.26	..	1896	..	2.98	2.43
1849	4.07	4.78	3.45	1897	..	3.58	2.64
1850	4.60	4.80	3.80	1898	..	3.78	2.82
1851	4.285	4.85	3.72	1899	..	4.47	3.22
1852	4.35	4.80	3.88	1900	..	4.37	3.69
1853	5.98	6.45	5.07	1901	..	4.33	2.72
1854	6.19	6.57	5.14	1902	..	4.07	2.45
1855	5.745	6.87	5.01	1903	..	4.24	2.51
1856	6.22	6.59	5.21	1904	..	4.31	2.60
1857	6.005	6.18	5.17	1905	..	4.71	2.98
1858	5.20	5.94	4.67	1906	..	5.66	3.77
1859	5.25	5.50	..	1907	..	5.33	3.15

The statistics of production, imports, exports, and consumption are given in the following table. The statistics of production are taken from the previous tables. The statistics of imports and exports include lead in pigs and bars, manufactures, and old lead, up to 1866 inculsive; after that pig lead only. The figures are for fiscal years ending Sept. 30, prior to 1843; for fiscal years ending June 30, from 1843 to 1886, inclusive; since 1886, calendar years. The figures of consumption represent simply the production plus the imports, minus the exports. For any single year they are likely to be incorrect, because statistics computed in this way fail to take into account the difference in stocks on hand at the beginning and end of the year, but over a series of years they indicate closely the actual progress in consumption.

Production and Consumption of Lead in the United States

Year	Production	Imports	Exports	Consumption *a*	Year	Production	Imports	Exports	Consumption *a*
1791	*b*	1,056	*Nil*	1,056	1822	1,900	2,603	33	4,470
1792	*b*	863	*Nil*	863	1823	2,068	1,711	26	3,753
1793	*b*	763	*Nil*	763	1824	1,987	1,353	9	3,331
1794	*b*	985	*Nil*	985	1825	2,232	2,997	95	5,134
1795	*b*	1,535	*Nil*	1,535	1826	2,379	2,930	24	5,285
1796	*b*	1,038	*Nil*	1,038	1827	4,490	3,993	25	8,458
1797	*b*	416	*Nil*	416	1828	7,452	4,038	38	11,452
1798	*b*	338	*Nil*	338	1829	8,571	820	90	9,301
1799	*b*	1,484	*Nil*	1,484	1830	8,000	356	64	8,292
1800	*b*	1,371	*Nil*	1,371	1831	9,500	1,054	76	10,478
1801	*b*	1,167	*Nil*	1,167	1832	9,750	2,667	36	12,381
1802	*b*	808	*Nil*	808	1833	10,500	1,634	60	12,074
1803	*b*	1,201	*Nil*	1,201	1834	12,000	2,550	7	14,543
1804	*b*	1,773	10	*c*	1835	13,000	710	25	13,685
1805	*b*	1,828	4	*c*	1836	16,500	490	17	16,983
1806	*b*	2,470	*Nil*	*c*	1837	15,300	232	149	15,383
1807	*b*	2,450	*Nil*	*c*	1838	16,300	113	187	16,226
1808	*b*	2,320	20	*c*	1839	18,000	283	40	18,243
1809	*b*	554	63	*c*	1840	17,350	283	441	17,192
1810	*b*	1,503	86	*c*	1841	20,000	48	1,088	18,960
1811	*b*	920	33	*c*	1842	19,700	29	7,276	12,453
1812	*b*	500	37	*c*	1843	23,600	7	7,683	15,924
1813	*b*	277	138	*c*	1844	26,000	2	9,210	16,792
1814	*b*	30	22	*c*	1845	31,000	8	5,094	25,914
1815	*b*	1,620	20	*c*	1846	30,000	3	8,412	21,591
1816	*b*	6,920	18	*c*	1847	31,000	13	1,663	29,350
1817	*b*	1,340	56	*c*	1848	28,000	162	997	27,165
1818	*b*	1,185	140	*c*	1849	26,200	1,342	390	27,152
1819	*b*	658	47	*c*	1850	24,000	18,500	130	42,370
1820	*b*		13	*c*	1851	21,100	21,735	115	42,720
1821	1,900	2,744	28	4,616	1852	18,800	18,772	373	37,199

PRODUCTION AND CONSUMPTION OF LEAD (*continued*)

Year	Production	Imports	Exports	Consumption *a*	Year	Production	Imports	Exports	Consumption *a*
1853	19,500	21,587	50	41,037	1881	117,085	2,161	....	119,246
1854	20,500	23,857	202	44,155	1882	132,890	3,040	....	135,930
1855	19,800	28,372	82	48,090	1883	143,957	2,019	....	145,976
1856	20,000	27,647	155	47,492	1884	139,897	1,536	....	141,433
1857	19,800	23,973	435	43,338	1885	129,412	2,931	....	132,343
1858	19,500	20,615	450	39,665	1886	135,629	8,791	....	144,420
1859	21,000	31,891	156	52,735	1887	145,212	3,858	....	149,070
1860	20,200	21,235	451	40,984	1888	151,919	1,291	....	153,210
1861	14,100	19,880	54	33,926	1889	157,397	1,387	....	158,784
1862	14,200	16,777	40	30,937	1890	142,065	9,668	....	151,733
1863	14,800	33,842	119	48,523	1891	178,554	1,696	....	180,250
1864	15,300	25,805	112	40,993	1892	181,000	775	....	181,775
1865	14,700	14,150	426	28,424	1893	163,982	1,980	....	165,962
1866	16,100	31,277	12	47,365	1894	162,686	19,584	....	182,270
1867	15,200	32,661	50	47,811	1895	170,000	55,775	....	224,775
1868	16,400	31,627	219	47,808	1896	188,000	5,275	....	193,275
1869	17,500	43,932	....	61,432	1897	211,000	8,025	....	219,025
1870	17,830	42,948	....	60,778	1898	228,475	156	....	228,631
1871	25,000	45,748	....	70,748	1899	217,085	1,736	....	218,821
1872	38,690	36,543	....	75,233	1900	279,107	1,837	....	280,944
1873	51,864	36,212	....	88,076	1901	279,922	1,802	....	281,724
1874	59,428	23,103	....	82,531	1902	275,000	6,222	....	281,222
1875	61,648	16,385	....	78,033	1903	282,402	4,486	....	286,888
1876	67,088	7,165	....	74,253	1904	307,204	8,667	....	315,871
1877	81,900	7,292	....	89,192	1905	319,744	5,720	63	325,401
1878	91,060	3,358	....	94,418	1906	355,309	11,763	73	366,999
1879	92,780	608	....	93,388	1907	352,237	9,277	55	361,459
1880	97,825	3,362	....	101,187					

a. Production plus imports, minus exports.

b. Statistics unavailable.

c. Statistics unavailable; the consumption in the early years of this period is nearly represented by the imports.

XIV

COMMERCIAL CONDITIONS

In the previous chapters I have presented the statistics of lead production and consumption in the United States, together with the statistics of price; have outlined the progress in metallurgical practice; and have traced the mining developments in the important lead-producing districts, taken up separately. It remains to summarize these facts, and add to them the records of commercial conditions affecting the industry as a whole in order to give an accurate insight into the economic development of lead mining in the United States.

The United States was favored by nature with bountiful resources of lead ore. At the present time its production of lead is greater than that of any other political division of the world, a statistical position which has been held since 1897, and indeed since 1880, if we except a period when it was surpassed by Spain. Other countries have, or have had, many important lead-producing districts; in some cases great lead-producing districts, like Sierra Mojada in Mexico, and Broken Hill in New South Wales, but no other country has had so many great lead-producing districts as the United States.

In the preceding chapters it has stood out clearly that the most powerful factors in the development of the great lead resources of the United States have been: (1) Discovery; (2) provision of railway transportation; (3) improvements in mining and metallurgical practice, especially the latter.

Discovery as a factor is largely fortuitous. The ore exists where nature has deposited it. It remains only for man to find it. When and how he may find it is more a matter of chance than anything else. The uncovering of a great deposit of easily mined ore has an immediate and unforeseen effect on the market for the metal and may completely upset previously existing conditions. We have seen how this has been in the cases of Eureka, Nev., and Leadville, Colo., especially. In the cases of deposits which are less easily worked, like those of the Cœur d'Alene, Idaho, and the disseminated ores of southeastern Missouri, the developments have been more gradual and the effect on the industry has consequently been less sudden. No connection can be established between new discoveries of the first order, and causes which have created an increased demand for the metal. It is true that fluctuations in the demand for the metal have increased and decreased the mining of lead ore in a powerful way, but prospecting is going on all the time and is practically independent of the demand for any particular metal. A prospector may be looking especially for a copper mine, because the price for copper is high and copper mines are eagerly desired, and instead of copper ore may find lead ore. In prospecting for gold he may find copper.

But, although the discovery of ore deposits is chiefly fortuitous, the progress in the science of economic geology has greatly improved the ability of the prospector to prosecute successfully his search for ore, and of the miner to estimate the value of his discoveries. A few examples of how the advance in geological knowledge has been a factor in the dedevelopment of our mineral resources may be usefully mentioned. Moses Austin, who was probably the most expert lead miner and smelter in America in his day, had a high opinion of the superficial deposits of lead ore in Missouri, which opinion was doubtless justified by the knowledge existing 100 years ago, but at present the occurrences which he observed would command but slight attention. Many attempts were made to mine lead ore in the Eastern States by adventurers who thought they had large deposits. Without doubt they did appear large to them, because never having seen a really large deposit they lacked all sense of proportion, but to an engineer who had gained experience at Eureka, at Leadville, or in the Cœur d'Alene, most of the mines of the Eastern States would appear simply laughable.

I have elsewhere remarked how the discovery of rich ore at White Pine, Nev., in a limestone formation was the prime cause of directing attention to the mineralization of the same kind of rock at Eureka, Nev., and ever afterward prospectors looked especially for great deposits of lead ore in limestone formation; not that limestone had not previously been known as a kindly rock for the deposition of lead, but that it remained for the discovery of the Eureka bonanzas to impress the fact on all minds. Similarly, the discovery of gold in the andesite and phonolite of Cripple Creek, in 1891, right in the shadow of Pike's Peak, a district that had been overlooked by prospectors ever since 1859, contributed largely to the rich discoveries at Tonopah, Goldfield, and Bullfrog about 10 years later. Previous to 1891 American prospectors did not know that gold occurred in the andesite class of rocks. The "heavy rock" that led A. B. Wood to the discovery of the carbonate deposits of Leadville doubtless troubled the placer miners of old Oro from the very beginning of their operations in 1860. Where was the prospector of 1880 who would not have identified it?

Leadville is perhaps still the best example of the successful application of the modern science of economic geology, as certainly it was one of the earliest. Soon after the importance of the district was recognized, Mr. S. F. Emmons was sent there by the U. S. Geological Survey. His monograph, which is one of the classics of the literature of economic geology, was not published until the district was decidedly on the wane, but fortunately, a summary of his work, together with his most important geological maps, were early made available and proved to be of the utmost importance in the development of the district. Emmons's work on Leadville alone is sufficient justification of the existence of the U. S. Geological Survey. As a miner in Leadville during the eighties I can personally testify as to the esteem in which it was held as a practical guide by miners of all classes, and the frequency with which the geological maps hung in the post-office were studied by booted and canvas-clothed prospectors.

One more instance of the application of modern methods to prospecting for lead ore: The disseminated deposits at Bonne Terre, Mo., were discovered by diamond drilling, this being one of the first, if not the first, uses of the diamond drill for prospecting for lead ore. It has ever since then been the most instrumental factor in the development of the lead resources of that region, and, in connection with the study of the geological conditions which extended the area of the field toward the end of the eighties, has made of this the lead-producing district of the United States which ranks second in importance.

Coming to the second of the dominating factors in lead production of the United States, viz., railway transportation, we reach that which has been of supreme importance. The deposits of lead ore having been discovered, the first question was the smelting of the ore and the next question was the transportation of the product to market; but the history of the West shows that comparatively little could be accomplished in smelting until the railway was at least near at hand. The early lead-producing districts, Missouri and Wisconsin, were situated near a great water-way — the Mississippi River — and the forwarding of their product to market was never a serious problem, while the railways reached St. Louis and Chicago at a comparatively early time, the first continuous line from the Atlantic coast to Chicago having been completed in 1853, and to St. Louis a year or two later. From St. Louis and Chicago, respectively, to the lead fields of Missouri and Wisconsin the distances were comparatively short. At the close of the Civil War, when promising deposits of lead ore were being found in Utah and Nevada, the western terminus of the Union Pacific railway was a little west of Omaha. The Hannibal & St. Joseph had carried the railway system to the Missouri River in 1859. The Central Pacific, building eastward from Sacramento, reached the eastern boundary of California in January, 1868. The transportation by wagon of ore and metal to those points was out of the question.

We may easily picture the eagerness with which the completion of the Pacific railway was awaited by thousands of miners. Its line was to pass not far to the north of some of the important prospects for base metal ore in Utah, and only a little further to the north of some of the best in Nevada. Upon the driving of the last spike this whole region would be put practically in direct connection with both the Atlantic and Pacific coasts. It would be only a few months more before branch lines would make the actual connection.

In fact, the beginning of argentiferous lead mining in the country west of the Rocky Mountains was the immediate consequence of the completion of the Pacific railway, which may be fairly estimated as the greatest event in the history of the industry in the United States. Within a year afterward the furnaces of Eureka and the camps near Salt Lake were beginning to pour their product of lead bullion to the East and West. After that the transportation problem was a comparatively simple matter. A branch line was soon built to Salt Lake and thence other branches were extended to Alta and Bingham. From Palisade a line was run down to Eureka. Other transcontinental lines began to come across the plains. The Santa Fé built westward through Kansas, the Northern Pacific from St. Paul. The Southern Pacific linked the Atlantic and Pacific through the southern part of the country, furnishing means for transportation in Arizona and New Mexico. The narrow-gauge system of railway was built through Colorado by the Denver & Rio Grande. Upon the discovery of new deposits of lead ore, waiting for railway communication was only a matter of a few months when the prospects warranted the construction. The first ore shipped from Leadville had to go by wagon only to Colorado Springs. It was only a little while before the Rio Grande was fighting its way up through the Grand Cañon of the Arkansas. The first ore from the Cœur d'Alene had to be shipped to Helena, Mont., but in the following year, 1887, a narrow-gauge railway was completed to Wardner Junction, and the Oregon Railway and Navigation Co. and the Northern Pacific railway were both striving to secure entrance into the district. It was only the districts of inferior importance that suffered from lack of transportation facilities, just as some of them, in Idaho for example, still suffer, but the extension of railways was rapid. There was scarcely a mining camp of any consequence in Colorado which could not be reached by railway in 1888, only 10 years after the excitement at Leadville had come to its high pitch.

In the early days the freight rates charged by the railways were high. Some figures bearing upon this have been given in the chapter on Nevada and Utah. However, the lines had been constructed at high cost, and in some cases to mining districts of uncertain life, making it important that the builders should recoup the first cost as rapidly as possible. Moreover, the conditions of approximately equal loads in both directions had not been developed; in some cases never could be. In other respects the cost of railway operation was often very high. At the same time there have doubtless been many evils in the railway transportation question, such as the levying of rates at the maximum certain ores would stand, at far more than the actual cost the service would justify, and especially in discrimination among certain places for the sake of favoring those which best suited the railway interests. Thus, in Colorado at about 1885–1887, the discrimination of the railways against Leadville in favor of Denver and Pueblo made smelting at Leadville quite unprofitable, although it cannot be said that this policy was contrary to the interests of the miners. But on the whole the policy of the railway managers has been broad and liberal, being based on the theory that where the profit was to be sought was in the movement of the largest possible tonnage of material, and rates have been made to conform to that theory. It is impossible to make a uniform rate on ore. Some special ores are absolutely required by the smelters for fluxing purposes, and in order to enable the miners to produce those ores it may be necessary for the railways to aid by carrying them at less than the actual cost, when of course the deficit must be made up on the ores of higher value which are able to stand a higher charge for freight. In general the freight rates per ton-mile on ore and bullion have trended steadily downward, and since 1870 the total reduction has been large.

The history of the progress in metallurgical practice has been so fully recited in previous chapters of this work that it is unnecessary to enter into further discussion of it here. Comparison of the figures given for the cost of smelting in Nevada and Utah in 1871, at Leadville in 1881, and at Denver and Pueblo in 1891 and 1901, shows the wonderful economy that has been effected in this step in the production of lead. This economy together with that in railway transportation has steadily enabled a lower and lower grade of ore to be mined and marketed, and the production of lead has been heavily increased, year after year, by the establishment of that condition. We need only to reflect upon what is being done at the present time to appreciate the immense importance of these economies. Leadville is to-day producing a larger tonnage of ore than in its whole history. The larger part of it, indeed, is non-lead-bearing, but nevertheless there is sufficient lead ore included in the output to cause Leadville to rank among the five chief lead-producing districts of the United States. It is doubtful if there are more than one or two mines at Leadville to-day which could be operated successfully under the conditions of 1881. From Leadville we turn to Eureka, Nev., and see the mines which had become unprofitable toward the end of the eighties now being reopened with fair prospects of becoming large producers again; in fact, the low-grade ore that was thrown away in the early days is already being shipped for smelting at Salt Lake.

The economies in mining have also been contributory to the ability to produce lower grades of ore, but on the whole to a considerably less extent than the economies in smelting and transportation. Yet it might be troublesome to support this conclusion. Certainly it would not be true for all districts. The cost of mining is an extremely difficult factor to analyze. When we talk about the cost of carriage and smelting of a ton of ore we speak of something definite and know precisely what is meant. On the other hand a statement of the cost of mining per ton of ore may mean any one of several things. It may mean the cost of extracting all the material hoisted from the mine, or the cost of only a part of it, the other part being thrown away as waste and not counted. It may represent only the cost of getting the ore after discovery, or it may include the cost of finding the ore, the two operations usually going on contemporaneously. In almost no case does it include the cost of the original deadwork and the equipment of the mine. Moreover, the cost of mining in the same property may be subject to great variations because of changes in conditions, geological and otherwise. A comparative study of the cost of mining in a single property is often of great value; indeed the comparison between different properties is of value when subjected to careful technical analysis. But to make comparisons of the bare figures of reported costs per ton in widely separated districts, at long intervals apart in time, is next to useless.

The relative importance of the economies effected in the costs of mining and smelting may perhaps be best illustrated by reference to the figures of Eureka, Nev. The cost of mining and delivering ore to the furnaces in 1872 was a little less than $8 per ton. In 1873 mining and carting were done as low as $7 per ton, the cost of mining alone being $5 per ton (Richmond company). The conditions at Eureka at that time were conducive to cheap mining, but without attempting any comparisons we should consider ore mined at a cost of $3 per ton anywhere in the country west of the Rocky Mountains to be reasonably economically produced at the present time. In 1883 the cost of mining to the Richmond company had risen to $13 per ton, and in 1884 it was $15.83 per ton. By that time the company had extracted its great deposits of easily mined ore and was necessarily spending large sums in exploratory work, which is a good illustration of the difficulty in making any conclusive analysis of this subject, to which attention has been called above. The cost of mining to the Horn Silver company, of Frisco, Utah, in 1884 was only $5.07 per ton.

Now, on the other hand, let us examine some of the figures of cost of smelting. In 1873 this cost the Richmond company $17 per ton. The cost to the Ruby company was $17.50, and to the Eureka company, $18.37. In 1883 the cost to the Richmond company was only $11.66 per ton. If smelting were to be done at Eureka at the present time, the cost would be considerably less than that. At Denver, Colo., in 1894, the cost had been reduced to approximately $5 per ton, which of course is not a fair basis for comparison with Eureka, where the conditions were decidedly different, but is nevertheless illustrative of the great economy that had then been effected in general smelting practice.

Not less instructive is a comparison of the charges for refining bullion. In 1872 the cost of carrying the bullion of Eureka to San Francisco and refining it there was $78 per ton. In 1874 the transportation charges were only $32.10 per ton. In 1884 the cost of refining base bullion at Chicago was $8 per ton; in 1901 it was $4 per ton. The matter of smelting costs, however, is only half the story. Of equal importance is the percentage of metals extracted. In this there has been a great and steady improvement. Instead of the high losses of lead and silver experienced in the early days of smelting in Nevada and Utah, which have been discussed in the chapter on metallurgy, in modern practice there is a recovery of 95% of the lead and 98% of the silver contained in the ore smelted. Converted into dollars and cents, on the basis of the average ore smelted, the gain in this respect has been enormous. Even in refining the advance has been not less noteworthy. Whereas in 1873, base bullion was purchased on the basis of its gold contents at the assay value less $2 per oz.; for its silver contents, less 5 oz., at the assay value, and for only 88% of the lead; in 1901, the terms were gold at $20 per oz., silver at the New York price, less 1 c. per oz., and 98% of the lead.

We can scarcely escape the conclusion that on the whole the improvements in transportation and smelting have been decidedly more important in increasing the production of lead in the United States, through enabling lower and lower grades of ore to be mined, than have the improvements in mining. This is because labor is one of the heaviest items both in mining and smelting, but more so in the former than in the latter, and the wages for labor have experienced comparatively little reduction in the country west of the Rocky Mountains since 1871. But in smelting there has been introduction of labor-saving devices to vastly greater extent than in mining. This is not to say that the mining practice has been backward; on the contrary it has been highly progressive; but the underground conditions of a metal mine do not so readily permit the installation of mechanical means for handling material as do the conditions of a smelting works, which can be laid out just as its designer desires. Even in a coal mine the conditions are more favorable than in the generality of metal mines.

Nevertheless, mining practice has been greatly improved by the introduction of better forms of machine drill, and especially by their more extensive employment, by the ability to secure a higher grade of explosives and better knowledge as to their use, by the introduction of more efficient types of hoisting engines and pumps and the many other forms of machines that are required in and about a mine. Most important of all has been the invention of improved methods of stoping, some systems dispensing with the use of timber, others employing it in a more economical manner than formerly. The art of timbering itself has advanced with increased knowledge. These have been important developments because the cost of timber has increased as time has gone on and it has become necessary to cut it further and further from the mines. Timber-framing machines have been introduced with marked economy. Drill-sharpening machines have reduced the cost of sharpening steel. New methods of hoisting, such as the hoisting by skips from large underground ore bins, have cheapened that item of mining cost. The transmission of hydro-electric power and its utilization for hoisting and pumping has led to great economy in certain districts. The diamond drill has been a powerful factor in reducing the cost of exploration work. All of these improvements, together with others that have not been mentioned, have contributed to our present ability to produce ores, not only lead ores but also ores of other metals, which only a few years ago could not be worked profitably.

Not less in importance have been the improvements in methods of ore dressing, in which art the cost of operation has been materially reduced, while the percentage of mineral extraction has been greatly increased. Moreover, it has become possible, especially during the last 10 years, to separate successfully ores that previously could not be worked profitably. For example, the mixed sulphide ore of Leadville, Colo., which about 1889 it became unprofitable to dress by the methods in vogue at that time, so that the mills had to be closed, could be successfully treated by improved methods less than 10 years later. The invention of the Wilfley table in 1896 marked a new era in the art of ore dressing and added materially to the production of lead. Professor Richards refers[1] to the appearance of the Wilfley table as "a most fortunate event for the cause of ore dressing." It provided an efficient means for the washing of finely crushed ore and thereby rendered possible the concentration of ores that required fine crushing to free their constituent minerals. Ten years later, in 1906, improved methods of magnetic separation, and certain entirely new processes, such as flotation and electrostatic separation, added to our ability to treat difficult ores.

Although the economies in mining and ore dressing, in looking back

[1] Preface to Ore Dressing.

40 years, have been less spectacular than those in smelting and transportation, they have nevertheless been of high importance, because even if small per ton of ore the saving is multiplied by a large factor. Thus, if the ore be of a character which requires a concentration of 10 tons of the crude ore into one ton of mineral suitable for the smelter, the reduction of $1 per ton in the expense of mining and milling is equivalent to $10 per ton of smelting ore. For this reason the little economies are especially important in the cost of producing lead from very low-grade ore, such as the disseminated ore of Missouri. In its case, and in fact, in the case of low-grade concentrating ores generally, the improvements in mining and milling have been superior in importance to those accomplished in smelting.

The relative importance of improvements in mining and ore dressing with respect to the improvements in smelting has steadily been increasing during the last 20 years, and hereafter the former will doubtless be the predominating factor as probably it has been for some time past. This is because the art of smelting has now been so highly developed that the room remaining for improvement is small. Indeed, smelting has been in some respects brought nearly to perfection, as for example, in the matter of metal extraction, it being now possible to win commercially as high as 98.5% of the lead of the ore. On the other hand, the major part of the lead now produced in the United States is derived from low-grade ore, which has to be concentrated mechanically. About 50% of our present production comes from two districts — the Cœur d'Alene and southeastern Missouri — whereof substantially all the ore requires such concentration. Consequently the accomplishment of comparatively small economies in the mining and milling of these ores is greatly multiplied when figured on the basis of a ton of smelting ore as previously pointed out.

The history of lead mining in the United States naturally divides itself into four epochs. In the first there were fitful, inconsequential efforts in Virginia and Missouri; it would be idle to speak further of the feeble attempts in the other States; the total production in this epoch was insignificant. The second epoch may be dated from 1799 when Moses Austin began operations in Missouri. He introduced bolder methods of mining and improved methods of smelting, which were of considerable importance in his day and taught the miners of Missouri how to operate. His influence extended to the Wisconsin lead region, which was developed largely by miners from Missouri. The production of lead in the United States, however, still continued to be small during this epoch. The third epoch begins with 1821 when attention was attracted to the Wisconsin lead mines. In the course of a few years these were actively developed, and in connection with the increasing production in Missouri the time came when the United States turned out more lead than it could consume and large exports were made. During this epoch the mines of Joplin, Mo., were discovered, and mines were worked in New York and Virginia. Curiously, all of these mines were non-argentiferous. The fourth epoch is properly dated from the completion of the Pacific railway, in 1869, which started the development of the silver-lead deposits west of the Rocky Mountains. It is a remarkable coincidence that it was at about the same time when the disseminated ore of southeastern Missouri began to be developed. These events led to the extraordinary proportions that the American lead industry has now attained. The great progress in production, and in mining and metallurgical methods, has been made since 1869. It was not until that time, or a few years later, that we began to have an organized lead industry. In comparison with the results of this last — the present — epoch, the history of all the previous ones, interesting though it may be, fades into insignificance when considered from the economic point of view. It is remarkable, moreover, that in the development of the modern industry so little was borrowed from the American experience in mining and smelting previous to 1869. The methods of modern practice in the country west of the Rocky Mountains are distinctly of its own growth. The seeds were German and British.

In tracing certain industrial developments which remain to be treated, attention will therefore be confined for the more part to developments since 1869.

XV

THE TARIFF ON LEAD

Almost since the organization of the National Government there has been a tariff on lead, and generally it has been high. The lowest rate was 15% ad valorem; the highest was 3 c. per lb. In general it has been distinctly a protective tariff, especially since 1869.

Under the Act of July 4, 1789, lead was admitted into the United States free of duty, but by the Act of Aug. 10, 1789, a duty of 1 c. per lb. was put on "bar and other lead." By Act of March 2, 1791, this duty was extended to "all manufactures wholly of lead, or in which lead is the chief article." As a war measure, the Act of July 1, 1812, increased all duties by 100%, together with an additional 10% upon merchandise imported in foreign ships. The latter provision was repealed March 3, 1815, in so far as similar discriminating duties should be abolished by other countries. Between July 4, 1789, the date of the first general tariff law, and 1816 there was a good deal of amending of the tariff, the purpose being always to raise more revenue. On April 27, 1816, a second general tariff law was enacted. However, no change was made in the duty on lead in pigs, bars, and sheets, which remained at 1 c. per lb. The next general tariff act, May 22, 1824, increased the duty on those forms of lead to 2 c. per lb. By the Act of May 19, 1828, the rate was further increased to 3 c. per lb. The Act of July 14, 1832, did not mention lead, which therefore continued at the previous rate. The same rate was reiterated in the Act of Aug. 30, 1842, which was the next general revison of the tariff. The Act of July 30, 1846, which was a general reduction of the tariff, fixed the duty on lead at 20% ad valorem, which was further reduced to 15% by the Act of March 3, 1857.

Coming to the time of the Civil War, we find that the Act of March 2, 1861, raised the duty on lead to 1 c. per lb. The Act of Aug. 5, 1861, raised the rate on lead in pigs and bars to 1.5 c., and on sheet lead to 2 c. Previously the rate on sheet lead had always been the same as that on pig and bar lead. The Act of July 14, 1862, which raised the rates on many articles, left lead unchanged, but it put a duty of 1 c. per lb. on lead ore. By the Act of June 30, 1864, however, an increase was made on lead in pigs and bars to 2 c. per lb., and on sheet lead to 2.75 c. per lb. These rates were reduced 10% by the Act of June 6, 1872, which was a general lowering of the previous tariffs. This reduction was repealed in the Act of March 3, 1875.

The Act of March 3, 1883, made pig and bar lead dutiable at 2 c. per lb., sheet lead at 3 c. per lb., and "lead ore and lead dross," 1.5 c. per lb. By the terms of the same act gold and silver ores were admitted free of duty.

Up to this time there had been but little importation of lead-bearing ore into the United States; in fact none at all save odd parcels which occasionally reached the smelters on the coasts and were of insignificant quantity. Consequently the tariff laws were vague as to that class of ore. The law of 1883 might have been construed as taxing an ore containing 20% or less of lead, at the rate of $30 per ton, although its value might be considerably less than half that amount, but apparently no such case came up.

In 1886 the smelters at El Paso, Kansas City, and elsewhere began to import in large quantity lead carbonate ore from Mexico, especially from the mines at Sierra Mojada in Coahuila. This ore was of high grade in lead, contained a good excess of iron over silica, was of fair grade in silver, and in all respects was a highly desirable ore for the smelters, who obtained in it the much-needed lead for collecting agent, together with basic iron flux. In computing the elements of its value, the silver reduced to dollars and cents predominated over the lead, the latter being figured at 90% of the New York price, less 1 c. per lb. at first; later by a Treasury ruling less 1.5 c. per lb. It was ruled that this ore should be admitted duty free as a silver ore. Under the circumstances it does not appear how the decision could logically have been otherwise. Properly the ore was both a lead ore and a silver ore, but under the then existing tariff law it had to be either one or the other, and there was nothing to do but classify it according to its predominant value.

As the free importation of this Mexican lead ore soon increased immensely in tonnage a storm of protest arose from the American producers of lead, who saw, or thought they saw, the props being cut from under the tariff which protected them. There was no protection in the tariff on pig lead, they argued, if lead ore could be imported duty free and be smelted here for pig lead. Most bitter of all were the few producers of high-grade lead carbonate ore, who had the smelters by the throat and were commanding for their ore more than the lead in it was worth, and now saw their monopoly seriously threatened.

For the next four years the discussion of this subject raged furiously and acrimoniously. Partisanship was determined solely by self-interest. The advocates of a duty which would exclude this Mexican lead ore were the producers generally, but especially those who had heavy carbonate ore, like the Henriett & Maid company of Leadville, Colo., and the May-Mazeppa company of the Monarch district Colorado. Incidentally it may be remarked that their motive in this case is an illuminating exhibition of the pettiness that has animated the wire-pulling since the tariff became a means of filling the pockets of special interests. At the time of this agitation neither of the mines mentioned had more than a few years of life to complete; yet for the premium to be gained on a comparatively small tonnage of remaining ore they were anxious to impose far greater burdens on hundreds of other miners. Especially opposed to the lead producers were the smelters who needed most a supply of the Mexican ore. Allied with them were other smelters who would be relieved from an onerous competition if concerns like that at Kansas City were enabled to keep out of their territory. Also opposed to the lead producers were the miners of silicious and refractory ores, on which the smelters were obliged to make excessive charges to recoup themselves for the losses suffered on the lead ores which were essential. The last ought to have been the strongest opposition and ought to have succeeded in defeating the lead ore miners, but it was unorganized, and in fact its side of the case, which involved the whole technical question of cost of smelting, was imperfectly understood by the persons most interested.

The whole case bristled with delicate technical and commercial questions. Should the value of lead and silver in the ore be determined *loco* mines, or *loco* frontier? How should they be determined? Would it be permissible to mix high-grade silver ore with lead ore, low in silver so as to bring the mixture within the classification of silver ore? Should lead ore proper be subject to the duty of 1.5 c. per lb. on its mineral content alone, or on its gross weight, making the worthless gangue dutiable at 1.5 c. per lb. as well as the lead mineral? Treasury rulings were made on all of these points and others.

It was pointed out by disinterested critics like the *Engineering and Mining Journal* that the smelters needed lead ore in greater supply than was available in the United States in order to smelt silicious and refractory ores with proper economy; that those who would be benefited by the exclusion of the Mexican ore were comparatively few in number; that the inevitable results would be an increase in the charges on silicious and refractory ores, and the building up in Mexico of a smelting industry which the United States could and ought to keep for itself. It may be remarked here that these prophecies immediately were fulfilled upon the passage of the McKinley bill.

The tariff act of Oct. 1, 1890, better known as the McKinley Act, settled the question with a victory for the producers. Lead ore was made dutiable at 1.5 c. per lb., "provided, that silver ore and all other ores containing lead shall pay a duty of 1.5 c. per lb. on the lead contained therein, according to sample and assay at the port of entry. Pig and bar lead was kept at 2 c. per lb., while the rate on sheet lead was reduced to 2.5 c. per lb. However, a very important concession was made by the provision in the McKinley tariff that ores and metals, of course including lead, might be smelted and refined in bond in the United States. This afforded the smelters a chance to obtain the much needed fluxing ore, but it greatly reduced their margin on it because they could no longer sell at the American price the lead which they purchased much cheaper in Mexico.

We may pause here to consider how the McKinley tariff operated as shown in the statistics. The Mineral Industry gives the following for the years 1887–1893:

Year	Total American Production	Produced from Mexican Ore	Total Production of Smelting Works	Average Price at New York Cents per Lb.
1887	145,212	15,488	160,700	4.50
1888	151,919	28,636	180,555	4.42
1889	157,397	25,570	182,967	3.93
1890	142,065	18,124	160,189	4.48
1891	176,751	21,162	197,113	4.35
1892	182,677	26,734	209,411	4.09
1893	166,678	29,270	195,948	3.73

About the only conclusion to be drawn from the above figures is what was remarked in The Mineral Industry, I, 307, viz.: "The amount of ore imported, notwithstanding the tariff, shows also that it is absolutely necessary for our smelteries to secure lead ore from foreign sources in order to reduce our own silicious silver ores. The additional cost of this imported fluxing ore was, of course, paid by our silver ore miners, as is shown in the heavy increase in smelting charges, averaging about $2.50 per ton on these ores."

The Act of Aug. 27, 1894, made an important reduction in the tariff on lead. Lead ore and lead dross were reduced to 0.75 c. per lb., with the proviso, "That silver ore and all other ores containing lead shall pay a duty of 0.75 c. per lb. on the lead contained therein, according to sample and assay at the port of entry. The method of sampling and assaying to be that usually adopted for commercial purposes by public sampling works in the United States." The rate on pig and bar lead was reduced to 1 c. per lb., and that on sheet lead to 1.25 c. per lb.

The Act of July 24, 1897, better known as the Dingley tariff, which is still in effect, not only increased the duty on lead, but also made a great change in the phraseology of the section relating to lead ores, correcting the loose and contradictory wording of previous acts. As we have seen, lead ore was not specified in any tariff act until that of July 14, 1862. In the acts of Oct. 1, 1890, and Aug. 27, 1894, a duty was placed on lead ore, but in the same clause the proviso was made that silver ore and all other ores containing lead should pay a duty only on their lead contents, which still left it open to dispute as to what might be defined as a lead ore and what as a silver ore. In the Act of July 24, 1897, section 181 read, "Lead-bearing ore of all kinds, 1.5 c. per lb. on the lead contained therein: *Provided,* That on all importations of lead-bearing ores the duties shall be estimated at the port of entry, and a bond given in double the amount of such estimated duties for the transportation of the ores by common carriers bonded for the transportation of appraised or unappraised merchandise to properly equipped sampling or smelting establishments, whether designated as bonded warehouses or otherwise. On the arrival of the ores at such establishments they shall be sampled according to commercial methods under the supervision of Government officers, who shall be stationed at such establishments, and who shall submit the samples thus obtained to a Government assayer, designated by the Secretary of the Treasury, who shall make a proper assay of the sample, and report the result to the proper customs officers, and the import entries shall be liquidated thereon, except in case of ores that shall be removed to a bonded warehouse to be refined by exportation as provided by law. And the Secretary of the Treasury is authorized to make all necessary regulations to enforce the provisions of this paragraph."

In paragraph 182, lead dross, lead bullion, or base bullion, lead in pigs and bars, together with old lead, were made dutiable at the rate of $2\frac{1}{8}$ c. per lb., while lead in sheets was assessed 2.5 c. per lb.

Under the old law it was provided that each day a quantity of refined metal, equal to the amount of imported metal smelted or refined that day, should be set apart and should not be removed from the works except for transportation to other bonded premises or for exportation. The tariff law of July 24, 1897, provided that each day a quantity of the refined metal, equal to 90% of the amount of imported metals smelted or refined that day should be set aside. The Act of 1894 specified no time within which the refined metal should be exported. By the Act of 1897 it was required that in respect to lead ores imported, the refined metal should either be exported or entered for consumption, and the duties paid thereon within six months from the date of the receipt of the ore.

The provisions of these recent tariff laws were the subject of many cases before the Board of General Appraisers and the Courts of Appeal, and regulations by the Treasury Department. The most important of these were the rulings that only 90% of the lead imported for smelting in bond had to be subsequently exported, and 90% of the bullion — not 90% of the lead content of the bullion — imported for refining. As the bullion commonly contains at least 98% lead, and the loss in refining is not more than 2%, the refiner secured $(0.98 \times 0.98) - 0.90 = 6\%$ of the bullion imported as "exempt" lead, free of duty. There was also a margin in the lead of ore smelted, whereof about 95% is ordinarily expected to be recovered.

It is obvious that the long record of a high tariff on lead, broken by only one period of comparatively low tariff, must have had an important effect on the industry. The nature of this effect has been the subject of bitter discussion at various times. The question has been extremely complicated, especially since about 1882, or at all events the early eighties, by the two values which lead ore came to possess, as I have previously pointed out, viz.: (1) Its value as a source of the metal; and (2) its value as a metallurgical agent. Before attempting to draw any conclusions, it is important to examine the facts.

The price of lead has always been lower at London than at New York; generally it has been a good deal lower. However, the difference between the London and St. Louis prices has not always been so great as in recent years, because formerly when transportation was more costly the St. Louis price was relatively much lower than the New York price than at present. Unfortunately, we do not possess a complete record of the fluctuations in these three markets during the nineteenth century, and the figures available for some of the earlier years are of such uncertainty that we cannot attempt to draw close deductions from them.

By 1840 the United States, through the production of the mines of Wisconsin, had achieved an output of lead which for its time was large. England was the largest lead producer of the world, its production being probably about 46,000 metric tons; next came Spain with about 30,000 metric tons; and then the United States with about 15,770 metric tons (17,350 short tons). In the early forties the output of Wisconsin increased rapidly, causing the United States to displace Spain (where the output fell off somewhat) and the United States began to export lead, sending out 1085 tons in 1841; 7275 tons in 1842; 9215 tons in 1844, in which year the maximum was attained; 8410 tons in 1846; 1000 tons in 1848; and 130 tons in 1850. The export movement was covered practically by the years 1841–1848. Except for that period the exports of lead from the United States have been of no consequence.[1] At that time the price of lead in Europe was relatively high, probably because of the declining production in Spain. The American tariff was of no great consequence

[1] Previous to 1886, imports and exports were reported for fiscal years ending June 30, and the references here, likewise similar references elsewhere in this work, correspond with that classification.

one way or the other. It had been fixed at 3 c. per lb. in 1832, and continued at that rate in 1842. The reduction to 20% ad valorem in 1846, which corresponded to 0.75 to 0.8 c. per lb., was immaterial, although it excited hot opposition at the time (see chapter on Wisconsin).

However, toward the end of the forties the domestic production of lead began to fall off seriously, and consumption being on the increase, imports of lead had to be made, nearly 19,000 tons being obtained from abroad in 1850. The movement in this direction continued for upward of 20 years. The tariff was reduced to 15% ad valorem in 1857, and raised successively to 1 c. per lb. in 1861 and 2. c per lb. in 1864 without any effect save to tax the consumer and emphasize the shortage in the domestic supply in creating a high range of price for the metal. The production of Wisconsin and Missouri declined. The United States simply was unable to supply the lead it required in spite of the incentive of high prices. The tariff was chiefly for revenue, but in so far as it may have been thought to serve any purpose as a developer of domestic industry it was quite useless. The high prices which prevailed during the Civil War did indeed stimulate mining at several places in the Eastern States, but the lead was not there to be got in any considerable quantity at any price.

It will be observed from an examination of the statistical tables that in 1861–1870 the price of lead at New York was rather uniformly above the price at London by the amount of the duty. Moreover, that the annual averages at London during the decade were comprised within the limits of 4.78 c. and 4.05 c. — a rather narrow range and not a remarkably high one as compared with that of 1851–1860. In 1870 the lead production of the world had been developed to a large total, Spain and Great Britain both having greatly increased their outputs, while Germany and France, especially the former, had become important producers. The United States ranked fifth — a bad fifth.

The next decade, when Nevada and Utah began to make an output of real consequence, was ushered in with prices for lead that were still high, the average for the year being 3.95 c. at London and 6.08 c. at New York, the duty being 2 c. per lb. and the importation for the year, 45,750 tons. Prices continued at a high level until the end of 1876, the American market being supported by the European market, and although the tariff had been reduced to 1.8 c. in 1872, but raised again in 1875, it is to be noted that the differences between the two markets were uniformly less than the tariff, while imports into the United States decreased and in 1877 practically came to an end. Then, at last, the United States as a lead-producing country became independent. It was well able to stand on its own feet, as is manifest from the fact that production continued to increase steadily in spite of the general decline in price started in 1877, by the magnitude that the new output had attained. In 1874 and 1875 American producers had been obliged to export surplus lead to China and Japan. In 1878 the average price at New York was lower than the price at London.

The bulk of the production was from ores rich both in lead and in silver. However, the low range of prices, which continued into 1879, began to tell seriously on the producers of Utah, first, and then Nevada, the production of those States decreasing, but nevertheless the total production of the United States increased because of the large supplies delivered in 1879 by the new discoveries at Leadville. In the autumn of 1879 the great "boom" period set in, and the demand for lead suddenly increased, carrying the market upward until at the end of December so high a price was reached that the importation of foreign lead became profitable.

Notwithstanding the important development which the lead industry of the United States attained in 1871–1880, and its independence of artificial support as was manifest at several times, there was early opposition to the movement to lower the tariff on pig lead. This movement was inspired by the manufacturers of lead products, who naturally sought the broadest possible market for their raw material, and during the seventies they carried on an agitation toward that end. The multiplication of lead manufacturing works in the West and Middle West already had alarmed the Eastern manufacturers, and they urged that the duty of 2 c. per lb. was prohibitory, raising the cost of materials to the consumer without adding revenue to the treasury, and if the duty on pig lead were taken off, the price of foreign lead would advance by an amount almost equal to one-half of the reduction of the duty, while the price here would fall a similar amount. Eastern smelters of lead ore asked for the removal of the duty on lead ore. Even so early as this, it was urged that free ore would tend to develop a large smelting business along the Mexican border. However, the interest in the question was rather mild, because the question itself was not acute. With conditions of production and consumption of such character that the American price was naturally working down toward the European, in spite of the tariff, and the producers of Utah and Nevada confronted by the prospect that they would have to export surplus lead, the matter of the tariff was not of great consequence. Obviously the preference of the Utah and Nevada producers was toward its retention, because whereas they might have to export lead, if consumption should improve at any time they were protected from the competition of imported lead, but in the political and economic discussion of the subject they were rather apathetic. The chief opposition to the movement for a reduction of the tariff came from the producers of Missouri, who mined non-argentiferous ore and consequently were solely dependent upon the price of lead, which the Utah-Nevada producers were not. Moreover, the producers of southeastern Missouri had begun to mine the low-grade, disseminated ores, on which the margin of profit was small, and a maintenance of a rather high price was deemed necessary to the welfare of the new and growing industry. Although the Missouri production was still small, the efforts of the Missouri miners, with the lukewarm support of Utah and Nevada, were easily successful in defeating the desires of the manufacturers and consumers and maintaining the tariff, especially as the party in political power was committed to the policy of protection and the fostering of special interests.[1]

The question came to a head in 1882, when a commission was appointed to revise the tariff. The Missouri producers were quick to organize to defend their interests. The Western producers were apathetic, at least at first. As it began to appear probable that a reduction in the duty on lead might be recommended, however, the Colorado producers organized at Leadville to lobby against such a step, and soon afterward the Utah producers took similar action. The tariff commission recommended a reduction of the duty on pig lead to 1.5 c. per lb., and on lead in ore to 1. c. per lb., a reduction which the *Engineering and Mining Journal* pronounced to be moderate and reasonable; but the efforts of the miners again prevailed and the Act of March 3, 1883, maintained the old rate of 2 c. per lb.

The question of the tariff on lead did not become of much consequence until toward 1890, when large imports of Mexican lead ore were being made. For many years previous the condition of the lead industry abroad had been of comparatively little concern to the American producers, though experience had taught them that in periods of extraordinary advances in the domestic price a check was imposed by the offerings of foreign lead. They were, however, effectually protected by the tariff, which continued at 2 c. per lb. This could not prevent the American price from going very low when there were accumulations of supplies,

[1] "The exports of lead have been very small except in 1874 and 1875. It is possible that the export of American lead to China and Japan will increase, and at a time more or less remote may decrease the shipments which England makes to that quarter. At the present time that result has not been attained. American smelters, unless forced by circumstances, will not be tempted to export a portion of the lead which they produce, protected as they are by a duty of 2 c. per lb. If the duty on lead were to be abolished, the fluctuation in the quotations of the metal would be less, and the price would go down; the mines and smelting works of Missouri would be less advantageously situated than formerly; and the miners and smelters of argentiferous ores would lose a smaller or greater proportion of their profits, and would be obliged to pay greater attention to their working and to their methods." (*Engineering and Mining Journal*, 1881, LXXXII, 301.)

but on the other hand it enabled prices to be carried to higher levels than would have been reached under conditions of free trade when demand was urgent, and when speculation for the rise was undertaken. About 1877–1880, and from 1881 to 1890, lead was a highly speculative metal. The Richmond company in particular made a practice of marketing its product in large blocks, and both producers and speculators made numerous attempts to maintain the price at a high point. In this they were of course assisted by the tariff, while correspondingly the consumers suffered. As to what effect the tariff may have had upon production it is difficult to say. The production steadily increased up to 1884, chiefly because of new discoveries; then for many years the statistics show ups and downs, the production in 1894 being only a little more than 160,000 tons, against about 144,000 tons in 1883 — a trifling advance. During this period the industry had several setbacks, such as the decreasing grade of the ore, the impoverishment of many of the old bonanzas, labor troubles in Idaho, and especially the declining value of silver. There were offsetting advantages such as improvements in the methods of mining and smelting, decrease in the cost of transportation, and the acquisition of a value by lead ore as a smelting agent in addition to its simple value as a source of lead. During the whole of this period the price of lead at London was materially below the price at New York. It is safe to conclude that if the price at New York had not been bolstered up by the tariff, the production of lead in the United States would not have shown the increase, small as it was, which it actually did.

While the tariff wall enclosing the lead industry of the United States remained practically unchanged from 1864 to 1894, the conditions of production in the United States experienced great alterations. From 1871 to 1880, and in the early eighties, the bulk of the domestic lead production came from ores of comparatively high grade in lead and silver, which in spite of high mining and smelting expenses caused the cost per pound of lead to be relatively low, but the producers were handicapped by the long and costly railway carriage on their metal. In 1872 the cost of transporting bullion from Eureka to San Francisco was about 3 c. per lb.; in 1874 it was about 1.6 c. From Salt Lake to Omaha the cost was 1 c. per lb. in 1871; from Salt Lake to Chicago 1.4 c. per lb. in.1872. In 1880 the cost from Leadville to New York was 1.75 c. per lb. Until the latter part of the eighties the producers of the West were under such heavy handicaps of freight rates. Even at the present time, when freight rates have come down to extraordinarily low points — 0.32 c. from Pueblo and Denver, and 0.54 c. from Salt Lake City to New York — the Western producers suffer from their distance — 2000 to 2500 miles — from the principal markets, the cost of carrying lead from Monterey, Mexico, to

New York being only 0.2 c. per lb. However, there has been a vast improvement in this respect from the conditions of 1870–1885.

But in the meanwhile the ores of high grade in lead and silver have disappeared and it has come to pass that the bulk of the lead production of the United States is obtained from very low-grade ore. It is undeniable that the tariff on lead has raised the price which American consumers have had to pay. It is doubtless true that at certain periods the price has been maintained in this way at figures which have given unnecessary advantage to the producers. But on the other hand it is evident from a study of the history of the industry that the increase in domestic lead production, which has not more than corresponded with the increase in domestic consumption, has been greatly stimulated by the advantage in price which the tariff has bestowed, and moreover, this has fostered not only the lead industry alone, but also the mining and smelting of ores containing the precious metals, which in the absence of an abundant supply of lead ore would have to be worked by less economical methods.

It is dangerous to generalize the cost of producing lead for the whole country, or even for a particular district. In the case of southeastern Missouri this can be done with more safety than in any other, because there the only value of the ore is in its lead content, and the grade of the ore mined, conditions of occurrence, and methods of mining are rather uniform throughout the district. In 1882 the cost of pig lead delivered at St. Louis by the large producers was 3 to 3.5 c. per lb.[1] In 1884 the *Engineering and Mining Journal* expressed the opinion[2] that if freights were better adjusted the majority of the producers of the United States could stand a price of 3.5 c., or even 3.25 c., but the pressure of lead at 2.75 c. would be such that as that figure was approached the number of idle mines would increase in geometrical ratio.

In 1899 the cost to the principal producers of southeastern Missouri was 2.25 c. per lb., delivered at St. Louis. However, none of the figures above given includes interest on the money invested, return of the principal, etc.[3] The purchase of an acreage of land sufficient to warrant development on a large scale, the sinking of shafts and equipment of plant a few years ago would cost about $1,000,000 for a productive capacity of 10,000 tons of pig lead per annum. Estimating amortization at 10% and interest at 5%, the annual fixed charge would have been

[1] Mineral Resources of the United States, 1882, p. 312.

[2] Feb. 2, 1884.

[3] It is utterly misleading to draw conclusions from figures which do not take those factors into account. Producers who are already established may be willing for a time to sell their output at a price which returns only the direct cost, or even less, rather than incur the greater loss of suspending operations, but so long as such a condition exists no new capital will go into a business where the adventurers can not see a return of the principal and a proper interest upon it.

$150,000 or 0.75 c. per lb. of lead. A total cost of production of 3 c. per lb., basis St. Louis, is probably the lowest on record for the southeastern Missouri lead. At present the cost is considerably higher. It is a fact that this lead has been sold at a lower price than 3 c., but it has been at a loss, all charges considered.

In Chapter I, it was estimated that the cost of producing lead in the Cœur d'Alene in 1907 was in the neighborhood of 3.3 to 3.5 c. per lb., basis New York delivery; *i.e.*, if the price of lead should be 3.5 c. per lb. and the price of silver 50 c. per oz. at New York, some of the Cœur d'Alene large producers would realize no profit, even after disregarding allowances for amortization. It would be highly difficult to generalize the capital account in this district, but probably it would not be far out of the way to say that the total cost of producing lead in the Cœur d'Alene is in the neighborhood of 4 c. per lb., when silver is worth only 50 c. per oz.

The Cœur d'Alene and southeastern Missouri together furnish nearly 60% of all the lead now produced in the United States. The actual cost of this lead has been about 3 c. per lb. under the most favorable conditions. The average cost of all the lead produced in the United States is probably considerably higher than that.

There is no question that lead can be produced more cheaply in Mexico, Europe, and Australia than in the United States, inasmuch as the price at London for long periods has been lower than 3 c. per lb., and the output of the mines is maintained. The superior advantage of the foreign countries is partly in cheaper labor, partly higher grades of ore, which more frequently than in America yield two valuable products, *e.g.*, zinc and lead, as in Australia, and partly to shorter railway hauls. The cost of smelting and refining is as low in the United States as anywhere in the world; the freights on the whole are higher — not per ton-mile, but in the aggregate of miles; the cost of mining per ton of concentrated product is doubtless higher on the whole, which is attributable to the higher rates of wages.

It may be said in conclusion that the tariff on lead, which has indisputably raised the price of the metal to the consumer, has greatly stimulated the domestic production, especially at the period when the latter began to be derived chiefly from low-grade ores; that without the tariff the production would have been seriously checked at certain periods of depression; that the fostering of the lead industry has been a great stimulus to the development of the mining and smelting of the precious metals in general; that it has contributed to the maintenance of wages in the Rocky Mountain States at a wastefully high level; and that it has been the basis on which the Smelting Trust, aided by all the other producers, forced the price of lead to an excessively high point between 1901 and 1907.

XVI

LABOR CONDITIONS

In the century of active lead mining in the United States there appears to have been comparatively little change in labor conditions. In Missouri and Wisconsin, which furnished the major part of the output previous to 1871, the mining was done largely by individuals on their own account. The leasing system was generally practised. The conditions were on the whole substantially the same as exist in Washington County, Missouri, at the present time, and as existed in Wisconsin until recently. Operators of this class did not pay much attention to the price of lead. Indeed, they were not concerned at all by minor fluctuations in the market, selling their ore at a fixed price, as was the general custom. To a large extent they were not miners by trade, being to no small degree farmers, lumbermen, teamsters, etc., who worked at mining during part of the year. They were able to live cheaply and were satisfied with small returns from their industry. Probably on the whole their earnings from mining were rather less than during the last 40 years. At least this must be so if the market price for lead be a fair criterion. About 1845–46 there was a low range of prices for pig lead, while production remained about stationary.

The miners of Missouri were descendants of the French, and of the Americans who went thither after the purchase from Spain. The same people constituted the bulk of the mining population in the disseminated district until recently when the shortage in men available to do the work required made it necessary to bring in Hungarians and other foreigners. Upon the discovery of the mines in Wisconsin a good many men went from Missouri to them, which also attracted many men from the States on the Ohio River. Later on there was a considerable influx into the Wisconsin lead region of Cornish miners, who were of considerable importance, because of their industry and shrewd mining knowledge, which enabled them to take hold of abandoned mines and still get a profit from them. In 1849 a good many of the miners of Wisconsin went to California.

In the early days of lead mining west of the Rocky Mountains, we find wages established at about the same rates as at the present time. A wage of $3 to $4 per day was the common custom. The day was either

8 hours or 10 hours. Both the rate and the hours of work varied in different camps. The minimum was $3 for 10 hours' work; the maximum was $4 for eight hours' work. At present the minimum is $3 for 10 hours' work, and the maximum is $3.50 for 8 hours. This high scale of wages was established in the early days when men were comparatively scarce and when the cost of living was high, but even then the net earnings of the laborer were extraordinarily high. For many years back — 37 or more — the regulation charge for board has been $1 per day in almost all camps of the West, and the food that is supplied in a well-managed company boarding-house has been, and is, bountiful in quantity and palatable in quality. The cost of lodging, clothing, and other necessary expenses is comparatively small. A miner has no difficulty in saving 50% of his income if he desires, and is able to work and to get work for a remarkably high percentage of the year. There are many large mines which show 306 days of work out of the 365 possible, year after year. I am able to present these statistics of cost of living from personal experience more than 20 years ago. Ocular evidence as to the high net earnings of the Western miner is to be found in the large number of drinking saloons, gambling houses, and brothels which exist in every mining camp, and the extravagance of the miners in supporting those institutions and in giving free rein to other follies. This deplorable waste is contributory to high cost of mining. The miners regard it as a prerogative to have large surplus earnings to be expended on extravagant amusements; or to enable them to gain sufficient money in a comparatively brief period of work to be idle for an equal period, or to go off on a private prospecting venture; and consequently have bitterly resisted all attempts to reduce wages to a scale corresponding to the wages paid miners elsewhere in the United States. It is well known that the wages paid west of the Rocky Mountains are materially higher, in proportion to the cost of living, than are those paid in the southwest and southeast of Missouri and in the Lake Superior and other eastern mining districts.[1] This condition has existed during the last 37 years, and more, substantially without change.

The spirit of the labor situation in the West was accurately set forth by Dr. Raymond in his report as commissioner of mining statistics for 1869, where he said (p. 120): "The rates of labor in eastern Nevada have not changed for several years. . . . In general, any white man who will work at all demands $4 per day for his labor. It does not matter whether he is a green hand . . . or has worked in the district since its first discovery, there is one common price. . . . This startling injustice works evil to both laborer and employer. . . . The best men are kept down for

[1] There are exceptions to this statement. There are some places, *e.g.*, Butte, Mont., where the cost of living is very high.

the benefit of the poorest. And yet the working classes who are really most injured are most strenuous for the continuance of this absurd system. . . . The miners' leagues insist, and generally succeed, in the suicidal demand that these men, whose labor has such different values, must all receive the same wages. . . . It would be a great improvement if labor were classified into different grades, with pay proportionate to the character and amount of work. By this system good miners would get the higher wages, which they honestly deserve, and employers would get something like the worth of their money."

On p. 123, Dr. Raymond says: "The ruling rates for common labor are far too high. . . . There is no good reason why ordinary, unskilled labor should be cheap elsewhere and dear here. The country is easy of access; the cost of living, though relatively greater than in some States, is nevertheless entirely disproportionate to the high price paid for work; and the climate, though certainly not always agreeable, is almost universally healthful. Nor has it proved that the laboring class has generally benefited by the existing state of things. Many shining examples there certainly are, where industry and economy have taken advantage of high wages; but in the majority of instances, the working man earns the money only to enrich the gambler or the dram-seller. One good reason might perhaps be assigned for the continuance of these high rates, and that is, that it is of great help to many prospectors (who are doing the hardest and best work in the State), as it enables them to earn in a few months enough to supply them with provisions and materials for the remainder of the year. But there is no use in finding new mines if we cannot make them available when they are found."

Apparently, Dr. Raymond exaggerated the uniformity of the wage scale in 1869–70, inasmuch as his own reports elsewhere show differences in the rates paid in various districts to first-class miners, second-class miners, and surface laborers, but these differences were comparatively slight and his strictures were in the main correct. The same characteristics have been manifest in the attitude of the miners of the West up to the present day.

As Dr. Raymond pointed out, the excessive demands of the wage earners were from the outset a great drawback upon the development of the mines west of the Rocky Mountains. Efforts to secure an amelioration of these conditions were defeated by the united action of the miners, who formed leagues in various districts. Unionism among them was therefore of early origin. However, there was no serious or general strike until 1880, when the miners of Leadville quit work and practically every mine of the district was idle during the month of June. This strike was accompanied by many acts of lawlessness.

For many years the mine operators appear to have been afraid of the men. They pursued the policy of letting a sleeping dog lie and avoided any action that would stir up the labor question. It was argued in private conversation that wages were too high — some bold spirits advocated openly a reduction, as Dr. Raymond did as early as 1870 — but no one was sufficiently courageous to make the first move. Even at Leadville in 1883, when the outlook for the mining industry was decidedly gloomy and the necessity for lowering operating costs appeared pressing, it was proposed to reduce wages, but no one ventured to do so. One result of this strong attitude of the miners on the one hand, and the weakness of the operators on the other hand, was a great increase in the mining done under the tribute system, *i.e.*, the system wherein various portions of a mine are turned over to parties of miners who extract for their own account what ore they can, paying a percentage thereof to the owner of the mine. The tribute system in itself is a highly commendable one. Many mines that can no longer be worked profitably under company management continue to give good returns after being turned over to tributers, and the delving of the latter frequently leads to the uncovering of good ore-bodies that the company can advantageously take over. However, it is certain that the high scale of wages has caused many mines to be abandoned to tributers long before they would have been under less onerous conditions. This has been the case both at Eureka and at Leadville.

It remained for the Cœur d'Alene to bring the labor question to a head, but even there the fight resolved itself simply into maintenance of law and order, and the preservation of constitutional rights, rather than the adjustment of wages to economic conditions. The long record of labor troubles in that district is given in the chapter on Idaho and Montana. These originated at Butte, Mont., where the local union was strong and turbulent. In Montana there was a spirit of lawlessness, like unto that which prevalied in the anthracite region of Pennsylvania, which dated from the early days of Bannock, Virginia City, and Alder Gulch, when the safety of life and property against murderers and robbers had to be insured by the equally lawless acts of vigilantes. We have to go to California to find the like of this situation. The early history of Colorado, Utah, and the other Western States is a record of rough life and many isolated deeds of violence, but nothing approaching the widespread, organized criminality which existed in Montana. It is probable that the latter inspired the lawlessness which characterized the attitude of the labor union at Butte almost from the beginning. When the mines of the Cœur d'Alene were opened the miners came largely from Montana, and they brought their ideas with them.

From the beginning it was difficult to develop the low-grade mines of the Cœur d'Alene under the high Montana scale of wages. When the prices for lead and silver fell so heavily in 1893, it became impossible to continue operations on the old basis. The series of strikes which followed the attempt of the operators to ameliorate conditions is recorded elsewhere in this work. After many years of disorder, during which neither life nor property were safe, a conclusion of the troubles was not reached until the district had been placed under martial law, the ringleaders of the labor unions had been induced to leave the district, and the card system of employment had been introduced. The card system was the result of an agreement among the operators that no man would be employed by them unless provided with a card, issued by their association as evidence of good character. As the final outcome of the labor war in Idaho, the miners continued to receive $3.50 per shift of eight hours, which the operators were then able to pay because of the higher prices for lead and silver, but the operators were set free from the tyranny of the union and could feel secure in the possession of their property. The great prosperity of the Cœur d'Alene dates from that time.

When the panic of 1893 closed many of the mines of Colorado and Utah, it was considered that at last the time was ripe to bring about a general reduction in the wage scale. However, the riots in the Cœur d'Alene, when only a small reduction was attempted there, showed promptly what was to be expected from any more drastic or more general movement elsewhere. By that time the Western Federation of Miners had acquired a strong hold in many of the mining camps of the Rocky Mountains. Men who had worked in the Cœur d'Alene scattered through the other States and sowed the seeds of discontent, cupidity, and lawlessness. This was to result in the actual warfare in Colorado which lasted off and on for five years, the Western Federation of Miners being practically in rebellion against the State, which had to exert its full military power to quell it.

As I have previously pointed out, the mine operators, struggling for 25 years against an exorbitant scale of wages, and during the latter part of that period against tyrannous actions of the unions, found themselves compelled at last by commercial conditions to make a stand for more favorable terms or cease to work their mines. In a few districts, especially Aspen, Colo., where the conditions were so obvious that even the miners could see that it was indeed a question of making a concession or losing their work entirely, a reduction of wages was agreed to, the operators on their part promising to restore the old scale when the price of silver should rise above a certain figure. This promise was fulfilled in 1906. In the majority of cases the operators backed down, which defeated what might have been accomplished by concerted action. In some cases the attempts of the operators were fought by strikes of the miners, in which rioting and bloodshed were promptly begun. The record of the strikes at Cripple Creek, Leadville, Telluride, Clear Creek, and in the coal fields forms a part of the general history of labor in the United States. The criminal destruction of property by dynamite, the murdering of many honest men and the maiming of others, and all the other evil results of the conspiracy and rebellion promoted by the worst labor union that the United States has known, not even excepting the Molly Maguires, is an ineradicable blot upon our industrial history. No less a blot is the lawless action to which the associated mine owners were driven to combat the lawlessness of the men. The outcome was the same as in the Cœur d'Alene, viz., the restoration of order by martial law and the reëstablishment of the freedom of labor by military power. As in the Cœur d'Alene, the card system of employment was introduced and the scale of wages was continued as before the silver panic, the pressing necessity for a reduction having passed away in the meanwhile.

Thus we find at the end of 1907 substantially the same scale of wages as existed in 1869 and earlier. The pay of miners then was \$3 to \$4 per day. Now it is \$3 to \$3.75 per day, \$3 being the common rate in Colorado and \$3.50 in Idaho and Montana. But whereas the shift of 10 hours was formerly the common practice, now in most districts the shift is only eight hours. In the meanwhile the cost of living has been reduced. In 1869 the rate for board was commonly \$1 per day; it is the same now. But the cost of clothing, miscellaneous supplies and luxuries has been greatly reduced. The mining camps, which 20 years ago used no coins smaller than nickels, now consent to employ pennies.

In the smelting industry the conditions have been quite different. In the early days of Eureka and the other camps where the smelting was done at the mines, the wages paid in the works ruled on as high a scale as those which prevailed in the mines; but as the smelting became concentrated in works away from the mines operations gradually transformed themselves to the same basis as in other manufacturing industries. Wages have gradually come down, which has played an important part in the economy effected in smelting cost. Unlike the miner, the smelter is not the victim of the gambler and the dram-seller; at least not to the same extent.

Of the eastern lead districts, Joplin has been notoriously a non-union camp, but in 1905 it began to be unionized. The only labor troubles in these districts are those which occurred recently in southeastern Missouri, referred to in the chapter on that State. In depicting the interesting labor situation in Missouri, I can do no better than quote in full an article which appeared in the *Engineering and Mining Journal* of Nov. 3, 1904:

"In Missouri there are two important mining districts. The Joplin district, in the southwest, is the largest producer of zinc in the United

States. The mines of St. François County, in the southeast, rank that district as the second largest producer of lead. The Joplin district is also a considerable producer of lead from ore concentrated, as a by-product, in the milling of the zinc ore. Such comparisons as are to be made in this letter are not for the purpose of pointing out the relative merits of the two districts as fields for mining operations, but merely to show in a striking way the baneful results of the labor union policy as applied to mining. Every one knows what the results have been in Colorado, but — fortunately lacking the gloomy record of outrage and bloodshed — Missouri presents the more instructive industrial picture of before and after, which it can show contemporaneously.

"The ore mined at Joplin yields on the average about 4.5% of blende, worth, say, $35 per ton, under the normal conditions of the present time, and 0.5% galena, worth, say, $50, or an aggregate of 5% of mineral worth about $36.50. The ore mined at Bonne Terre and Flat River yields about 5% of galena, worth about $37.25 per ton f.o.b. mines, when lead is at 4 c. St. Louis. At Joplin there is great and general prosperity. In St. François County the mining companies are struggling along at little or no profit, hoping vainly for an amelioration in the conditions. It is strange that ore of the same grade and value can be worked profitably at one place and cannot be worked profitably at another place in the same State, especially when the physical conditions are all apparently in favor of the unprofitable mines.

"At Joplin there are comparatively small lenses of ore and sheet deposits, averaging only about 8 ft. in thickness, the mineralized ground being the hardest kind of chert. The mines are worked in a crude kind of way, opened by small shafts, hoisting ore in small tubs by means of uneconomical engines, and dressing the ore in ramshackle mills of comparatively small capacity, the entire cost of opening a mine and equipping it with plant to treat 10 tons per hour being only about $15,000. At Bonne Terre and Flat River there are immense shoots of ore, affording stopes of 20 ft. to 80 ft. in height, and width almost to suit; the ore an easily mined dolomite, ground of character requiring no timbering, depth of mines only slightly greater than at Joplin, and no greater influx of water, except in two or three instances; the mines opened by fine large shafts, equipped with nearly the most modern facilities; the ore dressed in complete and costly mills of 500 to 1500 tons daily capacity. Surely St. François County has all the advantages of physical condition, and theoretically ought to surpass Joplin in operating costs. The explanation of why it does not involves some technical factors, but the chief cause is to be found in the character of the miners and their work.

"The mines of St. François County used to make money. The minimum price of lead in the history of that metal did not stop them, and they have shown good profits when lead was considerably less than 4 c. per lb. This, however, was before the labor union was organized in the district.

"The mines of St. François County are operated by large companies. The cost of opening and equipping a mine there is so large that a company with abundant capital is required. For that reason there is no leasing nor any individual operations. The condition of the miners was good; they were paid high wages, as compared with the scale for other trades in that part of the country; the day's work of 10 hours was no longer than was required of other artisans; the mines were sanitary and in no way especially dangerous; the men were well cared for by the companies. The entire mining district is pleasantly situated, far more pleasantly than the average. The climate is good; all the conditions of living are good. The men were well satisfied, and a general air of prosperity pervaded the entire district. This was before the poisons of unionism and socialism were contracted.

"In the struggle which ensued the unions were victorious. The companies made no fight in line, shoulder to shoulder. Some of them made no fight at all, and surrendered without a shot. The others fought alone, one by one, and were overwhelmed one after the other. The unions won an increase in wages, a reduction in working time to eight hours per day, and the victor's right to despise the conquered, which in successful labor wars takes the form of cheating the employer in the work that he pays for. The amount of work done per hour at Flat River is materially less than before the advent of the union. This is the chief reason why the mines of southeastern Missouri are not making money.

"Joplin has never been tainted with unionism. It has always been the great camp of the small miner. The capital required to open and operate a mine there is not large, and the operators themselves to a large extent take hold and work with their men. Every hired man wears on his head the hat of a future operator. He saves his money, and sooner or later does some prospecting on his own account. If he is lucky, good for him. If he is unlucky, he goes back to work until he can save enough to try it again. Everybody works hard — works hard every minute of the day, and when the day's work is done he seeks enjoyment in such way as most appeals to him. The general aspect of things at Joplin and Flat River shows at first sight that the Joplin man has the more fun. The man who has done a good square day's work is better calculated to enjoy himself, anyway, than the man who has listlessly loafed through his task. And the Joplin men certainly work. A pair of men break more to the drill in their hard, flinty ground, with no very high breasts to stope on, than the Flat River man breaks in his magnificent chambers in limestone, and when it comes to shoveling and tramming there is no comparison at all. Nor has the former any kind company to provide him with lavatories and lockers, look out for his safety, and pay him damages for unavoidable accidents. The Joplin man simply takes his chances — often they are big chances — puts in an honest day's work, and gets on in the world if there is anything in him at all. But Joplin has no union. Joplin has the best American spirit, and, consequently, Joplin is prosperous and can mine 5% ore with little tubs and ramshackle mills and make money, while the far greater deposits of an equally valuable ore in St. François County cannot be made to pay a reasonable return on the capital required to work them."

The changes in the rates of wages in southeastern Missouri since the mining industry there became well organized are shown by the following table prepared from the records of the St. Joseph Lead Co., which I owe to the courtesy of Mr. Dwight A. Jones, president of that company.

Year	Drillers	Backhands	Year	Drillers	Backhands
1870–1877	1.75	1.50	1896	1.25	1.00
1877–1878	1.50	1.10	1897	1.35–1.45	1.10–1.20
1879	1.20	1.00	1898	1.45	1.20
1880–1883	1.25	1.10	1899–1901	1.60	1.30
1884	1.50	1.25	1901	1.65–1.60	1.35–1.30
1885	1.35	1.10	1902	1.60	1.30
1886–1890	1.50	1.15	1903	1.80	1.50
1890–1893	1.60	1.25	1904–1906	1.90	1.60
1893	1.40–1.50	1.15–1.25	1906	2.00	1.70
1894	1.25	1.00	1907	2.25	1.95
1895	1.15–1.25	.90–1.00			

Until 1893 the shifts were eight hours; from 1893 to 1901 they were 10 hours; from 1901 to 1907 they were eight hours. Of course it requires only a superficial examination of this table to show the remarkable increase in wages during the six years, the pay of drill-runners having increased from 16 c. per hour in 1901 to 28 c. per hour in 1907. The reports of the State mine inspector show that the mines of this district operate uniformly about 306 days per annum.

XVII

TRADE AGREEMENTS AND COMBINATIONS

THE silver-lead industry had hardly become fairly started when the rapid decline in the price for the metal induced by the large new production alarmed the producers, especially those of Missouri, who were more dependent upon the price than were the others. We have seen already how they united to oppose the movement of the consumers toward a reduction in the tariff. In 1877, under the pressure of the increasing production in Utah and Nevada, the price of lead declined greatly, in spite of a speculative movement, early in the year, to maintain it. At the beginning of 1878 a large stock of lead had accumulated in the hands of the producers. Its volume continued to swell and the price continued to decline. The average for February, 1878, was 3.75 c., New York. Matters were taking so serious a turn, that at the suggestion of the Missouri interests a meeting of the leading lead miners and smelters of the whole country was held at St. Louis in March to consider a remedy. As a result of this meeting the producers organized the American Pig Lead Association, the members of which bound themselves not to sell lead at a price less than 4 c. delivered at New York. With the market already at 3.75 c., this attempt to unite such radically divergent interests as those of Missouri and Utah-Nevada was folly. The members did not stick to their agreement, and the effort proved a complete failure. In June the average price was 3.30 c. Later in the year the falling off in the production in Utah and the shipment of the surplus of Nevada lead to China, together with an increase in the domestic consumption, strengthened the position of the metal, although the reports of the extraordinary developments at Leadville caused uneasiness.

There was no other attempt to control the price of the metal until more than 20 years later, although there were several short-lived and more or less ineffectual associations formed to regulate conditions. Following the great depression of 1878 the history of the business for many years is one of ups and down, resulting from the discoveries of new, easily worked supplies of ore, the fierce and unrestrained competition among the smelters, the effect of railway discriminations and the fluctuations in the demand for consumption. On the whole, the conditions of the 20 years previous to 1898 were unsatisfactory, and the complaint was general, being relieved only for brief periods when a good demand, with the aid of speculative interests, sustained the market. The great increase in the production of Leadville in 1879 coincided with the inauguration of a great "boom" period, wherefore this new supply of lead was readily absorbed in an advancing market. However, by 1883, the market had gone down so that even the Leadville producers were complaining of the condition and were considering the closing of some of their mines and the taking of joint action to improve their status. Among other things a reduction in the wages of the miners was seriously considered, but that step was not ventured. The general outlook was so gloomy that the leading miners and smelters of the State organized the Western Mining and Smelting Association to consider the questions of restriction of output, reduction of wages, reduction of freight rates, etc. However, nothing was accomplished beyond a general discussion of the troubles. Neither railway rates nor wages were reduced. The smelters had been sailing as close to the wind as possible for some time previous. The industry continued as before, and after all the situation was probably not quite so bad as it was felt to be at the time.

In the early eighties, the smelters of Colorado made some agreements to regulate the conditions of sampling and assaying of ores purchased, but otherwise the competition among them was fierce and unrestrained (see chapter on Colorado). The Denver and Pueblo smelters competed with those of Leadville and Salt Lake on their own ground, aided by the rates made by the railways, which liked to obtain the long hauls of ore rather than the less tonnage of bullion. The smelters of the various districts competed with each other. The miner who was dissatisfied with the terms or treatment of one smelter could open negotiations with many others. As for the smelters themselves, some made a good deal of money; some did only moderately well; others lost money and went out of the business. In 1888 the high prices for lead produced by the attempt of one Corwith to corner the market gave a brief period of general prosperity, but this was short lived, and his failure caused a collapse in the market. The stocks accumulated in this attempted corner hung over the market for two or three years, and as a consequence the price was generally low, but in the fall of 1890 an increasing demand absorbed the stocks and elevated the price to nearly 6 c., so that several thousand tons of foreign lead were entered for consumption. After that there was a general downward tendency and the silver panic of 1893 precipitated prices to a low level from which they did not recover for many years.

In the meanwhile the fierce competition among the smelters continued and margins were cut down to low figures. There were three parties in the struggle, viz., the refiners, the smelters, and the miners.

The smelters hemmed in by the terms of the refiners on one side and fighting among themselves to get from the miners the supply of ore required to keep their furnaces going were in an unhappy position. It was realized that this could not safely continue, and consequently the principal smelters of Colorado (all but one of those at Leadville had already quit the business) formed an association to limit the prices to be paid for ores. This was in 1894. The combination met the fate of many loose understandings of that time, and went to pieces early in 1895, when sharp competition was again inaugurated.

However, the association of 1894–95 showed clearly the advantage that was to be gained from such coöperation and paved the way for a stronger association a little later on. As has been repeatedly pointed out in this work it is essential to successful silver-lead smelting to have ores of various kinds and in the proper proportions to make a good fluxing mixture, *i.e.*, a mixture which will produce an economical slag without the necessity of adding more than 20% of barren fluxes. It was the inability to conform to that condition which made smelting so unsuccessful in the early days at Salt Lake, while with the self-fluxing ore of Eureka it quickly became successful. In the competition among the smelters of Colorado and Utah, between 1881 and 1900, the stress generally came from this necessity. One smelter might be well stocked up with silicious and limy ores, but lacked irony ore and had to have it at any cost. Another might have enough limy and irony ores, but especially needed silicious ore. Every one needed lead ore at almost all times (see chapter on Colorado). The evils of this condition were increased by the lack of foresight of some smelters in stocking up ahead. It will be readily seen how the competition inspired by an ample smelting capacity was inflamed by this essential requirement of the business and caused cuts in price which wiped out margins. Nor was the competition of unmitigated benefit to the miners. Some of the latter did indeed benefit greatly, but just so much as they gained an advantage, the smelters had to try to recoup it out of other miners. Thus the cutting off of the supply of Mexican lead ore was to the advantage of the domestic producers of lead, but the producers of dry ores had to make it up by an increase in smelting charges on their products.[1]

The outcome of the competition among the smelters was the organization of a clearing house which purchased the ores at a fixed schedule, and distributed them among the various smelters so as to give each one his equitable share of the total tonnage and in the requisite proportion as to kind. This association was formed in November, 1897. The meet-

[1] According to The Mineral Industry, I, p. 314, the exclusion of Mexican lead ore by the tariff led to an average increase of $2.50 per ton in the smelting charges on dry ores in the United States in 1892.

ings of the smelters at that time were initiated with a view to forming an actual consolidation, but it proved that the ideas as to valuations, etc., were too wide apart to enable agreement upon a practicable plan.[1] Moreover, the loud outcry of the miners showed immediately that any effort in this direction would meet with much opposition. The *Engineering and Mining Journal* considered that it would be a great misfortune to the miners if the smelters should consolidate, but predicted that they would assuredly come to that if they continued to lose money in the business, and remarked that it was undeniable that they had been losing heavily through paying too much for their ores.[2] As it was, the new ore-buying association, which entered into an agreement with the mill-men of the Cripple Creek district as to the division of and rates on its ores, was bitterly opposed by the mine owners, who regarded it as a trust and organized associations of their own in defense. However, those served no very good purpose. The smelters' association proceeded on its way and made terms to which the miners had to accede. The relations between the smelters and the larger producers became entirely friendly, but among the smaller producers there developed a feeling of injustice which still survives. However, the alarm of the miners in 1897 proved unjustified. The smelters simply raised rates sufficiently to put their business on a profitable basis, which previously was not so.

The success of the ore-buying association paved the way for the actual consolidation of the smelting industry which was begun in 1899. It having been proved that there was great benefit in the elimination of the previously disastrous competition in the buying of ores, the individual smelters were ready to listen to the claims of promoters who pointed out the further advantages that would arise from the actual consolidation of all the works and the closing of such of them as were antiquated, uneconomical, and unnecessary. This was the era of great industrial consolidations, a boom of dazzling strength was just setting in, and it was natural that shrewd promoters should see the possibilities of such a combination.

The result was the organization in March, 1899, of the American Smelting and Refining Co., with a capital stock of $65,000,000, one-half in 7% preferred, the other half in common, $27,400,000 each of preferred and common being issued. This company took in the United Smelting and Refining Co. (smelteries at Great Falls and Helena, Mont.); the National Smelting and Refining Co. (refinery at Chicago); the Omaha & Grant Smelting and Refining Co. (smelteries at Denver, Colo., Durango, Colo., and Omaha, Neb., and refinery at Omaha); the Pueblo Smelting

[1] Between 1895 and 1897 there had been considerable talk as to the advantage of a smelter consolidation, and in various districts there had been more or less definite understandings as to terms for buying ore.

[2] December 18, 1897.

and Refining Co. (smeltery and refinery at Pueblo, Colo.); the Colorado Smelting Co. (smeltery at Pueblo, Colo); the Hanauer Smelting Co., Pennsylvania Smelting Co., and Germania Lead Works, each having a smeltery at Salt Lake City; the Pennsylvania Lead Co. (refinery at Mansfield, near Pittsburg, Penn.); the Globe Smelting and Refining Co. (smeltery and refinery at Denver, Colo.); the Bimetallic Smelting Co. (copper-matte smeltery at Leadville, Colo.); the Chicago & Aurora Smelting and Refining Co. (refineries at Chicago and Aurora, Ill., and smeltery at Leadville, Colo.); and a majority of the stock of the Consolidated Kansas City Smelting and Refining Co. (smelteries at El Paso, Tex., Leadville, Colo., and Argentine, Kan., and refinery at Argentine). Provision was made for a working capital of $7,500,000 in cash and $2,000,000 in securities acquired from some of the companies purchased. The companies consolidated produced annually about 175,000 tons of lead and practically controlled the market for ores and to a large extent the market for lead. Outside of the consolidation were the Guggenheim Smelting Co. (smelteries at Pueblo, Colo., Monterey and Aguascalientes, Mexico, and refinery at Perth Amboy, N. J.); the Balbach Smelting and Refining Co. (refinery at Newark, N. J.); the Selby Smelting and Lead Co. (smeltery and refinery at San Francisco, Cal.); the Puget Sound Reduction Co. (smeltery and refinery at Everett, Wash.); and the Tacoma Smelting Co. (smeltery at Tacoma, Wash.).

In the organization of the American Smelting and Refining Co. some of the smelters whose works were taken over sold out for cash and quit the business, but in general the leading factors in the business, including Grant, Eddy and James, Eilers, Meyer, Barton, Sewell, and others took payment in the securities of the new company and joined its board of directors. The company was certainly liberally capitalized. Roughly, its plants had capacity for smelting 2,500,000 tons of ore per annum and refining 250,000 tons of lead, besides some blister copper and other by-products. Disregarding the copper and by-product plants, which were of comparatively small importance, it would have been possible to duplicate the smelteries for $7,000,000 to $8,000,000; and the refineries for $1,500,000 to $1,700,000. The physical value of the works, plus the working capital provided, was about half the capital in preferred stock, but there were further assets in the by-product plants, mining interests, etc. However, no one would pretend that these would raise the physical and tangible value to the equivalent of the preferred stock. The remainder represented the good-will, organization, experience, contracts, etc., of the companies entering the consolidation. The stock of the company was offered to the subscription of the public at the rate of 10 shares of the preferred and seven shares of the common for $1000. The subscriptions quickly commanded a premium.

The advantages of the new company were the control of the ore market and ability to insure the most economical distribution of the ore; the elimination of certain uneconomical and unnecessary plants and the concentration of operations at the best places; the ability to secure suitable adjustment of transportation questions; the free exchange of technical and administrative experience. It is doubtful if the claim of great economy in administrative and general expense, which was made for all of the consolidations of the time, was ever realized in this case, or any other. However, the advantages mentioned above were real ones, and together with others which subsequently developed contributed largely to the remarkable success of this combination.

The American Smelting and Refining Co. immediately began to exert a powerful influence in the market for lead, although it by no means had control thereof. It was formed at the beginning of a period of great industrial activity, when the stocks of lead were practically exhausted and the price was steadily rising. The shortage of the supply would have undoubtedly carried the price to the importation figure had it not been for the manipulations of the American Smelting and Refining Co., which held the market steady and prevented importations that might have overstocked the market and led to bad effects subsequently. In 1900 the market was fairly steady, but not quite so strong as in the previous year. In the fiscal year ending April 30, 1900, the American Smelting and Refining Co. realized a profit of $3,524,961. This was not very satisfactory and the failure of the company to stay the decline in the price of lead in 1900 showed that its position in the industry was far from being so strong as it was hoped. The independence of the powerful Guggenheim interest was a menace. In the latter part of 1900 overtures were resumed to bring the Guggenheims into the consolidation, and were brought to a successful issue early in 1901. The capital stock of the American Smelting and Refining Co. was increased to $100,000,000, and $45,200,000, half in common and half in preferred shares (worth about $36,000,000 at the quotations of January, 1901) were given to the Guggenheims in payment for their smelteries at Monterey and Aguascalientes, Mexico, the smeltery at Pueblo, Colo., a smeltery in Chile, the refinery at Perth Amboy, together with the working capital and cash assets of the firm and $6,066,667 in cash additional. There was severe criticism with respect to the high price paid to the Guggenheims, who were considered to be capturing the American Smelting and Refining Co., although nominally they were being absorbed. Several of the brothers entered the directorate of the company, wherein they soon became paramount. Ever since then the American Smelting and Refining Co. and "the Guggenheims" have been commercially regarded as practically synonymous terms.

The Guggenheims were comparatively newcomers into the silver-lead smelting business. It is worth while to relate briefly how they became interested in it. In the early eighties, Meyer Guggenheim, a lace manufacturer of Philadelphia, at the instigation of a fellow Philadelphian, Graham by name, acquired a half-interest in the A. Y. and Minnie mine at Leadville. The venture proved highly profitable. Benjamin Guggenheim, a son of Meyer, was sent out to the mine as accountant, and he acquiring more or less information concerning the smelting business induced his father and brothers to go into it largely because of the unfavorable terms the smelters were making on the A. Y. and Minnie ore, which was of zinky and not highly desirable character. They built the Philadelphia works, a large plant at Pueblo, Colo., in 1889. At first this venture was decidedly unsuccessful, but gradually coming to the appreciation of the necessity for securing the best possible technical advice, and acting upon that principle, together with their own sharp commercial acumen, they converted into a success what promised to be a failure. Thus having acquired an insight into the smelting business, they early appreciated the great possibilities of smelting in Mexico when the lead-bearing ores of that country were practically excluded from the United States by the tariff of 1890, and erected works at Monterey and Aguascalientes. In connection with the latter they first became interested in copper mines and copper smelting. Their product of metals soon became so large that they established a great refinery at Perth Amboy, N. J. Later they became interested in smelting in Chile. Unlike some of the older factors in the silver-lead smelting business, such as Anton Eilers, August R. Meyer, and others, the Guggenheims were not trained metallurgists and never learned to be, but that kind of assistance they knew how to employ and themselves possessed the remarkable business talent that characterizes the most acute representatives of their race.

Although at the time of their consolidation with the American Smelting and Refining Co. the Guggenheims were thought to be receiving an exorbitant price, it soon came to be recognized that they were making the success of the enlarged company. Their former interests in Mexico were the most profitable part of the whole business, and they personally were highly valuable assets. With their advent, early in 1901, the American Smelting and Refining Co., since referred to commonly as the "Smelter Trust," acquired control of practically the entire output of domestic desilverized lead. The only independent refiner on the Atlantic Coast was the Balbach company, which handled chiefly Mexican lead in bond, while on the Pacific Coast the two independent refiners were naturally limited to that comparatively small market. The Trust at once declared its domination. It fixed a price which was regarded as fair to both consumer and producer and aimed to maintain it independent of foreign markets. It is to be remarked that at this time the Trust was not itself really a producer of lead; it owned a few lead mines, but they were of no great consequence. Its position was that of middleman who bought from the producers — the miners — smelted and refined the product and sold it to the consumers. However, its declared policy of fixing a price which should be fair to both producer and consumer was not entirely altruistic. The Trust although not directly a producer was always the possessor of a large quantity of lead which it acquired at much below the market price or at no price at all. It refined a large amount of foreign base bullion in bond under regulations which required it to account for only 90% of the weight of the bullion, the remainder being assumed to be metallurgical loss, but as a matter of fact the yield of refined lead was upward of 96% of the bullion, and there was therefore 6% of the imports, purchased on the basis of the London market less smelting deductions, etc., which could be marketed in the United States free of duty. Moreover, in many cases the Trust having fixed one price for the sale of refined lead to the consumer fixed another price for the purchase of lead in ore from the miner, and the latter price was more below the former than the freight and refining costs amounted to, wherefore the greater the differential the more advantage to the smelter. However, in many cases the Trust did indeed pay for lead in ore on a sliding scale based on the New York price with a constant differential to cover freight, refining, etc., but in these cases, as in the others, the payment was commonly for only 90% of the lead by fire assay (which is notoriously short) and in ores of very low assay (less than 5%) did not pay for the lead at all, while the actual extraction of all lead acquired was upward of 92% on wet assays (the actual results). These things do not imply that the Trust was necessarily unfair to the miner, because these unpaid items appear in the smelter's calculation of margin, and it is that on which he bases the net price to be paid for ore; but they show the smelter's interest in at least keeping the market price of lead at a figure corresponding with what he paid for it and in maintaining it as high as possible. Correctly stated, therefore, the position taken by the Smelter Trust in 1901 was this: The miner and the smelter would both benefit by a steady price for lead at as high a figure as could be maintained, the benefit to the miner being the more in the aggregate. The manufacturer, *i.e.*, the maker of white lead and the oxides, the roller of sheet lead, the maker of shot, etc., would welcome a steady market, which would enable him to gauge his profit without concern as to fluctuations in price, so long as the price for his products would not check consumption — a result equally objectionable to the smelter and miner. Finally, the ultimate consumer, *i.e.*, the citizen who paints his house, the sportsman who uses the shot, and the chemist who employs sheet lead in many ways, would have to pay all he could stand.

If the Smelter Trust did not calculate in precisely the above way, it is at all events what its plans amounted to. In carrying out its policy, it was recognized that the domestic supply being sometimes in excess of the consumption it would be necessary to export surplus lead or limit the output. The latter could be done in two ways, viz., (1) by agreement with the miners; (2) by such increase in smelting charges as would make certain ores become unprofitable and thereby check their production.

In this connection it is important to note another change from previously existing conditions that was effected. The largest single consumption of pig lead is for the manufacture of white lead. About 1892 the principal corroders had been consolidated in the National Lead Co., which also had other lead manufacturing interests, such as the rolling of sheet lead, and became by far the largest single consumer. The shot towers of the country had been largely consolidated by the American Shot Co. These important consumers had a powerful effect upon the market for pig lead. They had the greatest possible interest in keeping down the price of pig lead and keeping up the prices of their products from it. Having concentrated the buying of pig lead, and being able to equalize the stocks at the various factories, they were able to buy at such times as best suited them and to force the refiners to come to them, whereas previously the manufacturers had been obliged to go to the refiners. The entry of the Smelter Trust into the market developed the situation of a big refiner and two big manufacturers.

However, in the very first year of its dominion the Smelter Trust fell upon evil times. Consumption did not increase, but supplies did. In the early part of the year, when quotations in Europe were nearly on a parity with New York, the Trust exported lead. The foreign demand soon fell off and prices in Europe declined to a point much below the Trust's schedule. Arrangements were then made with the principal producers to reduce their output, a certain indemnity being paid them on this account, but notwithstanding this expedient the stocks in the hands of the Trust continued to grow, and when near the end of 1901 the European price fell to a point where importations into the United States seemed likely, the Trust which had maintained the price at 4.35 c. for 11 months abandoned its policy of one price and made a reduction. At the end of 1901 it was said reliably that the Trust had 80,000 tons of lead in stock in ore, base bullion, and refined metal.[1] Of course, a

[1] Neither the statistical reports of The Mineral Industry nor the Mineral Resources of the United States for this year appear to reflect the actual conditions as outlined above, although the commercial report of the former does so.

part of this great stock was represented by the raw material which the smelter is bound to have on hand at all times.

The surplus stock of refined lead was worked off by the Trust with great skill in the following year. Production was limited by agreement with the principal miners, as stated above, and by refusal to buy from some of the less important; in the line of the latter policy the Trust withdrew from the ore market of British Columbia. Consumption was stimulated by a reduction of the price to 4.07½ c., New York. And movement of metal was helped by a new rule to the effect that orders for prompt shipment would be executed only at 2.5 c. extra per 100 lb. This was intended to induce consumers and dealers to cover their requirements ahead, and to carry part of the supplies which had accumulated at the refineries. Having safely passed through the crisis of 1901–1902 there was no further question as to the control of the price of lead by the Smelter Trust until the autumn of 1907. It established a schedule covering the delivery of lead at all the principal cities of the United States, and moved these rates up or down according to its judgment of commercial conditions. A regular differential of 10 c. per 100 lb. above the price for desilverized lead was made for corroding lead. The prices were for 50-ton lots, or larger. Orders were taken subject to the ruling price at date of shipment from the works. To a large extent the business was put on a contract basis, the important consumers entering into agreements for the delivery of the required quantity of metal for a period ahead, settlements being made on the monthly shipments at the average of the quotations for the respective months. The large independent producers adopted both the policy and the prices of the Trust. Outside quotations, which at times were higher or lower than those of the Trust, represented transactions in only an insignificant part of the business and of more or less retail character.

The above was the situation which existed from the end of 1901 to the end of 1906. During that period the industries of the United States were generally in a remarkably prosperous condition, and it was possible to market an increasing supply of lead at an increasing price, the annual averages for these years having been as follows:

1902—4.069 c., New York
1903—4.237 c., New York
1904—4.309 c., New York
1905—4.707 c., New York
1906—5.347 c., New York

History is made even while it is being written. When the present chapter was penned, early in 1907, it was said, "The Trust has not yet acquired control of the entire lead supply of the United States, probably cannot do so, and has not yet been put to the test of a great industrial setback." There was a case of over-production in 1901, accompanying a small recession in business, which was skilfully met as has been described, but although decidedly embarrassing this was nothing like the condition arising in a great financial upset, such as occurred in the autumn of 1907. A falling-off in the demand for the metals was noticeable in March. By July it was strongly marked. The American Smelting and Refining Co. at first bowed to the adverse conditions by reducing its price, but at every move it was undersold by the outside producers, who previously had been willing to accept the price fixed by the Trust. After a while the Trust ceased to make cuts and an awkward situation finally arose which was explained in an editorial in the *Engineering and Mining Journal* of Nov. 16, 1907, as follows:

"The situation in the lead market, which for many months has been unsatisfactory, has failed so far to show any evidence of improvement, in spite of strenuous efforts to enforce a curtailment of production. The largest independent producers in Idaho and Missouri have refused to make any restriction; the American Smelting and Refining Co. and the United States Smelting, Refining and Mining Co. have succeeded in effecting some reduction in output by discouraging the delivery of lead ore; the Federal Lead Co., of Missouri, has reduced its production. But in spite of these measures the stocks of refined metal, about 4000 tons at the beginning of 1907, have increased, especially since the mid-year, until to-day they amount to 25,000 to 30,000 tons.

"The slackening in the demand for lead has created new conditions in the market. For several years upward of 90% of the lead produced from domestic ores has been refined and sold by three interests, chief among which is the American Smelting and Refining Co. The market price has been practically controlled by the latter, inasmuch as the price fixed by it was adopted by the other large producers. A comparatively small amount of lead was sold during 1906 by independent dealers at prices higher than those of the Trust, but the total volume of this business was insignificant in comparison with the great production marketed on the established terms. The Trust showed great moderation at that time in not marking up prices when it might easily have done so.

"It has been fully recognized, however, from the beginning that the apparently successful regulation of the price of lead by the American Smelting and Refining Co. was based on a generally rising market; and that the test of its control would develop on a falling market. This has been proved by the experience of recent months. When the demand became slack, independent producers, who previously had been selling at the Trust price, began to undersell, and manufacturers whose contracts expired decided to take their chances in the open market, so that the latter acquired a magnitude greater than for years past. At the present time it is the market in which competition is active and wherein is transacted the bulk of the business not previously arranged by contract.

"Consequently there are now two markets for lead, viz., the Trust market, in which deliveries are made under contract at the selling price fixed by the Trust; and the open market in which wholesale trading is done in the ordinary way. The difference in prices between the two markets has steadily been increasing under the pressure of the independents to sell their product until now the open market stands about $\frac{1}{4}$ c. per lb. below the Trust price. We have been quoting the two markets in our weekly report, but heretofore have been giving only the weekly range of the open market. In view of its present importance we shall hereafter give the daily quotations of the open market as representative of the situation in lead, reporting also the quotations of the American Smelting and Refining Co. As explained above, the production of lead is going into consumption on both terms, but it is to be remarked that a large part of the lead of the Trust is contracted with its own manufacturing subsidiaries."

In the week following the appearance of this editorial, the American Smelting and Refining Co. announced that it would cease to fix a price and would sell its lead under the conditions of the open market, which declined further upon that announcement.

To what extent the Trust, during its dominion, arbitrarily elevated the price of lead, *i.e.*, at what level it maintained it above that which it would naturally have found, it is impossible to say. That it achieved such a result is unquestionable after the experience of 1901 and 1902, but to what point the price might have fallen in those years if production and competition had been unrestrained, who can say? Certainly it was held far above the low levels of 1871–1880 and 1891–1900, which were reached under somewhat similar conditions. In 1906 the average was higher than for any year since 1876, when the silver-lead industry of the United States was still in its infancy, but can any one say positively that it might not naturally have attained the high figures ruling? Certainly the market was almost a runaway one during a long period of the year, when some belated consumers were glad to cover their requirements by purchases of imported lead at a premium, and the Trust refrained from advancing its price further when it appeared reasonable for it to do so. However, it appears from recent experience in all of the metal markets that high prices do not check consumption, when there are no available substitutes, in a period of extraordinary industrial activity, because the effect is spread so widely among the ultimate consumers that they do not feel it until after a long time and then only as the cumulative result of the rises in many commodities. It is possible, therefore, that a sudden demand for lead may have carried the price to a height that would not otherwise have been reached if the Trust had not already boosted it to a high level to start from. It is worth while to compare the averages of 1902–1906 with the decennial averages for a series of years previous to 1903. The decennial averages are given in the following table:

Year	Cents	Year	Cents	Year	Cents
1879	5.618	1887	4.365	1895	4.065
1880	5.497	1888	4.446	1896	3.900
1881	5.370	1889	4.425	1897	3.808
1882	5.231	1890	4.369	1898	3.744
1883	5.031	1891	4.323	1899	3.798
1884	4.804	1892	4.241	1900	3.787
1885	4.614	1893	4.182	1901	3.785
1886	4.464	1894	4.137	1902	3.783

The above table of decennial averages gives the arithmetical mean of the yearly averages for the 10 years ending as stated. The comparison of the average of any year with the average of 10 years previous can be readily made with the help of this table. The prices are for pig lead at New York as given by The Mineral Industry. It will be quickly observed that the average price for 1902 (viz., 4.069) was considerably higher than the average for the 10 years ending with 1901, and since then the annual average has risen steadily.

However, the Smelter Trust did a great deal more than regulate the price of lead. Immediately upon its organization it entered upon a policy of centralization, the idea being to have only one plant of the requisite capacity at each smelting center and to have that one of the most efficient character. At present Pueblo, Colo., is the only place where there are two plants in operation; they happened both to be good ones and Pueblo is a grand smelting center. The policy of centralization was begun by dismantling two of the works at Salt Lake City and concentrating the business at the Germania, the best of three previously competing plants. A large new works, the Murray plant, was begun, and when it was completed the Germania was abandoned. Similarly the Philadelphia plant at Pueblo, Colo., was closed because it was the least economical of the three at that place, and later, of the two at Denver the Grant plant was put out of commission. The refining of the base bullion was concentrated in four plants, viz., at Denver, Omaha, Chicago, and Perth Amboy. Some of the other refineries were abandoned because they were antiquated and uneconomical. The great refinery at Kansas City, which had only a year or so previously been modernized at great expense, was razed to the ground because it supplied practically the same market as the Omaha refinery did. The smelteries at Leadville, Colo., and El Paso, Tex., were practically rebuilt. In brief, the entire list of works of the company was put in a high degree of efficiency. This was done out of the earnings.

According to the report of the company for the year ending April 30, 1903, it bought ore containing 1,025,132 oz. gold, 63,389,483 oz. silver, 246,480 tons of lead and 23,959 tons of copper. From the sale of metals it realized $82,985,442, out of which there was a profit of $9,403-711. After deducting general expenses, repairs, betterments, and new construction there remained a net balance of $5,421,103. At the end of the year there were smelteries in operation with a capacity of 3,720,000 tons of ore per annum, and refineries with a capacity of 340,000 tons of lead bullion and 36,000 tons of copper bullion per annum. There were held in reserve, fully equipped and in good repair, smelteries of a capacity for 650,000 tons of ore per annum and refineries of a capacity for 125,000 tons of lead bullion.

While the Smelter Trust was pursuing this policy of centralization and modernization, it was also extensively broadening its scope, always in directions toward increasing its dominion over the smelting of gold and silver bearing ores, and the market for pig lead. Incidentally, it had some ideas as to controlling the world's market for silver, or at least influencing it strongly, being itself the largest seller, but this plan was too big even for its mighty strength. The large and increasing production of independent lead in southeastern Missouri was always a thorn in the flesh of the Trust and attempts were made to control it by buying out its producers. However, they asked prices for their properties that were considered too high, and the St. Joseph Lead Co. and affiliated interests, proud of its history and conscious of its impregnable position, would not listen to any overtures. Abandoning these projects, the Guggenheims acquired undeveloped property in the district and in a few years became one of the largest producers.

In 1903 the smeltery and refinery at Everett, Wash., was acquired; next the smeltery at Tacoma, Wash., together with its copper refinery. In 1905 the famous old Selby Smelting and Lead Co. of San Francisco was bought up. In the meanwhile the company had built a large zinc smeltery at Pueblo, Colo., a large lead smeltery at Alton, Ill., and had increased the size of its copper refinery at Perth Amboy to such an extent as to make the company rank among the large producers of refined copper. In 1907 a large copper smeltery was erected at Garfield, Utah, and the Baltimore Copper Smelting and Rolling Co., of Baltimore, Md. — a large copper-refining interest — was acquired.

Of far-reaching importance was the extension of the mining interests of the company. Originally these were small, being inherited from some of the constituent companies, but from time to time new properties were acquired on no definite plan. Then the Guggenheims as a private venture organized the Guggenheim Exploration Co. to acquire and develop mines. It is unnecessary for the purposes of the present history to trace the growth of that remarkably successful enterprise. It is sufficient to say that in the course of a few years it became closely identified with the Smelter Trust and included among its holdings important lead mines in southeastern Missouri, at Leadville, Colo., and elsewhere. The lead-mining interests of the Trust were further increased by the purchase of a controlling interest in the Federal Mining and Smelting Co., which was a consolidation of many of the important mining companies of the Cœur d'Alene.

The Smelter Trust was equally active in consolidating the lead manufacturing business. The largest consumption of pig lead is for the manufacture of white lead and the various oxides. This business was the field of one of the earlier combinations, viz., the National Lead Co., organized in 1892, contemporaneously with others, like the Sugar Trust, among the group that were trusts in fact as well as in name. Indeed, the National Lead Trust, originally formed, was dissolved by order of the courts and had to be reorganized as the National Lead Co. As a combination it was more or less of a failure, *i.e.*, it failed to consolidate a sufficient proportion of the corroders to give it control of the business, and it settled down simply as the largest concern in the business. As such it pursued a successful and respectable career, never failing to pay a dividend on its preferred stock, sometimes paying a little on its common stock, and never becoming the subject of any disgraceful speculation. It was a safe and conservative, not very enterprising, industrial company. One of its constituents, viz., the St. Louis Smelting and Refining Co., owned the old smeltery and refinery at Cheltenham, St. Louis, which was operated now and then for the smelting of purchased ore. In 1899 this company acquired mining property at Flat River, Mo., and developed it on a large scale, smelting the product at first at Cheltenham; and later at a new works which it built at Collinsville, Ill.

The Guggenheims early cast eyes toward the lead manufacturing business, and organized the United Lead Co., which took over the principal shot towers of the country, which had previously been consolidated under the name of the American Shot Co.; the principal lead-alloy factories; and some of the white lead works outside of the National Lead Co. There was talk of competition with the latter in the white lead business, but that is a very conservative business and the United Lead Co. had too small a production to be a great factor in it. Plans were then discussed to consolidate the two companies; they hung fire for two or three years, and never were consummated, but finally in 1906 the Guggenheims acquired a controlling interest in the National Lead Co., and then their mastery of the lead business of the United States became as complete probably as it would be humanly possible to make it, but still far short of commanding the industry, as we have seen from the experience of 1907. All of the consolidations, amalgamation of interests, and trade arrangements were effected between the end of 1901 and the end of 1906.[1]

The amalgamation centers in the American Smelting and Refining Co., which is both an operating company and a holding company. Affiliated with it is a congerie of other companies, which have their own subsidiaries. It is unnecessary to describe the system in detail. We may pass on to a summary of the situation in the lead and smelting business as it existed at the end of 1906. The production of pig lead in the United States in 1906, according to The Mineral Industry, was as follows:

Desilverized, domestic	220,095 tons
Antimonial, domestic	7,434 tons
Southeast Missouri	100,492 tons
Southwest Missouri	16,528 tons
Miscellaneous	980 tons
Total	345,529 tons
Desilverized, foreign	67,441 tons
Antimonial, foreign	2,686 tons
Grand total	415,656 tons

There were three producers of desilverized lead, viz., the American Smelting and Refining Co. and affiliated companies; the Balbach Smelting and Refining Co.; and the Pennsylvania Smelting Co. The United States Smelting, Refining and Mining Co. had put a large refinery in operation near Chicago in the closing days of the year.

Disregarding four or five small producers in the Wisconsin and Missouri districts, the only important producers of non-argentiferous lead were the Federal Lead Co. (a subsidiary of the Trust), the St. Louis Smelting and Refining Co. (a subsidiary of the National Lead Co., which was controlled by the Trust), the St. Joseph Lead Co., the Granby Mining and Smelting Co., and the Picher Lead Co.

The production of white lead in 1906 was 123,640 tons, corresponding approximately to 99,000 tons of pig lead, nearly 30% of the total production of desilverized and soft lead. Of the production of white lead about 85% was made by the National Lead Co. and United Lead Co. Both of those companies were controlled by the American Smelting and Refining Co. The same companies made the bulk of the output of

[1] According to the report of the National Lead Company for 1907, no single interest is now in control of it, the accumulation of holdings referred to in this text having evidently been dispersed.

litharge, red lead and orange mineral, lead shot, and the lead alloys, such as babbitt metal. Also they were large producers of sheet lead and lead pipe.

It is evident, therefore, that the production of refined lead and of the manufactures of lead had passed to a large degree into the hands of the American Smelting and Refining Co. That company also controlled a large part of the production of lead in Mexico.

In the general smelting business, the American Smelting and Refining Co. had more competition. In certain States it had an active and powerful competition, especially from the copper smelters. As was remarked elsewhere in this work, there is a large class of gold- and silver-bearing ore which can be treated either in the lead-smelting furnace or the copper-smelting furnace, the latter process having an advantage which may be generalized as approximately $1 per ton of ore. On the part of the lead smelters this has led to a combination plant, capable of treating ores by either process, according as it may be most desirable. Such works are in operation at Salt Lake City, Utah, Tacoma, Wash., El Paso, Tex., Aguascalientes, Mexico, and elsewhere. The possession of these works has made the American Smelting and Refining Co. one of the great factors in the copper business, a position which it will soon increase greatly in importance through the recent acquisition of some immense copper mines. Every silver-lead smelting works needs a little copper to mix with its other ores in order to secure the best extraction of the precious metals, but while the lead smelter is always in the market for any ores which contain copper, the copper smelter proper is highly averse to any ores which contain lead. Consequently this imposes a limitation upon the competition to which the American Smelting and Refining Co. is at present subject.

In the State of Colorado the American Smelting and Refining Co. is paramount. The only opposing lead smelter is the Ohio & Colorado Smelting Co., of Salida. The Boston & Colorado Smelting Co., of Argo, is a competitor on a comparatively small scale for copper-bearing, and for silicious, non-lead-bearing ores. In the Cripple Creek district, which produces the largest tonnage of any district in the State with the exception of Leadville, the ore being a silicious-aluminous gold ore, the American Smelting and Refining Co. and the United States Reduction and Refining Co. (commonly known as the mill trust) are the buyers, but they operate under a mutual understanding, wherefore there is no competition between them. However, independent mills for the treatment of the ore of this district will go into operation in 1908. In this case there is a fair field for competition, the product of the ore being gold bullion which finds unlimited sale with the U. S. Mint at the standard price.

In Utah the United States Smelting Co. (a subsidiary of the United

States Smelting, Refining and Mining Co.) and the American Smelting and Refining Co. are direct competitors for all kinds of ore. The Utah Consolidated Mining Co. and Bingham Consolidated Mining Co. buy copper and silicious ores. All of these are powerful concerns.[1] Their competition, especially that of the United States Smelting Co., extends into California, Idaho and Nevada.

In Montana the American Smelting and Refining Co. is alone in so far as lead smelting is concerned; also in Washington. There is no important lead smelter in Idaho. The United States Smelting Co., Ohio & Colorado Smelting Co., and Pennsylvania Smelting Co. (of Pittsburg, Penn.) all obtain considerable supplies of ore from this State, but the bulk of the output of the Cœur d'Alene goes to the American Smelting and Refining Co., which has long-time contracts with the most important mining companies, including the Federal Mining and Smelting Co., which it controls.

In California the American Smelting and Refining Co. is practically free from competition, although the Mammoth Copper Mining Co. (a subsidiary of the United States Smelting, Refining and Mining Co.) and the Mountain Copper Co. are in the market for non-lead-bearing ores, and the former invades the southwestern Nevada territory.

In Arizona and New Mexico, which are commanded by the El Paso, Silver City, and Pueblo plants of the American Smelting and Refining Co., non-lead-bearing ores are competed for by the Copper Queen Consolidated Mining Co. of Douglas, Ariz., the Arizona Smelting Co. of Humboldt, Ariz., and the Boston & Colorado Smelting Co., of Argo, Colo. There are several small lead-smelting plants which are in the market for lead ores.

It appears, therefore, that in the general smelting business the American Smelting and Refining Co. is subject to a good deal of competition, which has developed since its organization, and promises to increase. Its position in the lead-smelting business is more monopolistic, but in that also it is experiencing a good deal of competition, some of which is of a new and strong character. Its chief bulwark in this direction is its possession of the supply of essential ores through long-time contracts and the ownership by itself of many mines. Of especial importance is its strong foothold in the Cœur d'Alene.

The only sure basis for a permanent monopoly is the control of the raw material. Smelting and manufacturing plants can be duplicated. Metallurgical and business experience can be purchased. But valuable mines are only where Nature put them and they are not common. It

[1] At the end of 1907 the Utah Consolidated and Bingham companies were obliged to close their works owing to a court injunction resulting from litigation respecting the smoke nuisance complained of by the farmers.

is the realization of this principle that has guided the American Smelting and Refining Co.; hence the activity of the Guggenheim Exploration Co. It was the acquisition of an adequate independent ore supply that enabled the United States Smelting, Refining and Mining Co. to enter the field as a powerful competitor. It is the difficulty of competitors in obtaining the requisite ore supplies that gives the American Smelting and Refining Co. its strong hold in Colorado, where, moreover, its profit in smelting is comparatively so small that there is little inducement toward outside competition.

Unquestionably there has been, and still is, much dissatisfaction among the producers of ore, especially in Colorado, over the policy of the American Smelting and Refining Co. Doubtless they have suffered some injustice from arbitrary methods of doing business, some bullying that is naturally repugnant, and some miners have probably been favored with advantageous terms at the expense of others, but that the producers as a whole have been unfairly taxed for the smelting of their ore does not appear to be the case in view of the comparatively small profit that seems to be realized on this part of the business. On the other hand, the producers of lead ore have distinctly reaped a great advance from the high price of lead that prevailed from 1902 until near the end of 1907, in the creation of which the Smelter Trust was instrumental. For this the consumer has had to pay.

PART II

ZINC

XVIII

INTRODUCTION

The history of zinc in the United States is much less interesting than the history of lead. For one thing it is briefer; for another it was never hampered in its early development by lack of cheap transportation, and was wholly without the romance accompanying the opening of the silver-lead mines west of the Rocky Mountains; and finally, whereas in lead smelting American metallurgists have led the world in their marvelous improvements, in zinc smelting American practice until very recently has been on the whole not only almost without initiative, but also has been backward in adopting the improvements introduced in Europe. The reasons for lack of enterprise will be explained further on.

The world's history of zinc is brief, covering but little more than a century. Zinc mines have been worked for several hundred years, but the ore was used only for the manufacture of brass by the cementation process. It was not generally known how to obtain spelter from zinc ore until the beginning of the nineteenth century.[1] Zinc smelting was first carried on commercially by Isaac Lawson at Bristol, England, in 1740 or 1741. He probably obtained his knowledge of the process from China. Apparently spelter, or tuteneague,[2] was imported in small quantity from China previous to his time. In 1798 Johann Ruhberg discovered the art of smelting at Wessola, Upper Silesia, Prussia, and in the same year Dillinger made a similar discovery at Delach, Carinthia, Austria. In 1807 the Abbé Dony made his discovery at Liège, the story of which is a classic in metallurgical literature. The evident fact that he was ignorant that spelter was even then being produced in Silesia is testimony to the slowness of dissemination of technical information 100 years ago. These four discoveries were the origins of four distinct methods of smelting, viz., the English, the Silesian, the Carinthian, and the Belgian. Of these, only the Silesian and the Belgian have survived. The best modern practice is a combination of them, known as the Rhenish.

[1] For details of the history of zinc refer to B. Neumann, Die Metalle; L. von Wiese, Beiträge zur Geschichte der Wirthschaftlichen Entwicklung der Rohzinkfabrikation; Ingalls, Production and Properties of Zinc; Ingalls, Metallurgy of Zinc and Cadmium; and Lodin, Métallurgie du Zinc.

[2] This peculiar word is spelled in various ways.

The occurrence of zinc ore in the United States must early have been known, because the mineral blende is the commonest associate of galena. However, none of those occurrences, if known, was in connection with workable deposits, either then or at any subsequent time, with the sole exception of those in Sussex County, N. J., where the mineral was not blende, but franklinite, willemite, and zinkite. The first mention of zinc ore in the West appears to have been made by Bradbury in 1810, who recognized its occurrence at Mine á Burton.[1] Schoolcraft also observed it in Washington County, Mo., and with his characteristic acumen predicted the future value of the ore, which was a remarkable forecast in view of the infancy of the zinc industry in Europe at that time (1819) and its non-existence in the United States.[2] As the lead mines of Missouri, Wisconsin, Virginia, and other States were opened in the first three decades of the nineteenth century the occurrence of zinc ore must have been observed in many of them. The first attempt to work zinc ore for the production of spelter, however, was made in New Jersey, and to that State, therefore, belongs the title of birthplace of the American zinc industry.

[1] H. M. Brackenridge, Jr., Views of Louisiana, p. 304; through Winslow, Lead and Zinc Deposits of Missouri, I, 274.

[2] However, it appears that even then the manufacture of brass by the cementation process may have been practised on a small scale in the United States. Details are lacking.

XIX

OCCURRENCE OF ZINC ORE IN THE UNITED STATES

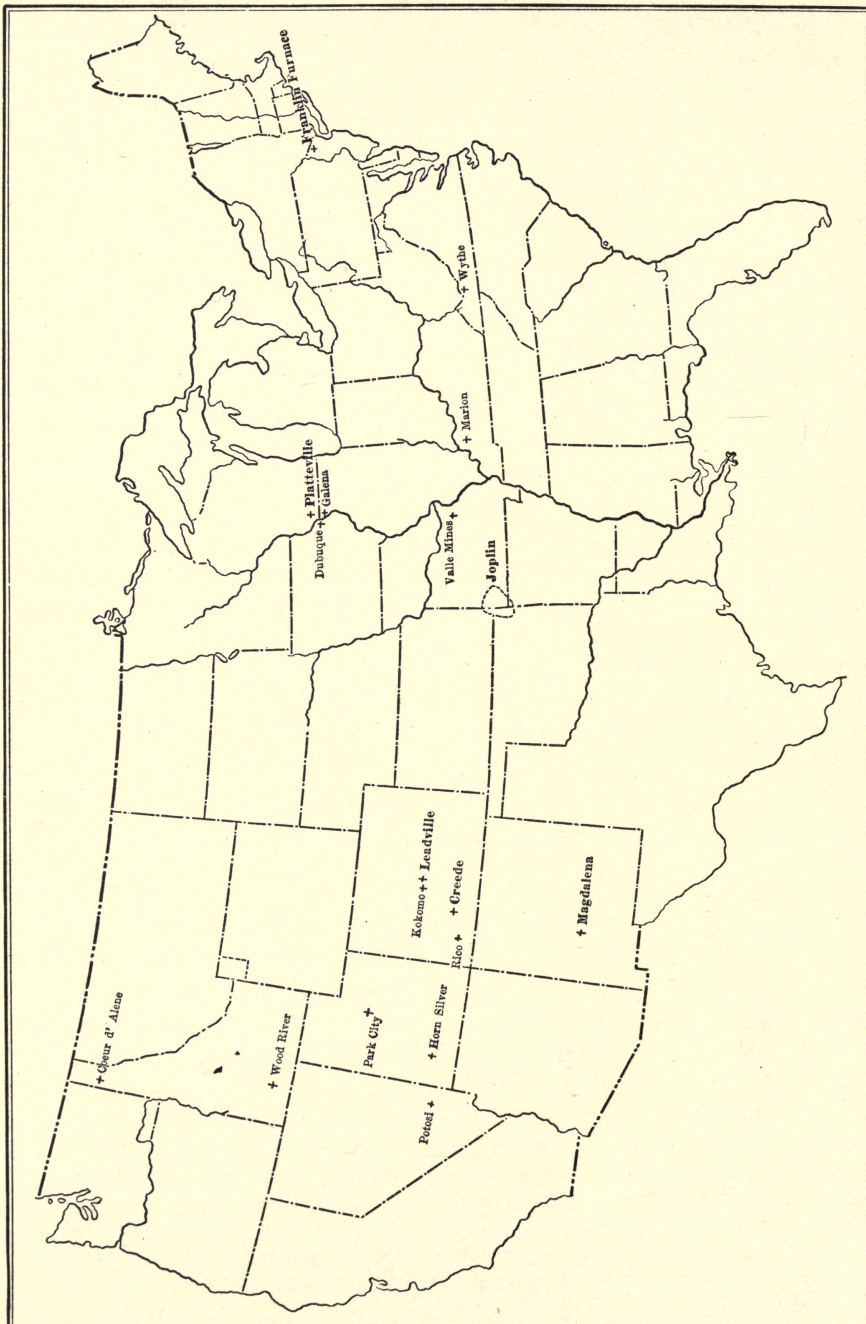
Deposits of zinc ore are widely distributed in the United States. The most important are situated in the Joplin district, of southwestern Missouri and southeastern Kansas; at Stirling Hill and Franklin Furnace, N. J.; and at Leadville, Colo. The places at which zinc ore has been mined, or is known to exist in workable quantity, are shown in the accompanying map. The relative importance of the several States as producers of zinc ore is shown in the following table, which is from The Mineral Industry, vol. XV:

Production of Zinc Ore in the United States

State	1904		1905		1906	
	Tons	(g) Value	Tons	(g) Value	Tons	(g) Value
Arkansas	(e) 1,900	$66,000	2,200	$96,000	4,200	$168,000
Colorado	(a) 94,000	940,000	105,500	1,529,750	114,000	1,824,000
Idaho	*Nil*	....	1,700	37,400	2,150	45,150
Kentucky	(d) 958	10,538	(d) 414	6,624	975	34,125
Missouri-Kansas	(b)273,238	9,692,160	(b)258,500	11,455,280	(b)283,500	12,219,675
Montana	*Nil*	....	2,000	25,000	4,900	98,000
Nevada	*Nil*	....	*Nil*	....	7,080	70,800
New Mexico	(e) 21,000	168,000	17,800	222,500	30,000	360,000
New Jersey	(d)280,029	560,058	(d)361,829	723,658	404,690	809,380
Utah	*Nil*	....	9,265	120,445	10,700	214,000
Wisconsin	(c) 19,300	598,300	32,690	1,307,600	42,130	1,390,290
Others	(a) 2,600	36,400	(f) 3,800	72,200	(h) 850	17,000
Totals	693,025	$12,071,456	795,698	$15,596,457	905,175	$17,250,420

(*a*) Estimated. (*b*) Production of Joplin district, plus output of southeastern Missouri, the latter as reported by the State mine inspector. (*c*) According to H. F. Bain, "Contributions to Economic Geology," 1904. (*d*) Report of State Geologist; crude ore. (*e*) Partly estimated. (*f*) Arizona, Nevada, Illinois, Iowa, Tennessee and Virginia. (*g*) Values are estimated, no direct reports having been received; they are reckoned, in all cases, f. o. b. mines, on the basis of the average price for spelter in each year and the average grade of ore. (*h*) Indian Territory, Tennessee, Arizona, and California.

The production of zinc ore in the United States in 1906 was 905,175



The Principal Occurrences of Zinc in the United States.

tons, against 795,698 tons in 1905, and 693,025 tons in 1904. The statistics for 1906 are not strictly comparable with those for 1905, because while the latter omitted some of the zinc ore used for the production of zinc oxide and zinc-lead pigment, the statistics for 1906 include all zinc ore consumed for all purposes. These statistics represent the concentrated marketable product, and show the actual supplies of raw material that were available to the smelters.

It will be observed from the table that a large part of the production of ore in 1906 was due to New Jersey, of which the product is used to only a small extent for making spelter in the United States, the bulk of it being employed for the manufacture of oxide and for export to Europe as a spelter ore. Omitting the New Jersey production, it appears that the Western spelter and oxide manufacturers received 590,000 tons of ore in 1906. The production of the Joplin district accounts for about 137,000 tons of spelter, against 124,000 tons in 1905.

Arizona. — Zinky ore occurs at many places in this Territory, and during the last few years considerable attention has been devoted to some of the deposits, especially those near Tucson, but up to the present time the total production of the Territory has been insignificant. Most of the occurrences of zinc appear to be in the form of mixed sulphides.

Arkansas. — Zinc ore has been discovered at numerous points in this State. The deposits which have attracted most attention are situated in Marion, and adjacent portions of Boone, Baxter, Newton, and Searcy counties in the northern part of the State. They are described as irregularly distributed in crevices and along joint planes in magnesian limestone, the crevices frequently enlarging into pockets or cavernous spaces filled with ore, clay, and other gangue. At some points the ore has impregnated certain strata, and thus occurs at a definite horizon.

The zinc region of northern Arkansas lies, generally speaking, to the north of the Boston Mountains and west of the St. Louis, Iron Mountain and Southern Railway. The tardiness of the development of the region is due in part to its topography, it being a hilly and partly mountainous country, through which there have been no railways until recently.

Both the blende and the calamine of northern Arkansas are remarkable for their purity. The early zinc mines of Arkansas were opened on deposits of smithsonite in the surface clays and soils, along and near the outcrops of deposits of blende. Zinc silicate ore is much less abundant in northern Arkansas than either blende or smithsonite.

Besides in northern Arkansas, zinc ore has been mined in a tentative way in the southern part of the State, in Sevier County, about 70 miles north of Texarkana and four miles from the Indian Territory, where there is a fissure vein in black slate, which is traversed by dikes of diorite. The ore is a mixture of blende, chalcopyrite, and argentiferous galena.

Colorado. — The immense shoots of sulphide ore at Leadville had large quantities of a mixture of blende, pyrites, and galena, which assayed about 24% Zn, 6% Pb, 25% Fe, 39% S, 4% SiO_2, and 8 oz. silver per 2000 lb.[1] The occurrence of these ore-bodies and their early history are described in the section of this work which relates to lead.

Since 1899 a large quantity of zinc ore has been produced from this district, which as a source of spelter has come to rank second only to the Joplin district. The ore as marketed consists of concentrate prepared by magnetic separation, which contains 40 to 45% zinc; concentrate, which contains 35 to 40% zinc, made by Wilfley tables; and crude ore, which contains about 30% zinc after a rough hand-sorting. The last is produced especially by the Moyer mine, in which the ore-body is essentially a mixture of blende and pyrites, the galena content of the ore shoot which passes through the A. Y., Minnie, Col. Sellers, and Moyer mines decreasing in lead content toward the last.

Since 1899 considerable zinc ore has been produced at Creede, where it is concentrated to a product assaying 55 to 59% zinc, 4 to 6% lead, and 1:1 to 2.1% Fe. The Creede blende generally carries 2 or 3 oz. Ag per ton, and sometimes is auriferous.

Important deposits of mixed sulphides, somewhat similar to those of Leadville, exist at Kokomo, Summit County, where there is a bedded vein, 10 to 12 ft. thick, of great extent. In this there are shoots of high-grade silver-lead ore, but the great mass of the ore is very low in lead, or destitute of it, being essentially a mixture of blende and pyrite. Its composition is approximately 20% Zn and 28% Fe. It contains 4 or 5 oz. Ag and 0.2 to 0.4 oz. Au. These deposits have been worked for zinc to a considerable extent.

Zinc ore is also produced at Montezuma, Breckenridge, and elsewhere in Summit County; at Red Cliff in Eagle County; at Georgetown and Silver Plume in Clear Creek County; at Rico, in Dolores County; and at various places in the Gunnison and San Juan districts. Indeed, zinc ore occurs in Colorado almost everywhere that lead does, the two ores being found commonly in intimate association.

Idaho. — Zinc ore was first mined in this State in the Wood River district, where a small production was made from the War Dance mine in 1905. The ore is blende associated with galena and siderite. In 1906 the production of zinc ore was begun in the Cœur d'Alene, where all of the veins are zinky to a small extent, and some contain sufficient blende to be workable for that mineral. The zinc ore production of Idaho has not yet attained much importance.

[1] During the last two or three years this zinc-lead ore has been largely exhausted and the production of Leadville has been chiefly blende-pyrites ore, carrying only a little lead, from the same ore shoots.

Kentucky. — Zinc ore occurs in Kentucky near Marion in Crittenden County, where it is found in connection with the deposits of fluorspar and galena which have been worked to some extent. The Columbia mine is opened on a fissure vein along the line of a fault of which one of the walls is limestone; the other a sandstone or quartzite. The vein varies in width from 18 in. to 6 ft. In some places the ore spreads out laterally as "flats" or beds. The ore consists of galena and blende, with a gangue of fluorite, some calcite, a little clay, and small quantities of barytes and quartz. In most parts of the vein only the ore and fluorite are met with. The galena and blende occur in bunches and crystals scattered through the fluorspar.

The Tabb mine, south of Marion, has a wide vein, standing vertically, of great longitudinal extent, of which one wall is limestone and the other a sandstone or quartzite of undetermined character. The mineral is a resinous blende, low in iron, which is very finely disseminated in a gangue of fluorspar. Other veins in the district are of similar character. The district has been extensively faulted, the numerous mineral veins occupying fault-fissures.

Owing to the finely disseminated occurrence of the mineral and the difficulty of separating it from the fluorspar (sp. gr. 3.1 to 3.2), which was not satisfactorily surmounted until 1906, the development of the Zinc mines of Kentucky has not yet been of important character.[1]

Missouri, Kansas, and Oklahoma. — Zinc ore is found in several parts of Missouri, but the only important mines are those of the Joplin district, by which designation is understood an irregular area comprising the mines of the Quapaw reservation in Oklahoma, those of Galena, Kan., and those at Webb City, Carterville, Oronogo, and Joplin in Jasper County, Mo., Granby in Newton County and Aurora in Lawrence County, besides various less important mining centers. Circumscribing this area by an ellipse, its long axis, extending from Aurora, Mo., on the east, to Galena, Kan., on the west, is about 50 miles, while its width on the short axis extending north from Granby, Mo., is about 25 miles. The country-rock of the region is chiefly limestone of the Lower Carboniferous formation, which immediately underlies the adjacent coal measures of Kansas. This limestone is not everywhere ore-bearing, but only in local areas where the conditions have favored the deposition of mineral. Surrounding such areas are broad tracts of barren ground.

Broadly considered, the ore deposits are (1) horizontal or nearly horizontal sheets, or blanket veins, of brecciated and mineralized chert;

[1] The Kentucky zinc deposits occur in an extension of the lead and fluorspar district of Rosiclare, Ill., the geology of which has been described by S. F. Emmons, in Trans. Am. Inst. Min. Eng., XXI, 31. Reference may also be made to several publications of the U. S. Geological Survey and of the Kentucky Geological Survey.

and (2) vertical or inclined deposits. The deposits of the first class so far as developed at present occur in a belt extending from Duenweg northwesterly through Webb City and Carterville to Oronogo. The rocks in which the ore occurs are bedded cherts, the ore being found in seams in the somewhat broken beds. Deposits of this form are always near ore-bodies of the second class. The latter may be subdivided into (*a*) lenses of elongated form (runs) or approximately elliptical or circular form, and (*b*) irregular deposits. These deposits are also mineralizations of brecciated chert. Many of these lenses are of great size, especially in the vicinity of Webb City and Joplin, Mo., and Galena, Kan., where stopes occur 75 to 150 ft. wide, 40 to 80 ft. high, and 200 to 400 ft. long, from which all the material extracted has been milled.[1] The smaller lenses are 15 to 50 ft. wide, 5 to 30 ft. high, and 100 to 500 ft. long. In one instance near Joplin a channel of ore was followed for 1000 ft. These lenses and channels are frequently of highly irregular shape, often sending out sheets and pipes into the surrounding barren country-rock. They are connected with a system of fissures in the country-rock and occasionally the latter are found mineralized in coincident sheets. Thus, Jenney (loc. cit.) describes vertical fissures in the district which traverse the limestone without disturbing the stratification or producing any brecciation except between the cheeks of the fissures, enclosing veins of mineral after the usual manner of "fissure veins." A fissure of that character near Joplin carried ore to a depth of 60 ft., with a longitudinal extent of 200 ft. and thickness of 4 to 12 ft. between walls.

The common lenticular masses of mineral-bearing chert in general are closely associated with the limestone country-rock of the district, and occur along fault planes and at the intersection of faults. The distribution of mineral through the chert is irregular. The blende occurs impregnated in seams and bunches in the chert, so that frequently the fragments of the latter appear cemented together by the blende, which everywhere permeates the mass in a net-work. As the ore becomes richer the seams of blende increase in thickness and sometimes pockets of solid blende or loose aggregates of crystals (gravel jack) are found. Usually the proportion of blende increases in the lower part of the deposit, where it sometimes entirely replaces the chert, but at the bottom of the deposit there is commonly a layer of very solid, dense chert, which cuts off the zinc ore. It is often the case, however, that another ore-body comes in under such a layer of chert and there are instances where four successive ore-bodies have been opened, one under the other, with intervening partings of chert. The ore-bodies are sometimes identical with the chert lenses, so that the entire lense is more or less impregnated with blende, but more frequently separate ore-bodies occur in various parts of the larger lenses.

[1] Walter P. Jenney, Trans. Am. Inst. Min. Eng., XXI, 31.

Until about 1901 nearly the whole production of the Joplin district was derived from the deposits of the second class, *i.e.*, the runs, lenses, and irregular forms. The ore of these was comparatively rich, sometimes very rich, but the deposits were comparatively small. A run or lense that yielded 100,000 tons of crude ore, which would be exhausted in about three years by the mining of 100 tons per day, was of very fair size. Consequently the history of the district was the constant exhaustion of ore deposits, the discovery of new ones, and the development of new producers to take the places of the old ones. The deposits of the first class, *i.e.*, the sheet ground, are much larger and much more regular, consisting generally of a fairly regular bed of ore 8 to 14 ft. in thickness, and of great longitudinal and lateral extent. These deposits were early known, but for a long time could not be profitably worked because of their generally low tenor in zinc. Since 1901, however, the demand for spelter has increased so much that the price for the metal has risen to an extent permitting these low-grade deposits to be worked, and by 1906–1907 probably upward of 40% of the Joplin production was derived from them. The large dimensions of these deposits has warranted the installation of mining and milling plants of far greater capacity than could safely be installed for the older runs and lenses, which has led to great improvements in the mining and milling practice.

The grade of the ore mined at Joplin is variable at present, and always has been, but in general it has decreased from decade to decade. In the early days ore yielding as high as 50% of mineral was mined. In 1894 few mines could be worked at a profit which did not yield 10%.[1] In 1899–1901 the average was about 5%. In 1905–1907 a great deal of sheet ground yielding only 3% was worked, and even as low as 2.5%.

Deposits of smithsonite and hemimorphite, classed together as "silicate ore" by the miners of the district, occur especially in the vicinities of Aurora and Granby, where ore of that character rich enough to ship in lump form is obtained. As sent to the smelters it averages 40 to 45% Zn. Elsewhere in the Joplin district blende is the predominant mineral. Galena is commonly associated with it. In the runs and lenses the galena occurs more abundantly in the upper portions, while in the lower parts of the ore-bodies there is less of it, and often none at all. Where the two minerals occur together there is no sharp line of demarcation, but in dressing there is no difficulty in separating the two minerals when intermingled. As the surface deposits became exhausted the proportion of lead ore to zinc ore decreased. However, this falling off has been offset by the increasing production of ore from the sheet ground, which averages a little higher in lead than the other ore.[2] There is not as a

[1] J. R. Holibaugh, The Mineral Industry, III, 537.

[2] The production of lead ore and zinc ore during the last twelve years was as follows,

rule a large percentage of pyrite associated with the blende of the Joplin district, but there are some mines where it runs so high as to prevent the production of a marketable ore by ordinary gravity concentration.

The Missouri blende is commonly of the brown, resinous character, often ruby red, sometimes black, and rarely white. Mineralogically, it is very pure, containing only an insignificant proportion of isomorphous iron, but it is high in cadmium as compared with the blende of other mining districts. The concentrated ore produced at the present time averages about 58% zinc. Its average tenor in lead may be put down at 0.5 to 1%, and in iron from 1 to 2%. It assays about 30% S, and the remainder of its composition, besides a little cadmium, is silica.

The operating of mines on leased land is almost a universal practice in the district. Under this system the fee-owner usually gives a lease on a large tract of his land at a royalty of from 8 to 15% of the gross output of mineral, the lease being made usually for a period of 10 years. The lessee prospects the tract by drilling or sinking shafts, and if mineral is found, sub-leases portions of the property, usually lots of 200 ft. square, at a royalty of 15 to 25% of the gross output of mineral.[1] In some cases the fee-owner operates his own mines and frequently a lessee prefers to work a rich deposit rather than to sub-lease it. This system has had at least one good result, inasmuch as it has made the district largely free from labor difficulties, so many miners being directly interested in the operations. Experience has shown also that in the long run the system is probably the most economical under the conditions which have heretofore existed, since, although a company operating its own property on a large scale can mine and mill most cheaply, lessees are at an advantage in exploring for new ore-bodies. The past record of the district has been one of constant exploration for new ore-bodies. In the last few years, when the high price for zinc ore has permitted the mining and milling of the large deposits of "sheet ground," there has

the zinc ore being stated in brackets: 1895, 31,294 (144,487); 1896, 26,927 (153,082); 1897, 29,578 (177,975); 1898, 26,457 (235,123); 1899, 24,100 (256,456); 1900, 28,500 (242,500); 1901, 35,000 (258,000); 1902, 31,625 (262,545); 1903, 28,656 (234,873); 1904, 34,362 (267,240); 1905, 31,679 (252,435); 1906, 39,189 (278,930). According to these figures the ratios are: 1895, 1: 4.6; 1896, 1: 5.7; 1897, 1: 6; 1898, 1: 9; 1899, 1: 10.6; 1900, 1: 8.5; 1901, 1: 7.4; 1902, 1: 8.3; 1903, 1: 8; 1904, 1: 7.8; 1905, 1: 8; 1906, 1: 7.1. The Joplin lead ore, as concentrated, assays about 77 % Pb on the average, the best grades having a tenor of about 80% Pb.

[1] These figures represent the conditions in 1899–1901. The rates of royalty have undergone more or less change. In 1882, according to F. L. Clerc (Mineral Resources of the United States, 1882), royalties of 25% on blende and 50% on galena were paid to the land owner. In 1892, according to Winslow (Missouri Geological Survey, report on Lead and Zinc, I, 302), the royalties then ranged up to those rates in certain cases, but generally were lower. In 1906 the royalty on blende was 10 to 15%, the average being much more nearly the latter figure than the former.

been a tendency toward consolidation of properties and the conduction of operations on a larger scale. It is possible that if the true conditions of the occurrence of ore in the district had been recognized in its early history a different and better system of exploitation might have developed. As it was, the inherent drawbacks of the system which actually developed were offset to a large extent by the ingenuity and high intensity of the mine operators, who with cheap and insignificant equipment succeeded in reducing the cost of mining and milling per ton of ore to figures which compare favorably with the results of work on the largest scale anywhere in the United States. Mining for 75 c. per ton, with milling for 25 c., and general expense and administration at 10 c., were by no means uncommon figures in 1899–1906.

New Jersey. — The great zinc mines of this State are situated in the towns of Ogdensburgh and Franklin Furnace, at Stirling and Mine hills respectively, in the valley of the Walkill River, a small stream, about 12 to 15 miles south of the New York State line and 40 miles in a direct line and 60 miles by railway from New York City. Both at Stirling Hill and Mine Hill, the former being two miles, south 20° west, from the latter, the ore-bodies occur as beds lying between strata of white limestone of Cambrian, Cambro-Silurian, or Archæan age, which have been contorted in a remarkable manner. The Stirling Hill bed, or vein, as it is commonly referred to, strikes southwest for 1100 ft., then curves around for 300 ft. and strikes northeast, parallel with its own extension, for about 475 ft., until it ends. Both parts of the vein dip about 60° east.

The vein at Mine Hill presents analogous but even more complicated features. It strikes south 30° west for about 2500 ft., then bends around in a sharp fold and strikes to the east at an angle of about 30° with its other extension, and after running approximately 600 ft. pitches below the surface at an angle of 27° or 28°, though it has been proved by borings and a shaft to extend about 2000 ft. further, where its depth below the surface is about 1000 ft. In the western vein the ore dips southeastward at angles varying between 37° and 60°; in the eastern vein it is nearly vertical.

The outcrop of the Stirling Hill vein resembles a hook in its shape. That of the Mine Hill vein resembles a wire bent sharply in two legs at an angle of 30°, one leg being short but of equal length to the other if its known extension underground be plotted. In transverse sections both deposits show as two veins dipping more or less in the same direction and one apparently underlying the other, wherefore they are frequently referred to as the "front" and "back" veins.

The Stirling Hill veins vary from 4 to 20 ft. in thickness, throughout which the zinc minerals are disseminated, but not uniformly. In the front vein the portion near the foot wall shows a band richer in zinkite and willemite than that near the hanging, but it is hardly enough to justify speaking of two veins, a zinkite vein and a franklinite vein, as has been done.[1] Both are irregular and pinch because of the coming in of the foot wall. The ore-body is an impregnation of the limestone along this horizon, with the ore-bearing minerals in a greater or less degree, and with a streak richer in zinc next the hanging. As much as 20 ft. in thickness has been taken out up to the limits where the walls became too lean to work.

The Mine Hill vein is as much as 50 ft. thick in places, and even more at the bend. Frank L. Nason, in a paper in Trans. Am. Inst. Min. Eng., February, 1894, which goes extensively into the geology of the deposit, considers that the ore-body is equivalent to a prism 3500 ft. long, 800 ft. wide, and 25 ft. thick.

The zinc ore of New Jersey is essentially a mixture of zinkite, willemite, and franklinite, forming a rock-like mass in appearance not unlike a granite, in which the franklinite represents the quartz, the willemite the feldspar, and the zinkite the mica. The analogy would be more exact if the ore were compared to a garnetiferous syenite, in which the greenish orthoclase might stand for the willemite, black hornblende for the franklinite, and the red garnet for the zinkite, but neither any granite nor the imaginary syenite would have the distinctly crystalline appearance and brilliancy of the New Jersey zinc ore. Besides the franklinite, willemite, and calcite there are small quantities of zinkite, tephroite, garnet, and occasionally other minerals. The average tenor of zinc in the deposit at Mine Hill is 21%. Owing to the low tenor in zinc and the high percentages of iron and manganese the ore was not used extensively for the manufacture of spelter until recently, but was employed chiefly for making zinc oxide and spiegeleisen. Since 1896 it has been an important source of spelter, the metal produced from it being of exceptionally high grade, because of the freedom of the ore from lead, cadmium, arsenic, antimony, etc. This has been effected by the success of the Wetherill process of magnetic concentration, which has enabled a willemite concentrate assaying 48 to 50% zinc to be produced from the crude ore, this concentrate being of excellent grade as a spelter ore.

Montana. — Nearly all of the lead-producing districts of this State contain blende in association with galena, and some of them have deposits of such grade and magnitude as to be workable for zinc. Blende also occurs in some of the veins of Butte, and attempts have been made to operate the Alice and Lexington for this purpose, but these have not yet proved commercially successful.

[1] J. F. Kemp, The Ore Deposits at Franklin Furnace and Ogdensburgh, N. J., in Trans. New York Academy of Science, XIII, 76 to 98. Reference should be made to this paper for a more complete knowledge of the highly interesting geology of these New Jersey mines.

Nevada. — The Potosi mine, near Olcott Peak, on the western slope of Spring Mountains, in southwestern Nevada, has been a small producer of zinc ore since 1905. The ore occurs in irregular shoots in a bed of limestone about 5 ft. thick, the ore shoots following crevices in the limestone. The ore so far shipped has been carbonate, containing 40 to 45% zinc, but some ore running 35% zinc and 20% lead has also been shipped.

New Mexico. — Deposits of zinc ore near Hanover in the southwestern part of this Territory have been exploited to a small extent. They occur in gray and white limestone of Lower Carboniferous age, or older. The deposits are of two classes, calamine and blende, and according to W. P. Blake[1] are rather unique in some respects. Apparently the deposits of calamine and blende have no direct connection. The former have been quarried out from the surface downward in irregular pits and cave-like excavations, in some cases to a depth of 60 ft. or more, gradually thinning out to mere seams. The ore is chiefly smithsonite, often in close association with aggregations of small crystals of quartz. The best ore as shipped assays 35 to 38% Zn. Blende also occurs in masses in the limestone, but although they may be oxidized superficially, these deposits have no connection with those previously described. The blende is of the dark, reddish-brown variety, free from arsenic and antimony, but commonly intermingled with pyrites; galena is entirely absent.

The masses of blende ore generally occur at the contact of the limestone with dikes of igneous rocks, from which the ore is separated by a sheet of hard, tough rock, known locally as "green rock," which consists of fibrous amphibole, together with garnet and probably epidote, and in places carries hematite, with blende and pyrite more or less intermingled. The form of the deposits of blende is generally lenticular, but being mostly, if not in all cases, along the planes of contact of intrusive dikes, or following the plane of faults, they have such linear extension and sequence as to present the general appearance of lodes. Actinolite and garnet occur with the mineral elsewhere than near the dikes, and Blake considers them to be of contemporaneous origin with the ore. The garnet is of a wax-yellow color, the variety grossularite, and somewhat resembles resinous blende in its appearance.

The most important deposits of zinc ore in New Mexico occur at Magdalena, where the Kelly and Graphic mines are situated. These mines were originally opened for lead ore (see Section on Lead). After the deposits of lead carbonate were worked out there remained large bodies of zinc carbonate and of mixed sulphides. In these mines ore is found at the contact of Carboniferous limestone with an underlying formation of schist; also in the limestone above the contact. The ore-bodies are of lenticular form, but are very irregular. Some of them are large, indi-

[1] Trans. Am. Inst. Min. Eng., XXIV, 187.

vidual stopes 25 ft. wide, 100 ft. high, and 300 to 800 ft. long having been opened. The character and grade of the ore are variable. The Graphic mine in 1906 was shipping sulphide ore assaying 20 to 25% zinc and 15% lead, which was sent to Coffeyville, Kan., for the manufacture of zinc-lead pigment. In the same year the Kelly mine shipped calamine assaying 36 to 37% zinc, and sulphide ore assaying 30 to 35% zinc. This ore was used partly for oxide manufacture and partly for spelter. Some of the ore of this district contains a little copper. In point of tonnage Magdalena was the second largest producer of zinc in the Rocky Mountain region of the United States in 1906.

Elsewhere in New Mexico, especially in the Pecos River district, there are deposits of zinc ore which have not yet been worked on any important scale.

Pennsylvania. — Zinc ore has been mined at several places in this State, especially at Friedensville, Lehigh County; in Sinking Valley, near Birmingham in Blair County; near Landisville in Lancaster County; on the Susquehanna River a few miles below Sunbury in Northumberland County, and on Pickering Creek a few miles south of Phenixville in Chester County. Of these the Friedensville deposits were the most important.

The Friedensville mines are situated in the Saucon Valley, a few miles south of Bethlehem. Three mines, known as the Ueberoth, Hartman and Saucon, were opened; they are situated within half a mile of each other. The ore occurs in a formation of magnesian limestone of Lower Silurian age, which strikes northeast and southwest. There are three zones of ore, on which the three mines named were respectively opened, formed by replacement of a part of the limestone, or of parallel strata of it, with connecting cross-seams. In each mine the ore shoot pitches to the southwest. In the Ueberoth mine the limestone strata are much disturbed and stand nearly vertical; in the Hartmann mine, distant about half a mile from the Ueberoth, the strata are less disturbed and the dip is less steep; in the Saucon mine, distant two furlongs from the Hartmann, the regularity of the strata is still more pronounced and their dip more gentle.

In the Ueberoth mine there were six parallel seams of ore interlaminated with limestone strata and connected by six perpendicular seams. At the intersections there were found enlargements of the ore-body, some of these bulges being 20 ft. thick and 60 ft. wide. These seams were followed for more than 1000 ft. on their strike to a depth of 225 ft. vertically, or 250 ft. on the dip, at which depth the operation of the mine was discontinued with no signs of failure. In the Hartmann and Saucon mines the ore shoots were more compact and lenticular in form. That of the Saucon mine was remarkably regular in pitch, course, and width. It pitched to the south at an angle of about 30°, was 60 ft. in width and had a thickness of 30 ft. The Hartmann mine was worked to a depth of 150 ft. The Saucon ore shoot was followed 250 ft. by the Bergenpoint Zinc Co., gaining a vertical depth of 110 ft., and was followed 150 ft. further by the Lehigh Zinc Co., into whose property it had passed, a total depth of 200 ft. being reached.

The ore of the Saucon Valley was calamine (smithsonite and hemimorphite) near the surface, changing to blende with depth. The oxidation was deepest in the Ueberoth mine and least in the Saucon. The blende was of the cryptocrystalline variety, with a conchoidal fracture and bluish slate color. It was remarkably free from lead, arsenic, and antimony, wherefore a high grade of spelter was made from it, but it was somewhat mixed with pyrite, which, together with its cryptocrystalline character and fine dissemination in the dolomite, caused it to be difficult to concentrate. According to F. L. Clerc,[1] ore sent to the works assayed from 35 to 40% Zn, and since he describes it as resembling broken limestone, I infer those figures represent a cobbed and sorted product.

Tennessee. — Zinc ore has been mined at several places in upper East Tennessee, where deposits of the mineral have been found in nearly every county of the region, though but few of them appear to be of any economic importance. The mines which have principally been worked are at Straight Creek, at Lead Mine Bend, and in a district extending about 20 miles eastward from Knoxville, just south of the Holston River. In the Holston River district, masses of smithsonite were found originally lying on a jagged surface of dolomite of Lower Silurian age, and surrounded by, or covered by, a bed of red clay. The ore was of great purity, like that of the Virginia deposits, which are not a great distance away, and in some respects its occurrence was similar, although where exploited the overlying bed of clay was not so deep nor has the corroded surface of the limestone the pinnacle structure of the Bertha mines. Calamine deposits of this character were worked at Mossy Creek by the Edes, Mixter & Heald Mine Co., and the Bertha Mineral Co., and at New Market by the Ingalls Zinc Co.

Immediately under the surface deposits of carbonate ore the dolomite carries blende of a light brown color, occurring as thin veinlets or seams ramifying in all directions. The dolomite is greatly broken up. The seams of ore are rarely half an inch wide and seldom more than a few feet in length. They appear to have been deposited in joint planes and irregular fractures in the country-rock. The mineral is distributed in this manner through a thick stratum of dolomite; and near the surface, at least, there were no systems of enrichment which might be followed in mining the ore, wherefore the only practical method of mining was to

[1] Mineral Resources of the United States, 1882, p. 364.

break out all the rock and sort that in which the mineral was most thickly disseminated. Ore could be so sorted as to assay 8% Zn, and then could be concentrated up to 50% Zn by jigging. There was little or no profit in the mining of this ore because of its extremely low grade as mined. Recently several shafts have been sunk in this district to considerable depths and it is reported that these have disclosed shoots or "runs" of ore of higher grade, but the mines have not yet become productive except in a small way.

A mine was also worked by the Edes, Mixter & Heald Zinc Co. at Straight Creek in Claiborne County, about three miles west of Lone Mountain Station, on the Knoxville & Cumberland railway. At this place there is a limestone formation. A shoot of ore pitching east and partly replacing a stratum of the limestone outcropped on the side of a hill and has been followed several hundred feet, changing from calamine to blende with depth. The ore bulges and pinches in lenticular form, sometimes attaining a width of 20 ft. and a height of 30 ft., but is generally of less dimensions. Near the ore-body caverns of irregular shape are frequently found in the limestone. The sulphide ore consists of small streaks or lenticles of blende interlaminated with limestone. The blende is of the grayish brown, cryptocrystalline variety. It is quite free from pyrites, but some galena is intermixed with it. In 1905 this mine was reopened by the Tennessee Zinc Co., which erected a mill to dress the low-grade ore.

About 16 miles west of the Straight Creek mine, within a quarter of a mile of the Powell River, is the Lead Mine Bend property, which occurs in a similar limestone formation, but the beds there lie more flatly. This mine was originally worked for lead, as its name implies, and has been extensively developed. The mineral occurs in a channel made up of bunches and lenticles of galena and blende interlaminated with limestone and following a crevice which breaks longitudinally an anticlinal fold in the limestone. The axis of the anticline dips 8° east. The crevice, which is nearly vertical, shows a nearly continuous streak of ore for a longitudinal distance of several hundred feet and a depth of 40 ft.; perhaps more. The ore extends out into the limestone 50 to 100 ft. on each side of the crevice, and the strata appear to be mineralized for about 20 ft. perpendicularly to their dip. The mineralization is irregular, however, and generally a large proportion of barren rock must be broken to get the ore. The blende is grayish brown and cryptocrystalline, free from pyrites, but intermixed with galena.

Both the Straight Creek and Lead mines belonged to the Edes, Mixter & Heald Zinc Co., which closed them down in 1893, owing to inability to operate them profitably under the then existing conditions. The ore of the Lead mine, which was the most productive, had to be carted 20 miles over a rough road, or floated down the Powell and Clinch rivers in flatboats to Clinton, for which there is enough water only during a short period of the year. The ore was formerly smelted at Clinton, where the Edes, Mixter & Heald Zinc Co. had a small plant, which is now in ruins. Since it was dismantled such ore as has been produced in Tennessee has been shipped to smelters in Missouri, Kansas, Indiana, and to the Bertha works at Pulaski, Va., the last receiving only calamine.

Utah. — This State, like several of the other mining states of the Rocky Mountains, possesses extensive resources of zinc ore, chiefly of a mixed character, which have not yet been developed to any important degree. The Horn Silver mine, at Frisco, has large bodies of ore, which average 5 to 8% Pb, 3 to 7% Fe, 35% Zn, 0.06 oz. Au and 7 oz. Ag. The gangue is silicious. The great ore deposits of Bingham Cañon contain considerable blende in some portions. A good deal of blende occurs in the ore raised from the mines at Park City. Both at Frisco and at Park City the zinc ore occurs in connection with lead ore. Recently these mines have become commercial sources of zinc ore.

Virginia. — The zinc mines of this State are situated in the southeast corner of Wythe County. Four mines have been worked there, namely, those of the Bertha Mineral Co., those of Manning & Squier adjoining the Bertha on the northeast, those of the Wythe Lead and Zinc Co. at Austinville, eight miles to the southwest, and the Clark mine at Allisonia. Mines have been opened at Ivanhoe, a little beyond Austinville, and at other places in the district, but none of these has yet proved to be of commercial importance. These mines are included within an area 10 miles long in a direct line bearing north 55° east, on the south side of New River, which flows northeastward in a tortuous course. The greatest distance of any of the mines from the river is a little less than two miles. The most important mines are those of the Bertha company.

The Bertha mines, situated about 20 miles southwest of Pulaski, occurred in magnesian limestone of the Lower Silurian formation, which dipped between 6° and 7° toward the river, and carried the zinc-bearing strata below the latter at a depth of several hundred feet. The outcrop of this limestone was covered with a heavy bed of clay, beneath which, resting in hollows in the limestone, the zinc ore was found. Apparently the outcrop of the limestone had weathered with extreme irregularity, so that if the overlying clay and ores were entirely removed there would be presented a wilderness of limestone pinnacles of varying heights, up to 100 ft. Rarely the limestone showed small caves in the form of clefts and crevices. The deposits of zinc ore invariably rested against the sides of these pinnacles and in the hollows between them. Sometimes they completely covered a pinnacle, particularly the lower ones, but in general they covered them only partially. The occurrence of the ore was irregular and frequently pinnacles and the hollows between them showed none at all. The ore was smithsonite and hemimorphite, chiefly the latter, in a clay gangue. The deposits varied in thickness from a few inches up to 40 ft., the latter having been found between chimneys (pinnacles). On the sides of the pinnacles thicknesses of 5 to 10 ft. occurred frequently, but the average was less than 5 ft.

The ore consisted of hard and soft varieties, the former occurring through the mass in all sizes from small grains up to blocks weighing several tons. Rarely the hard zinc ore clung to the limestone in sheet form. The ore-bodies were entirely distinct from the overlying clay and underlying limestone. The matrix or gangue in which the ore occurred was an unctuous clay, both hard and soft, the former being known as "hard buckfat" and the latter as "soft buckfat." The latter dissolved in water when violently agitated; the former was insoluble, but having a fine-grained, brittle structure, like common chalk, and a lower specific gravity than the hard ore, could be separated by jigging.

The ore raised from the mines contained about 26% Zn. It was dressed by sluicing, which washed out a good deal of soluble clay, and by jigging, so as to yield about 33% of concentrate, which assayed 38.08% Zn, 29.37% SiO_2, 9.23% Fe_2O_3 and Al_2O_3, 4.54% $CaCO_3$, 2.07% $MgCO_3$ and 8.23% combined water. This ore yielded a spelter of exceptional purity.

Blende was found in irregular deposits through a depth of a hundred feet or more of the limestone underlying the calamine, and in following the limestone on its dip it was expected that larger deposits would be found, but prospecting for such has not yet proved successful.

The thickness of the clay cover varied from 10 ft. to 150 ft. In the early days of the mine the method of working was simply to remove and waste this clay covering and then mine the ore by open-cut methods. In later years, owing to the increasing thickness of this overburden, underground methods of mining were used exclusively and the open-cut work was abandoned; these underground methods consisted of sinking shafts through the clay and zinc ore to the bed-rock and then removing the zinc ore by drifts and galleries, hoisting the ore through shafts, and of course timbering every foot of the ground to support the overburden. In 1898 the zinc ore of the mine was exhausted, and subsequent operations have been confined to the extraction of iron ore (limonite) from the clay overburden.

Wisconsin, Illinois, and Iowa. — The area of the Wisconsin-Iowa-Illinois mining region, which for convenience will be referred to as the "Wisconsin region," including under that expression its extensions into Iowa and Illinois, embraces about 2600 square miles, its length in an east and west direction being about 65 miles, and its breadth north and south about 55 miles. About five-sixths lie in Wisconsin, and one-sixth covers the contiguous corners of Iowa and Illinois.

The geological formation comprises sandstones, limestones, and shales of the Cambrian and Lower Silurian systems, the ore being found in the Galena dolomite, 250 to 275 ft. thick, the blue limestone, 50 to 75 ft. thick, immediately underlying, and the buff dolomite, 15 to 20 ft. thick, which next underlies the blue limestone, the three formations belonging to the Lower Silurian. The Galena limestone is the most important ore carrier.

Geographically, lead ores are distributed over the whole region, but especially in the southern portion, in the vicinity of Galena, Ill., and Dubuque, Ia., while zinc ore is more abundant in the northeast, at and near Mineral Point, Mifflin, Linden, and Dodgeville, where the lower beds of the ore-bearing horizon are more exposed. It is a generally observed rule in this region that the zinc ore occurs at greater depth than the lead ore, even when both are found in the same crevice, and it is considered possible by the geologists who have studied the region that deeper mining would reveal zinc ore in the southern portion. Besides the places named above, Platteville, Shullsburg, Benton, Hazel Green, and Potosi are important mining centers.

The ore first mined in the Wisconsin region was found chiefly in residual clays near the surface, but since then it has been obtained from vertical crevices or flat sheets in the country-rock. The former characterize especially the Galena limestone and are preëminently lead-bearing. They rarely exceed 100 ft. in depth, but are often several hundred feet in length. They sometimes exist as fine seams filled solidly with galena, and elsewhere expand to large caves, 50 or 100 ft. long, and as much as 30 ft. wide. Flat sheets are most abundant in the Trenton limestone, and like the vertical crevices may be filled with solid masses of galena or blende, but more often the mineral is intermixed with a gangue of calcite and sometimes barite. A modification of the flat deposits are the so-called "flats and pitches," in which ore extends downward, generally on two sides, from a central flat sheet in a series of steps, which are alternately transverse to and parallel with the strata. The largest mines are in deposits of this class. Sometimes the country-rock between two series of flats and pitches is wholly mineralized with a dissemination of blende and marcasite, affording a large body of low-grade ore.

The zinc ores of Wisconsin comprise blende, smithsonite, and hemimorphite, with which are associated galena and its derivatives, pyrite, marcasite, chalcopyrite, calcite, dolomite, and barite. The blende is characteristically of a black color, but is not high in isomorphous FeS. Calcite is more common than dolomite and barite in the gangue, and smithsonite is a good deal more common than hemimorphite as oxidation product of the blende. The utilization of the zinc ore of Wisconsin was greatly retarded by the common association of blende and marcasite, which could not readily be separated. The introduction of a suitable process of roasting, converting the marcasite into a magnetic form, about 1904, enabled an economical separation of the two minerals to be made and gave a great impetus to zinc mining in this region, and since then the production has increased rapidly.

XX

ZINC MINING

THE zinc mine of the United States which has the longest history is that at Franklin Furnace, N. J., commonly known as the Franklin mine. The nature of this ore deposit and the character of the ore have been referred to in Chapter XIX. The mine was known in pre-Revolutionary times, it being owned by Lord Sterling, and there are records of attempts to work it as far back as 1774, but these were directed toward the treatment of the ore as an iron ore, not as a zinc ore. However, as an iron ore it was of too low grade, and contained too much zinc to permit of economical smelting, and the attempts at that were failures.[1]

In 1835, or 1838, Dr. Fowler, a member of Congress, who then owned Mine Hill, furnished some of the red ore (zinkite) to serve as a source of spelter for making the brass for the Government's standard weights and measures, which had been ordered by Congress. The spelter was made at the Government arsenal at Washington. The process was so expensive, however, as to preclude any idea of producing zinc commercially in the same manner. The place from which this ore was taken is still pointed out, and ever since has been known, as the "Weights and Measures Opening."[2]

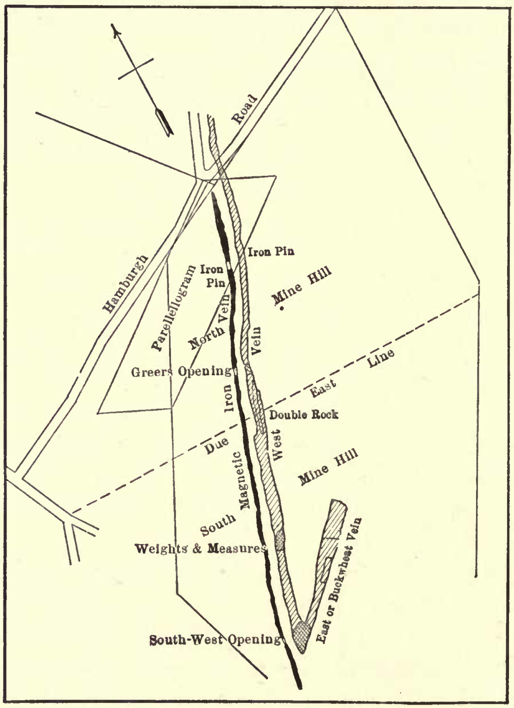
Dr. Fowler appears to have had definite ideas as to producing spelter on a commercial scale from this ore, but his experiments showed it to be necessary to free the red oxide from the associated franklinite, which at that time no one was able to accomplish, although the magnetic attractability of the franklinite was early recognized and some attention was given to a practical utilization of that property. Separation by jigging was, of course, out of the question because of the nearness of the two minerals in specific gravity.

[1] According to J. E. Wolff (Contributions to Economic Geology, U. S. Geol. Survey, 1902, p. 214), this celebrated occurrence of zinc ore was noticed and prospected as early as 1640, but Lord Stirling did the first mining in 1774. About this time several tons of red zinc ore were shipped to London. The first descriptions and analyses of this mineral were given by Dr. Bruce in 1810, and of franklinite by Berthier in 1819.

[2] It is said that brass was made from the red oxide of Mine Hill (probably by the cementation process) during the war of 1812. In the cementation process copper was imbedded in zinc ore and heated, no spelter being produced. This is an ancient process, by which brass was extensively prepared in Europe, long before the art of producing spelter had been discovered.

The peculiar character of the ore of Mine Hill, and the early ignorance as to the precise nature of its constituents and the metallurgy of zinc, gave rise to the most protracted and one of the most interesting mining litigations in the history of the United States. At the expense of anticipating some of the important developments in the American zinc industry, it will be most useful to follow the records of this matter to their conclusion.

In 1848 the Sussex Zinc and Copper Mining and Manufacturing Co.



Map of Mine Hill, New Jersey.

was organized to develop and utilize certain ores of Mine Hill, and on March 10 of that year Col. Samuel Fowler and his wife, to whom the property had descended, deeded to that company for 20,000 shares of its stock, "all the zinc, copper, lead, silver, and gold ores, and also all other metals and ores containing metals (excepting the metal or ore called franklinite, and iron ore when it exists separate and distinct from the zinc)" on Mine Hill farm. On the same day Fowler deeded to the same company "all the metal, mineral, or iron ore, usually designated and known by the name of franklinite," within the lines of a certain parallelogram on Mine Hill (see map), the area covered by this second deed being included within the limits covered by the former deed. The zinc deed as first drawn excepted franklinite when existing separate and distinct from the "other ores"; but before signing, "other ores" was erased and the words "the zinc" inserted. The wording of this deed gave rise to the litigation which followed.

Explorations made by the Sussex company, immediately upon obtaining its deed, demonstrated no occurrence of zinc ore on Mine Hill, except at the Weights and Measures opening and at the crossing of the Hamburg road. Attempts were made to work the ore from these two openings for metallic zinc, but resulted in failure, because of the presence of the franklinite. The failure to find extensive supplies of zinc ore prompted the persons interested to form, in 1849, the New Jersey Exploring and Mining Co., which acquired the northern half of Stirling Hill, where the supply of red oxide was abundant. This company continued the efforts of its predecessor to separate the franklinite and produce zinc, and erected at Newark, on the site of the present works, a large furnace, which was intended to smelt the ore after removal of the franklinite by means of a magnetic separator. This attempt also failed, but in connection with the experiments it was found that zinc oxide could be made from the ore. The then recent discoveries of Sorel and LeClaire in France, in substitution of zinc white for white lead, insured a sale for the new product as a paint material.

At about this time an arrangement was effected to consolidate the Sussex company and the New Jersey company, and, March 8, 1852, the latter company secured from the former title to "all the zinc and other ores, except franklinite and iron ores," on Mine Hill; the change in wording from the deed of 1848 being introduced to avoid future misunderstanding as to the intended reservation in the Fowler deed, the object being to convey to the New Jersey company all that the Sussex company had acquired from Fowler.

The New Jersey company, thus reorganized, made extensive improvements, and a report published in 1852 defines its holdings of property and ore veins. Further efforts to utilize its franklinite in the manufacture of iron were urged, and it was suggested that, inasmuch as it contained 21% of zinc, the oxide therefrom might be made to pay most of the cost of smelting. This report attracted the desired capital.

On Dec. 13, 1850, Col. Samuel Fowler deeded to the trustees of the Franklinite Mining Co. all the reserved iron ore called franklinite, with all other reserved ores and metals on Mine Hill farm not conveyed to the Sussex company by the deed of March 10, 1848. In 1853 the Sussex company, having sold its holdings to the New Jersey company, secured an act of the State legislature, changing its name to the New Jersey Franklinite Co., with authority to increase its capital stock; and, on Feb. 26, 1853, the trustees of the Franklinite Mining Co. deeded to it all the franklinite and other reserved minerals secured from Samuel Fowler and wife on the southerly side of the east and west line on Mine Hill farm (see map).

The Franklinite company acquired the magnetic vein and the Franklin furnace, and expended large sums in trying to produce iron from franklinite, no objection and no claim to the ore being made by the New Jersey company. A report of the latter company in 1853 mentions experiments made to utilize its franklinite, stated to be over 1,000,000 tons in Stirling and Franklin hills, the expense of transportation being given as the chief obstacle to utilization. Mention is also made of "another company owning a portion of the franklinite on Franklin or Mine Hill," which, it was hoped, will improve communication, enabling the New Jersey company to market its franklinite. The New Jersey company, at about this time, also contracted to furnish 100,000 tons of franklinite to Edwin Post, at Stanhope, N. J. This sale was made in the knowledge that the zinc was to be collected from the escaping gases of the iron furnace; however, this proposed utilization proved a failure.

The Franklinite company undertook to apply the same process, and erected a costly plant at Franklin Furnace, but failed, and in 1854 adopted the process used by the New Jersey company. The Franklinite company took ore from Mine Hill and so worked it without objection from the New Jersey company. However, the technical results were not entirely satisfactory, because at that time the extraction of zinc from the franklinite, and the willemite associated with it, was not well understood. Consequently the Franklinite company sought ores on Mine Hill containing the highest percentage of red oxide of zinc it could find. To this no objection was raised until the southwest opening was made in the franklinite vein (see map), where one layer in the vein contained 15 to 20% of red oxide, and the New Jersey company claimed it as zinc ore. Suit for injunction was entered in 1857, the New Jersey company claiming it as zinc ore, and the Franklinite company claiming it as franklinite ore. The Franklinite company, which was previously in an unsatisfactory financial condition, could not stand the strain, and was sold out by the sheriff, being succeeded by the Boston Franklinite Co., which continued the contest on the same lines.

The case was tried before Chancellor Green, who decided that the intention of the parties making the original transfer must be considered in the light of the knowledge existing at the time. In that light, the "zinc ores" meant those veins in which red oxide of zinc predominated, and "franklinite" those in which the latter mineral predominated. He therefore decided that the ore in question was franklinite in the original deed, and dismissed the case with costs. It was appealed to the State Court of Errors and Appeals, of which the decision, in 1862, ruled the

Franklinite company without title and held the New Jersey Zinc Co. entitled to all the zinc ores mixed mechanically with franklinite; and held that the vein in dispute passed under the name of zinc.

The Boston Franklinite Co. quickly succumbed, efforts to utilize franklinite for iron ceased, and the New Jersey company became the owner at law of the franklinite vein on the southern half of Mine Hill. Oakes Ames, of Boston, by foreclosure of a $50,000 mortgage against the Boston Franklinite Co., came into possession of its assets. Moses Taylor, of New Jersey, had previously acquired the Franklin furnace and the vein of magnetite. He purchased from Oakes Ames the property of the Boston Franklinite Co., and in 1871 brought suit in the United States Circuit Court for an injunction against the New Jersey Zinc Co. The decision practically reversed the decision of the New Jersey Court of Errors and Appeals and reaffirmed that of the Chancellor, confirming Taylor's right to this vein as being the ore excepted in the Fowler deed of 1848. It was especially important as ruling out of legal consideration all discoveries made subsequent to 1848, enhancing the value of franklinite as zinc ore.

In order to appeal the case to the United States Supreme Court, it was necessary for the New Jersey Zinc Co. to furnish between $1,000,000 and $2,000,000 security, and in case the appeal went against it its only property would be a nearly exhausted mine at Stirling Hill and its works at Newark, which together were not worth the required security. When, therefore, Mr. Taylor offered terms of settlement, in 1880, the company accepted them. Its capital stock of $1,500,000 was doubled; Moses Taylor contributed $100,000 cash, receiving one-half the total stock, and purchased a few shares extra for control. The name of the reorganized company became the New Jersey Zinc and Iron Co., and its property embraced both zinc and franklinite on Stirling Hill; on Mine Hill, both zinc and franklinite within the parallelogram and south of the east and west line; and on the remainder of the tract, the zinc and all the other ores, "excepting franklinite and iron ore when it exists separate from zinc."

The excepted portion of the franklinite vein had been leased by the trustee to various companies, and between 1850 and 1860 about 1000 tons had been mined and used in efforts to utilize it for iron. After the Taylor decision in 1877, the surviving trustee leased 500 ft. lying north of the east and west line, to Chas. W. Trotter, who erected an oxide plant at Elizabeth; but on the destruction of his plant by fire, he sought to sell the ore, and some was disposed of to the Lehigh Zinc Co., whose mines at Friedensville, Penn., had been flooded.

As soon as Trotter began mining, the New Jersey Zinc and Iron Co. brought suit to eject him, and obtained an injunction; but Trotter removed the suit to the United States Circuit Court, where the injunction was dissolved, and in 1878 the suit was dismissed for want of prosecution. Meanwhile, after the Taylor decision and before settlement, the New Jersey Zinc and Iron Co. began to use the formerly rejected franklinite upon its own property within the parallelogram, mining extensively from the Ding Dong and openings north of it. In these operations the lines of the parallelogram were crossed, and the $100,000 contributed by Taylor were set aside to cover damages arising from the trespass.

In 1879 Trotter leased the remainder of the franklinite vein as far as the Hamburg road, and an error having been discovered in the survey of the parallelogram, Trotter brought suit in trespass against the New Jersey Zinc and Iron Co., claiming the vein to its northern extremity on Mine Hill Farm, and got judgment for $3000. He also entered suit for an accounting of ore mined since the previous suit, secured judgment and received $26,000 from the Taylor fund, the trustee of the property also receiving $11,000 as his share in the mine.

In 1881 August Heckscher, acting for the Lehigh Zinc and Iron Co., contracted with Trotter for 12,000 tons of franklinite annually and the company purchased the works of the Lehigh Zinc Co. at Bethlehem; certain improvements enabled it to produce oxide equal to that from the east vein ore.

In November, 1882, the New Jersey Zinc and Iron Co. brought suit to re-form the boundaries of the parallelogram, and after trial, iron pieces were set to mark the southern boundary where it crosses the vein, the settlement permitting Trotter to mine up to these pins, south of which the New Jersey Zinc and Iron Co admitted it had no property rights. Shortly after this definition (March 18, 1883), Mr. Heckscher purchased for the Lehigh Zinc and Iron Co. the rights of the lessor to the west vein of franklinite, between the east and west lines; for after this definition, ratified by the payment of nearly $40,000 for franklinite removed from the vein, it was believed that no serious claim would ever be made on the side of the zinc title. Trotter had continued to mine and furnish ore to the Lehigh Zinc and Iron Co., Ltd., and its successor, the Lehigh Zinc and Iron Co., until 1887, when it purchased the lease and became owner of the westerly vein of franklinite and all its extensions upon the northerly half of Mine Hill.

In 1889 the New Jersey Zinc and Iron Co. brought suit against the Lehigh company in the New Jersey Supreme court for 300 tons of zinc ore alleged to have been removed from the zinc vein belonging to it under the zinc deed of 1848. The suit was brought for 300 tons so as to keep the sum involved under $2000 and thus prevent its removal to the United States Courts, where Judge Nixon's decision had declared the ore to be franklinite. After a decision in the lower court, the Court of Errors and Appeals practically repeated Judge Nixon's decision in the United States Court, sustaining the Lehigh company.

The New Jersey Zinc and Iron Co. again brought action for 300 tons of ore, which it finally abandoned for a suit of ejectment from the mine. This suit was tried at Newton, N. J., in May, 1894, before a struck jury. After a trial lasting a month, the jury disagreed, and in May, 1895, the case was re-tried before the same judge and another struck jury. After a month, during which the case was even more elaborately presented, the verdict was given in favor of the Lehigh company, practically establishing the fact that the ore was known as franklinite and not as zinc ore in 1848. This was the first time in the history of the litigation, extending from 1857 to 1895, when the merits were passed upon by a jury.

The case was again carried up to the Court of Errors and Appeals, which in 1896 confirmed the judgment of the lower court in favor of the Lehigh company. All parties to the litigation were now thoroughly tired of it and when a proposition was made to amalgamate the conflicting interests and bring in the Passaic Zinc Co., which was the only other important manufacturer of zinc oxide in the United States, the plan met with ready acceptance. Consequently, the New Jersey Zinc Co. was organized in 1896, taking over the mines and works of the three companies and absorbing important interests in certain subsidiary companies. The subsequent history of this great company is related in a following chapter.

But while the Franklin and Stirling Hill mines were the first worked for zinc in the United States, the mines at Friedensville, Penn., were the first to be worked for zinc ore as a source of spelter. The first discovery at Friedensville was made in 1845,[1] and mining on an extensive scale was begun in 1853 by the Pennsylvania & Lehigh Zinc Co., which at the same time erected smelting furnaces and a zinc oxide plant at Bethlehem, Penn., a few miles distant from the mines.[2] The metallurgical treatment of the ore gave much trouble, and consequently the development of the mines was retarded. Especially was there difficulty in producing spelter, the iron and lime contents of the ore making it unmanageable. Many metallurgists undertook the problem and failed, or met only with indifferent success. However, about 1861 the art of successful smelting was learned and operations were then begun on an important scale. From 1861 to 1876 the mines were extensively exploited, chiefly by the Lehigh Zinc Co. Up to the end of 1876 the Ueberoth mine, the most important of the three, is said to have produced 300,000

[1] H. S. Drinker, Trans. Am. Inst. Min. Eng., I, 67.

[2] J. D. Whitney, Metallic Wealth of the United States, edition of 1854, p. 351.

tons of ore.[1] The ore came close to the surface and a rich pocket was found in the clay above and around limestone boulders, which is estimated to have produced 100,000 tons of ore. When this body of ore was exhausted, the ore was followed downward in crevices between the boulders. These crevices were formed in planes parallel to the bedding of the limestone, or in planes perpendicular to it, and preserved great regularity in position. They were nearly vertical, and at the depth of 225 ft., to which the mine was worked, they showed no signs of petering out. As depth was gained the ore changed from calamine to blende. All of the mines of Friedensville were worked as open pits; the great pit of the Ueberoth mine, now partly filled with water, is impressive in its size.

The greatest difficulty in the operation of these mines was the strong influx of subterranean water. Even at the depth of 46 ft. in the Ueberoth mine the flow was already large. At the depth of 150 ft. it was found necessary to put in what was then the largest pumping engine in the world. This engine, which was known as "The President," was a single cylinder, double-acting, condensing, walking-beam engine, with a pair of fly-wheels. The cylinder was 110 in. in diameter. The stroke was 10 ft. It was designed to operate four 30-inch plunger pumps and four 30-inch lift pumps, with 10 ft. stroke, and to take water from a depth of 300 ft. At the time it was stopped it was running from six to seven strokes per minute, was working three pairs of 30-inch pumps, and one pair of 22-inch, and was easily handling all the water that came to them.[1]

However, the high cost of mining, due largely to the great expense of pumping the water, was the prime cause for the suspension of operations in 1876. At that time the influx of water into the mine was as great as 20,000 gal. per minute, and the cost of pumping was about $4 per ton of ore produced.[3] The Lehigh works were able to obtain a supply of cheaper ore from New Jersey; hence the abandonment of the Ueberoth mine.

The Hartmann mine, distant about a quarter of a mile from the Ueberoth, did not have so much water as the latter, and was operated for a year after the large engine was stopped. The Saucon, or Correll, mine, about a quarter of a mile south of the Hartmann, was worked for several years later. This property was originally leased to the Passaic Zinc Co., by which it was sublet to the Lehigh Zinc Co. When the rich deposit of calamine first discovered was apparently exhausted, the sub-lease was surrendered. In 1875 the original lease passsed to the Bergenpoint Zinc Co., which opened a body of sulphide ore and followed it downward

[1] F. L. Clerc, Mineral Resources of the United States, 1882, p. 362.

[2] F. L. Clerc, *loc. cit.*

[3] *Engineering and Mining Journal*, July 18, 1876.

until it dipped into the property of the Lehigh Zinc Co. on the west. In 1879 all the property of the Lehigh Zinc Co. was foreclosed by its bondholders, and in 1880 the mines passed into the hands of the Bergenpoint Zinc Co. The latter company had a dressing works, smeltery, and oxide plant at the Saucon mine, and also had a smeltery at Bergenpoint, N. J. The ore of Friedensville was remarkable for its freedom from lead, arsenic, and other impurities that affect injuriously the quality of the spelter, and the latter had a great fame as metal of the most superior quality. The Ueberoth mine was re-opened by the Bergenpoint Zinc Co. in 1883, but it was not operated long, the entire business of the company being wound up in 1886, when its smelting works were closed. The Friedensville Zinc Co. erected a small smeltery at the Ueberoth mine in 1888, and toward the end of that year began making "Bergenpoint" spelter. The Ueberoth mine was reopened in 1890. The operation was, however, very brief. I had occasion to visit the mines in the summer of 1894, at which time all were idle and the smeltery already in ruins. No mining has been done at Friedensville since that time. In 1896 the Saucon mine reverted to the heirs of the original owner, Jacob Correll, of Bethlehem. Subsequently, the other mines of the district were purchased by the New Jersey Zinc Co. Since then there has been no further change in the ownership.

Unfortunately, there are no reliable statistics as to the production of zinc in the United States previous to 1873. In that year the total output was 7343 tons, which was somewhat less than the total consumption. Even so late as that in the history of the industry the production of New Jersey and Pennsylvania was comparatively insignificant. It is to be remarked, moreover, that the statistics for 1873 included the output of two works in Illinois, which were reducing ore from Wisconsin and were beginning to receive a little from the Joplin district.

It cannot be said definitely when zinc ore was first identified in Wisconsin. Probably it was known from the beginning of lead mining there, because the lead and zinc ores occurred in intimate association, but for many years there was no market for the zinc ore. At some time between 1850 and 1860, Georgi, an old Silesian smelter, is said to have built a zinc works in Wisconsin, but his undertaking was unsuccessful. Possibly there were other attempts of the same character; if so they were equally unsuccessful. Certainly there was no market for the zinc ore of Wisconsin until Matthiessen & Hegeler built their plant at Lasalle, Ill., in 1860. The circumstances under which they established themselves at that point are told in the chapter on smelting. A little later, the Illinois Zinc Co. erected a plant at Peru, which adjoins Lasalle. From 1860 to about 1873 these smelters derived their entire ore supply from Wisconsin, but the business was done on a very small scale, and the zinc production of the West did not begin to expand largely until the mines of the Joplin district of Missouri sent forward large supplies of ore. The failure of the miners of Wisconsin to rise to the situation was partly due to their primitive methods and partly to the association with their ore of the objectionable marcasite, which could not be successfully separated. This condition existed until 1904 or 1905. A few important companies had previously become interested in the Wisconsin district, but in general capitalists had overlooked it. At last, through improvements in mining and ore-dressing methods, it gives promise of becoming one of the important zinc-producing districts of the United States. The historical record of mining in Wisconsin has already been given in the portion of this work relating to lead.

The remaining history of zinc mining in the United States is chiefly a utilization of ore, previously known to exist through prospecting for lead, when the erection of smelteries offered a market for it. Thus, small deposits of calamine were early known to occur in the lead district of southeastern Missouri. In 1867, George Hesselmeyer erected a furnace at Potosi,[1] which did not continue long in operation. In 1869 the Glendale works were established at St. Louis, to which the Valle mines became immediately a large shipper, the zinc ore developing into a greater source of profit than the lead ore, previously exclusively mined.[2] Those mines have continued to be small, but regular, shippers to St. Louis up to the present time. Several other works were soon afterward erected at and near St. Louis.

The early history of the Joplin district, when lead only was mined, has been given in the first section of this work. Of course zinc ore had inevitably been recognized there from almost the beginning of lead mining, but there was no local market for it and no means for getting so crude a commodity to the smelters further east. In 1870 the St. Louis & San Francisco railway was completed to Peirce City; early in 1871 it was extended to and beyond the State line. In the meanwhile several smelteries had been established at St. Louis, besides which there were the two older works in northern Illinois. These circumstances made possible the utilization of the zinc ore of southwestern Missouri. In 1871 an agent of the Missouri Zinc Co. of St. Louis began to work for zinc near Granby.[3] In 1872 zinc ore was shipped from Joplin to the Illinois Zinc. Co. at Peru, Ill. It fetched only $3 per ton, but the price soon

[1] Chas. P. Williams, Industrial Report on Lead, Zinc, and Iron in Missouri, p. 112.

[2] Arthur Winslow, Lead and Zinc Deposits of Missouri, I, 292.

[3] According to E. Hedburg, Trans. Am. Inst. Min. Eng., XXXI, 381, the first shipment of zinc ore from the Joplin district was made by George Hesselmeyer, who shipped several car-loads of ore (for which he paid $1 per ton) from the waste dumps at Granby to his smelting works at Potosi.

rose to $15. In 1873 zinc smelting was begun at Weir, Kan. The new market for ore revived several of the old lead-mining camps. Thus, the discovery of lead ore at Joplin had drawn miners away from Granby, but the utilization of the zinc ores brought about not only a renewal of mining operations, but also an entire change in the character of the work. Exploitations became deeper and larger, though still of a rather crude character. In 1877 the discovery and development of the mines at Galena, Kan., gave an additional impetus to mining, while the market for ore was further increased by the erection of a smeltery at Pittsburg, Kan., in 1878.

About 1880 the St. Louis & San Francisco, the Missouri Pacific and the Kansas City, Fort Scott & Memphis railways were extended into Jasper County. Mining was vigorously conducted and camps multiplied in the vicinity of Joplin, and around Webb City and Carterville, along Spring River, Center Creek, and Turkey Creek, and especially in the vicinity of Galena, Kan. Early in 1886 development was begun on the mines at Aurora, Lawrence County, Mo. By 1890 the population of Joplin had grown to 10,000; that of Webb City and Carterville to 8000; and that of Carthage to 8000. The wonderful progress of the Joplin district is best shown by the table giving the statistics of its production (see Chapter XXIII). As early as 1875 it was furnishing the ore from which 75% of the spelter output of the United States was derived, and ever since then it has occupied the premier position among the zinc-producing districts of the United States.

The methods of mining and ore dressing in the Joplin district in 1871–1880 were very crude. The shafts were mostly very shallow and rudely timbered, timber not being employed at all except where absolutely necessary. The ore was hoisted in small buckets either by whim or by windlass, often the latter. If the mine made any water, the latter was hoisted out in the same way. Little or no attention was paid to ventilation. The operations were conducted generally by lessees. The owner of a tract of land leased it to a party or company for exploitation, the lessee paying a percentage of the mineral obtained as royalty to the owner. The first lessee sublet in parcels 100 ft. or 200 ft. square to miners who would open the ground, the latter paying an advanced royalty. The ore was crushed with rude breakers, and was concentrated with hand jigs.

Substantially the same conditions continued to exist in 1881–1890. Steam-engines were introduced for hoisting, but horse- and man-power were more commonly employed as late as 1891. The mines seldom, if ever, had shaft houses, and the work being performed in the open was subject to general interruption during periods of inclement weather. The methods of mining and the general situation of the industry in 1882 have been so accurately portrayed by Mr. F. L. Clerc in Mineral Resources of the United States for 1882, pp. 369–373, that it is useful to quote his description as follows:

"The most important zinc mines of this region are those at Carterville and Webb City, which are really parts of the same deposit. They produce more than half of the zinc ore raised, and are worked principally for zinc ore. As these deposits are very regular in their formation, and in a measure rule the ore market, and as the method of mining them is essentially the same as prevails throughout their entire district, a general description of them and the method of mining them will here be given. These mines lie in the open prairie, which was once cultivated in farms, about five miles northeast of Joplin, near the head of a small branch of Center Creek. They were discovered about the year 1877. Here, at a depth of from 40 to 100 ft., and often under a cap of limestone and flint 60 ft. in thickness, has been found an immense deposit of zinc blende, which has been worked continuously for over half a mile. The deposit is in the form of a bed of flint, traversed in various directions by solid bars of barren flint, but in general resembling a breccia of sharp, angular pieces of barren flint, closely cemented by crystallized blende, with occasional masses of bright crystallized galena. With the exception of these bars and occasional pillars to support the roof, the whole body is blasted out. Draining is difficult, and rock drifts are sometimes necessary to unwater the ore. Dr. Schmidt considers a secondarily deposited quartzite to be the cementing material between the chert and the zinc blende in the very similar deposits found at Oronogo; but this is certainly not the case in the best mines at Webb City nor at Sherwood, and zinc buyers soon learn to detect the difference. Where the cementing material is pure blende, the blende breaks freely from the chert, and can be almost entirely cleaned by crushing and jigging; where the cementing material is quartzite, or black sand, as the miners call it, crushing is difficult, and a satisfactory separation is impossible. The mines spread over about a section of land, 640 acres. Their weekly output is about 700 tons. The method of working them is as follows:

"When a good prospect is discovered in new ground the land around it is leased from the original owners on royalties ranging from 10 to 25% by a number of individuals, who organize various mining or, as they would more properly be called, land companies. The companies have the land divided up into lots 200 ft. square, and a plat of it made; select certain lots for themselves, and throw the others open to miners. They usually start a shaft on one of their own lots, and put in a pump. If the indications continue good, many of the lots, particularly those near the pump shaft, are quickly taken up by parties of miners, who sink shafts upon them, timber the ground, put up hoisting contrivances, furnish all supplies, and bear all expenses.

"When ore is struck it is drifted on and followed in all directions up to the boundaries of the lot in question. The ore is raised to the surface and crushed and washed by the miners, and is sold to one of the zinc or mineral buyers. It is weighed over the company's scales, and paid for to the company, which deducts a royalty of 25% on zinc blende, and 50% on 'mineral' (galena); and if it has pumps running, a pump rent of $1 a ton on zinc ore and $2 on 1000 lb. of galena; and pays over the balance to the miners. The royalties, of course, vary with circumstances, but the above are general. The holders of lots hire other labor to do the mining, at from $1 to $1.50 a day; and usually put up crushing and washing machinery on their lots. Very often the same parties control two or three adjoining lots or fractions of lots, and sometimes neighbors go into partnership. Most companies do not allow ores to be taken from the lots on which they are mined until they have been cleaned and have paid royalty. The machinery is usually of the simplest description — a farm or small stationary engine, covered by a shed of rough boards, a small-sized Blake's breaker, set over a pair of rolls, and a horse whim or a whip. The jigs are ordinary hand-jigs, with an overhead breakstaff, working a sieve $2 \times 3\frac{1}{2}$ ft. up and down in a box of water. The jigging is usually done by contract, and is paid for by the ton of cleaned ore. It is common to see from 10 to 20 of these jigs grouped together under a shed of poles, covered with branches of trees or rough boards. The ore as crushed yields from 10 to 50% of cleaned ore, and the No. 1 grade assays about 60 to 62% of metallic zinc. The tailings must in most cases be piled up on the lot from which they have come; they are drawn up into a mound with two-horse scrapers or belt elevators, and it is not an unusual sight to see jigs and crushing machinery perched on top of these mounds 15 to 20 ft. above the surface level, the shafts being timbered up to a corresponding height. Several land companies have put in fairly effective pumping machinery. Plunger pumps working in pairs, with wooden walking beams or bob cranks, and driven by gearing and a crank shaft, are the most common; but direct-acting steam-pumps, like the Worthington or Blake, have been largely introduced of late, notwithstanding the disadvantages they labor under from the gritty water of the mines. From a distance these mines, with their swarms of busy men and heaps of tailings piled around the shafts, remind one strongly of gigantic ant-hills, and present a sight not soon to be forgotten. No one can fail to be struck with the glaring defects of such a method of mining, the absence of system, the useless duplication of machinery, the cheap yet expensive expedients, and the crowding together of conflicting operations. Below ground the effects are if possible worse. Each lot is affected by the policy of its neighbors; pillars are left only where they are thought to be absolutely necessary; each miner tries to get as much as possible out of his own lot, is only interested in it as long as he expects to work it, and is not disposed to improve the value of adjoining lots by unwatering them or proving their ore. The roof and pillars are badly trimmed, and in many cases dangerous, fatal accidents being distressingly common. The officers of the land companies are generally individually interested in one or more lots, and all sorts of questions are continuously arising from the conflicting interests of the company and the miners.

"Looked at altogether, as the main dependence of the zinc industries of this country, such a condition of affairs is far from satisfactory, and yet it is not easy to suggest a practicable remedy. If a single company with sufficient capital should control all the lots and work them in connection with each other, the output could be largely increased, the cost of mining and dressing the ore greatly reduced, and the value of the mines kept up for a longer period, and the ore could be sold to better advantage than can be hoped for under the existing method. But this is seldom possible after the present system is once in operation; too many individuals have acquired rights in the mines, which they value at what they hope to get out of them. Nor is the present arrangement without obvious advantages in a new country, and it is seriously questioned whether any other could be as effective or as economical. When mineral is once discovered, it requires but little capital to open mines, and consequently the individual risks are small. The miners, working on their own account, with hopes of large ultimate gains, have every inducement to work hard and cheaply, and to follow every clew that may lead to the discovery of ore. There is a large body of keen, hard-working prospectors, who during the season wander from place to place, live in wagons, under tents, or in the open air, and carefully observe and follow every real or supposed indication of ore. How else, it may be asked, could prospecting be so well or so cheaply done? And there is a class of enterprising, skilful well-to-do miners, naturally associated as partners, who have made one or more good strikes, and are always ready to take hold of any new venture that promises well, either in working a lot or in forming a land company to open new mines. Where else could be found capitalists so willing to risk their money in a speculative venture? Men of this sort are always ready and able to work themselves, or to direct the work above or below ground. How else could be obtained as willing and as watchful superintendents, foremen, and clerks? New towns are started every year, and the mining district is rapidly extending. No uniform development seems to lead to this extension; chance and the policy of the land owners appear to be the only determining causes.

"The towns of Galena and Empire, on Short Creek, in Kansas, were brought into sudden prominence in 1878, and restored the waning fortunes of the Joplin region by the exertions of two land companies, which, on the strength of two or three rich but undeveloped prospects, laid out two rival towns, and sold town lots without reserving mineral rights; and by extensive advertising throughout Missouri and neighboring States created an excitement which had a purely speculative basis, but led to the collection of a large number of miners and a considerable aggregate of money. Fortunately, the results very nearly justified their most sanguine representations. The land companies then withdrew all of their remaining lots from the market, and the success of the mines was secured. They are now the principal mines for lead ore in the region, and their output of zinc is increasing.

"For the discovery and working of shallow deposits the present system seems the best that can be devised, but it is clearly not adapted to solve the problems of discovering deeper deposits or working them to advantage. No system can be defended which involves extravagant expense in mining and preparing the ore for market, forces the sale of it without regard to its value, and renders worthless large bodies of ore that might be profitably worked by a better system; and no basis for a great industry, like the zinc industry, which makes it depend on a hundred chances independent of the price of metal, the cost of smelting, or the known deposits of ore, can be considered very safe to build upon. The caving in of a single mine, the breaking down of a pump, less activity in lead mining, or the scattering of the miners to richer camps, may cause a falling off in the output of ore from which it would be very difficult to recover. That mining has on the whole been very profitable in this region is established from the fact that the country around has steadily and rapidly increased in wealth and population. Within the last few years three railroads, the St. Louis & San Francisco, the Missouri Pacific, and the Kansas City, Fort Scott & Gulf, have built branches through the ore fields to each of the three towns, Joplin, Webb City, and Galena. Joplin, with its good streets, gas, and water works, machine shops and foundries, flour and woolen mills, lead and zinc furnaces, street cars, and extensive jobbing and retail houses, has been built almost entirely from the profits of mining.

"Granby, 20 miles southeast of Joplin, presents a striking contrast. It is dependent on a single railroad, which owns much of the mining land; and the land is all leased or owned by the Granby Mining and Smelting Co. Lead ore has been extensively mined since 1856, and during the war the mines were worked for both armies. The zinc ore obtained is mainly calamine, but blende is also found. The mines are in general shallow, and less troubled with water, and the ores usually require less mechanical dressing than at other points in the lead region. The company receives from the men all of the lead and zinc ore, deducts the royalties paid to the railroad and its own royalties, and pays the miner on a sliding scale, based on the price of the metallic lead and the selling price of zinc ore, for the reason that it smelts the lead ore, and at present sells the zinc ore.

"This mining point is noteworthy, as it is the only one producing large amounts of calamine. The calamine is naturally rich, not much contaminated with other materials, and occurs with the lead ore in shallow horizontal openings. It was first utilized in 1871, prior to which time large amounts of it had been discovered and left in the ground or thrown aside. Since that time it has been extensively mined, and has added greatly to the prosperity of the mines. Calamine is by nature less rich than blende in the proportion of 53 to 67%; it is also much more difficult to clean when mixed with rock, on account of its lower specific gravity; but in proportion to the metal it contains it is more valuable than blende because it can be smelted more cheaply and the metal more perfectly extracted from it, and when mixed with blende in the furnace charge it makes it possible to get more metal out of the blende. It is also valuable on account of the superior softness and toughness of the metal obtained from it; but it will not bear transportation to a distance as well as blende, on account of its lower percentage of metal. This ore has been at times the principal supply of the Carondelet zinc works; large amounts of it have been shipped to La Salle and Peru, and in 1874, 4000 tons were shipped to Bethlehem, Penn., which yielded a little over 32% of metal on the weight of the raw ore. It is less favored by the zinc works in the neighborhood, because the freight upon it is heavier than the freight on ore from other points, and because furnaces working it cannot turn out as many pounds of metal a day as when working on blende, and the output of the works is reduced."

About 1890 improved methods of mining and milling, especially the latter, began to be introduced in the district. In The Mineral Industry for 1892 it was remarked (p. 466): "The deposits of zinc ore that are opened in Kansas and Missouri are of great extent and are easily worked. Hitherto they have been mined in extremely rude fashion, but within the past two or three years improved methods have been introduced, and machinery is beginning to take the place of manual labor. Probably steps will soon be begun to open the mines on a larger scale, with adequate hoisting and pumping plants, and with dressing works, of which there are surprisingly few in the district, most of the ore being washed by hand. As it is, the Joplin district is already able to maintain a more regular output than it could a few years ago, being less subject to delays by bad weather, etc., and the smelters therefore have more certainty of a steady supply of ore."

In 1892 there were five steam mills in operation near Joplin and 60 producing shafts, while Webb City, Carterville, and Galena were smaller producers. The producing capacity of the district already promised to be so large that disposition of the surplus engaged serious attention. With the object of developing a foreign market, the Southwest Missouri and Southeast Kansas Lead and Zinc Mining Association sent an agent to Europe in 1891. As a result of this about 3000 tons of ore were exported in 1892, but the business ceased because after deducting the transportation charges the producers did not realize so much as they could in the home market in spite of the low prices here. From time to time several other attempts have been made to export Joplin ore when dissatisfaction was felt as to the domestic market, but the results have been always the same.

The next few years witnessed a steady and important development in the district. Operations gradually came to be conducted on a larger scale. The number of steam mills rapidly increased. The amount of work done in the open air decreased. Mining thereby acquired a far greater regularity than it had previously displayed. By 1898 operations had settled down to a well-defined, though peculiar, and in many respects a still crude practice. However, this had been developed to suit the peculiar conditions, and in general the industry was very profitable.

Toward the end of 1898 the great industrial boom set in and the price for spelter, and along with it the price for zinc ore, rose sharply. The large profits which the Joplin operators began to realize attracted the attention of promoters in the East, especially in Boston, and through their instrumentality Eastern capital was heavily invested in the district. A few of these companies were successful, but in general it proved that they had purchased their properties at three or four times their actual value, and this, combined with unwise modifications in the mining and milling methods that some of them sought to introduce, led to disastrous failures.

The failure of the large companies which entered the Joplin field at about this time was due largely to defective recognition of the character of the ore deposits. The mineralization of the district was extensive, but the individual lenses of ore, which up to that time had been the only class of ore-body developed, were comparatively small. A mine which would supply 100 tons of crude ore per day for three years, *i.e.*, somewhat less than 100,000 tons in the aggregate, was probably better than the average. Consequently, it was poor business policy to erect expensive plants of the highest type for so short a period of usefulness. It was more profitable to erect rough, inexpensive plants, on which the outlay would be quickly reimbursed, even if the maximum extraction of mineral and the minimum operating cost were not attained. This is the reason for the peculiar practice which developed in the Joplin district. Engineers accustomed to operations on a larger scale, going to the district for the first time, were wont to pronounce the Joplin practice sadly defective and highly amusing, but in attempting to improve it they commonly learned that there was a good reason for the local practice, and that it was their own judgment which was defective and amusing. In Production and Properties of Zinc, pp. 251–252, the conditions existing in 1901 were explained as follows: "The ore-bodies of the district are of variable magnitude and frequently are exhausted quickly. The method of mining does not open reserves of ore, and the life of a mine is uncertain. The margin over the cost of mining and milling is likely anyway to be narrow. The capital of the men exploiting the mines is generally small. All of these conditions tend to limit the expenditure for original plant to the least that will enable the mine to be worked. In order to meet that requirement a type of mill has been evolved which costs only $30 to $40 per ton of daily capacity (as compared with $150 to $200 for an ordinary mill in other districts). The design has become well established, one mill resembling 90% of all the others in the district like peas in a pod, and the developer of a new mine can contract for the erection of a mill as easily as he can for a barn and with as little concern as to its promised efficiency in operation. The addition of recrushing and slime-washing machinery would introduce unfamiliar complications and would increase the first cost. The complications might be learned, of course, but the increased cost would always raise doubt as to the advisability of the additional investment until the mine had been tested. Hence it is that the reworking of tailings has been left until a sufficient quantity has accumulated to make it worth while." Since 1901, the conditions have changed so that it has become economically possible to erect larger mills and provide them with means, especially recrushing and slime-washing apparatus, for extracting a higher percentage of mineral from the ore.

In 1881–1890 and in the early nineties the one mined in the Joplin district was of comparatively high grade. At the best a ton of concentrate, assaying 60% zinc, could be obtained from two to five tons of the crude ore. J. R. Holibaugh in The Mineral Industry, II, 670, stated that some ore-bodies would yield 75% to 80% mineral, while in others the average would not be over 10%. In The Mineral Industry, III, 537, he stated that at that time (1894) few mines could be worked at a profit which did not yield 10% of mineral, the average value of the concentrate in that year having been $17.10 per 2000 lb., at the mines, although a large deposit of ore yielding only 7% had been worked profitably in the Victor mine at Carterville, where a large tonnage was handled daily. In 1901 the average yield of the district was probably not more than 5%, and many mines yielding only 4% were being worked. Since that time the exhaustion of the old lense deposits has been rapid, new discoveries having failed to make good the working out of the old ones, and it has been necessary to resort more and more to the low-grade sheet ground. The latter character of deposit, which is practically a mineralized bed of large extent, occurs in close association with the old lenses and had long been known, but for many years was regarded as too lean to work. However, it became necessary either to work it or experience a shortage in the domestic supply of spelter, wherefore, the price for ore rose to such a height that this low-grade ground could be worked profitably, and its extent being so great, the operators were justified in erecting larger mills and introducing other improvements.

It is not easy to analyze the economies which have been effected in the Joplin district during the last five years, especially during the last two years, because there have been so many offsetting conditions in connection with the increased cost of most supplies, and especially the increased cost of labor. Probably the economies in handling materials, etc., have been about offset by the increases in those respects. Among the leading economies have been the introduction into the district of hydraulic power, electrically transmitted from Kansas, the introduction of natural gas piped from Kansas, the general adoption of electric motors and gas engines, and the introduction of a superior class of mining machinery. At present, ore yielding only 3% of concentrate is profitably mined, and the general average for the district is probably less than 4%.

The improvements in the result of milling have been especially important. For many years the practice in the Joplin district was highly wasteful. Carl Henrich, in 1892, discussed the subject in the following words:[1]

"When we look at the tailing piles and see the vast amount of good blende left in them; when we follow the course of the water flowing from these concentration works into larger streams, and see everywhere the fine blende shining golden yellow in a bright sunlight, we begin to doubt the success of a method of concentration which on the average wastes certainly not less than one-third, and more frequently nearly one-half, of the ore contained originally in the crude material treated."

In 1904 the average extraction of mineral in the district was still probably not more than 65%. In 1906 the introduction of regrinding machinery and slime tables had increased the average extraction to somewhere between 65 and 75%. This has been a factor of extreme importance in maintaining the production of the Joplin district, and enabling the present low grade of ore to be worked at a profit. However, there is still room for great improvement in this particular, and the attention of Joplin mill-men being now more carefully directed toward it,

[1] Trans. Am. Inst. Min. Eng., XXI, 23.

further progress in increasing the percentage of mineral extraction is to be anticipated in the near future.

Until recently Virginia has been a small but regular producer of spelter which has been famous because of its exceptional purity. The most important mines have been the Bertha, in Wythe County. These mines were discovered by David S. Forney, a pioneer in the development of this mineral region, not from any visible outcrop or float, but in the amateur pursuit of mineralogical and geological investigations, suggested by the favorable appearance of the region to which he came from Pennsylvania to pursue his profession of landscape-artist.[1] The mines were not opened, however, until 1879. The occurrence of the ore was peculiar and was capable of being worked for a long time by open-cast mining. In 1883 the opening was 425 ft. long and 60 ft. wide. In 1893 a strip 1500 ft. wide was worked. As the depth of the stripping was increased by advancing into the slopes of the hills, the proportion of waste material to ore was largely increased, and the costs as well as the difficulties assumed serious proportions. This led to the adoption in 1889 of underground mining by an ingenious system devised to meet the peculiar conditions of the ore deposit. The ore was calamine, which assayed about 25% zinc as mined, and was enriched to about 38% zinc by washing. It was almost free from impurities affecting the quality of the spelter produced, and the latter was sold largely for the manufacture of brass for cartridges, commanding a large premium over the price of ordinary spelter. In 1898 the deposit of zinc ore was exhausted, and the property was leased for the purpose of mining the overlying clays for iron ore. Later on the ownership of the Bertha Mineral Co. was acquired by the New Jersey Zinc Co., which has continued to operate the smeltery at Pulaski, shipping thither willemite ore from New Jersey, which is suitable for the manufacture of the high-grade "Bertha" spelter, and also obtaining small supplies of ore from local sources, which produce lower grades of metal. This ore is obtained chiefly from the Wythe mines (see Section on Lead), which have been worked on a small scale for zinc since 1891. Other zinc mines have been worked in this section of Virginia, but their production has been unimportant.

The mines at Mossy Creek, in the Holston River district, Tenn., were opened by the Edes, Mixter & Heald Zinc Co. in 1883. The old mines at Straight Creek and Lead Mine Bend were reopened by the same company in 1889. Operations continued until 1893, when they were abandoned as no longer profitable. During this period the total production was 17,000 tons of ore, yielding 5750 tons of spelter. This represents the bulk of the zinc production of Tennessee. A little ore was produced

[1] William H. Case, Trans. Am. Inst. Min. Eng, XXII, 536.

by outside interests, but the total quantity was small.[1] About 1898 a mine was operated at Mascot by the Ingalls Zinc Co., the ore being shipped to Ingalls, Ind.; but the production was small and the venture was unsuccessful. In 1899 an unsuccessful attempt was made to reopen the old properties of the Edes, Mixter & Heald Zinc Co., which failed because of inability to secure the necessary capital. Since then, various mining enterprises have been inaugurated in the Holston River district, and at Straight Creek. The spelter produced from the ore in the Holston River district was remarkable for its purity. Both the ore and its occurrence are similar to those in Virginia. It is noteworthy that four districts (in Pennsylvania, New Jersey, Virginia, and Tennessee) producing zinc ore free from lead should occur in the Appalachian region, and nowhere else in America.

The occurrence of zinc ore in northern Arkansas has been known from a comparatively early date. David Dale Owen made a geological reconnoissance of the region in 1857 and 1858, but at that time no mining was going on. The first active mining, according to E. Hedburg,[2] was attempted by a Chicago company, which in 1875 erected a smeltery at Calamine, Sharp County, for the reduction of carbonate ores. The enterprise was unsuccessful. I believe that it was attempted there to use wood as fuel and charcoal as reduction material. No coal was available.

The Morning Star mine at Rush, Marion County, Arkansas, was discovered in 1884. Since that time intermittent shipments of ore (calamine) have been made to Buffalo City and thence by boat down the White River, and many other mines have been opened in northern Arkansas. It has been believed that this section contained important zinc resources, the development of which was retarded by lack of adequate transportation facilities. Since 1900 several railways have been built into the district, and the production has increased, but so far the extent of the increase has been disappointing. Zinc ore has also been mined in the northeastern corner of Oklahoma, but the production as yet has been insignificant. The ore deposits of Oklahoma are in the same formation as those of Joplin, and they are of the same character. Those of northern Arkansas are quite different.

The existence of zinc ore in the States and Territories west of the Rocky Mountains was known from the earliest days of occupation, but for many years there was no market for it. Nearly a quarter of a century ago attempts were made to reduce the ore locally. One of the first was made by Alfred and Eugene Cowles. Together with their father, Edwin Cowles, of Cleveland, Ohio, they purchased a mine on the Pecos River,

[1] During the eighties a small smeltery was also operated by the East Tennessee Zinc Co.

[2] Trans. Am. Inst. Min. Eng., XXXI, 397.

New Mexico, which had a deposit of mixed sulphide ore, a class which was then considered highly refractory. The Cowles brothers, who were educated electricians and practical men, undertook to smelt the Pecos ore in an electric furnace, several forms of which were invented and patented in 1883 and subsequently. This was probably the first venture in the field of electrothermic smelting of zinc ore, which even yet has not become an industrial process, in spite of many experiments. The Cowles brothers failed, but their work in this direction led them into the field of aluminum smelting, wherein their work was of great commercial importance.

In 1882 shipments of zinc blende were made to Peru, Ill., from the Cotopaxi mine, Fremont County, Colo., where there was a vein of comparatively clean ore, but whether from the smallness of the vein, from the high transportation charges, or the character of the ore, the business did not develop.

At Leadville, Colo., in 1886–1889, considerable experimental work on the treatment of the ores of that district by hydrometallurgical and electrometallurgical processes was done, but nothing of consequence resulted except the further drawing of attention to the problem.

In 1888 H. C. Rudge organized the Denver Zinc Co. and erected a small zinc smeltery at Denver, Colo., purchasing ore from Leadville, Colo., but it was not known how to smelt an ore so high in iron, the retorts would not stand up under the action of the corrosive slag, and after a few months of disastrous operation the attempt was abandoned.

In 1891 a market for the zinc ore of the Rocky Mountains became an established fact, although for eight years or more it continued to be a small one. In that year F. L. Bartlett, who had previously been operating a small matte smeltery at Portland, Me., where he had made many ingenious experiments, organized the American Zinc-Lead Co., which erected a works (of 100 tons per day capacity) at Cañon City, Colo., to utilize the mixed sulphide ore of Leadville and elsewhere for the manufacture of zinc-lead pigment. In 1892 these works treated 12,000 tons of ore and they have continued in regular operation, with several enlargements, ever since.

In 1891 also the zinc mines at Hanover, N. M., were opened, shipping their ore to the oxide works at Mineral Point, Wis. Up to the end of 1893 their output amounted to 1358 tons. The calamine assaying 35% zinc and upward yielded a fair profit when it fetched $20 per ton, but otherwise was produced at a loss, the freight rate from Hanover to Mineral Point being $12 per ton. The hard times of 1893 and the low prices for zinc ore put an end to mining in this district, but during the last year or two it has been resumed.

The great development of zinc mining in the Rocky Mountains dates from 1899 when some trial lots of concentrated ore were shipped from Creede, Colo., to smelters in Kansas. In the same year an enterprising ore broker obtained contracts with European smelters which enabled him to buy and export large quantities of ore from Leadville, Colo. The freight rate from Leadville to Antwerp, Swansea, or Hamburg was $9 per ton. The miners were glad to sell the ore for $5 per ton f.o.b. cars, it previously having been a waste product, and a large business developed. For several years this ore was mostly exported, American smelters, accustomed to the high-grade ore of the Joplin district, having great difficulty in smelting it successfully, but they finally succeeded and then promptly excluded the European smelters from the American market. After that, the production of zinc ore was inaugurated in nearly all of the Rocky Mountain States, the improved methods of concentration rendering it possible to make marketable ores that previously were valueless, the requirements of the zinc smelters for raw material causing them to bid up the price, and the railways making freight rates on zinc ore so extremely low that it was possible to fetch ores to Illinois and Kansas from points so remote as British Columbia and Mexico. The extraordinary development of zinc mining in these States is reflected in the statistics given at the beginning of Chapter XIX.

XXI

ORE DRESSING

RECENT improvements in the art of ore dressing, *i.e.*, the separation of valuable minerals from each other and from worthless gangue, have been largely contributory both to progress in zinc mining and in zinc smelting. The process of zinc smelting which is commonly employed, requires mineral concentrated ordinarily to a tenor of 40% zinc, while the higher in zinc and the lower in objectionable impurities (iron, manganese, lime, lead, fluorspar, etc.) the better is the result in smelting. Consequently great attention has always been devoted to the mechanical concentration of the crude zinc ore that is obtained from the mines.

Zinc ore dressing was inaugurated in the United States when the mines at Friedensville, Penn., were first worked for sulphide ore, which came in below the surface deposits of calamine. The blende of this ore was to a large extent disseminated finely through the gangue of dolomite, and it was impracticable to separate any but the coarser blende, leaving tailing still containing a comparatively large amount of zinc, which so far has defied all processes proposed for its extraction.

The ore of the Joplin district, Missouri, was from the beginning an occurrence of coarsely crystallized blende with a gangue of chert, from which it was easily released by a comparatively coarse crushing. There was but little pyrites mixed with the ore and the blende was practically free from isomorphous monosulphide of iron; wherefore it was easy to produce a remarkably high grade of blende concentrate by comparatively simple means. Until about 1891 this ore was concentrated solely by hand-jigging, as mentioned in the previous chapter. Then began the introduction of mills operated by steam, followed by other improvements the nature and effect of which have been referred to elsewhere.

While the Joplin ore was thus easily separated, that of Wisconsin presented great difficulty because of the association of marcasite with the blende, the two minerals being of nearly equal specific gravity. Yet the minerals were both coarsely crystalline and easily released by comparatively coarse crushing. By crushing and jigging it was easily possible to produce a concentrate which was a mixture of blende and marcasite, but to separate those minerals from each other remained an unsolved problem until about 1904, although many attempts had previously been made and some of them were so close to the right process that it is a wonder why commercial success was not reached.

Another class of zinc ore which for many years defied treatment was the mixed sulphides of the Rocky Mountains, which were difficult both because of the association of blende and pyrites and the intimacy of their mixture, which required rather fine crushing to release the various minerals. For half a century the treatment of this class of ore was one of the great problems of ore dressing and metallurgy, engaging the attention of many investigators and involving the expenditure of a vast amount of money in experiment and unsuccessful constructions.

As early as 1886 the mixed sulphide ore of Leadville, Colo., was milled in the conventional way of that time for the extraction of its galena, the blende-pyrites tailings, together with considerable galena, being thrown away, or accumulated in dumps to await a better method of treatment, the wisdom of which was subsequently proved. After a few years the grade of the available ore ran down and, there being no longer any profit in the milling of it, the several works of the district were closed and later were dismantled.

In the meanwhile the mining companies of Broken Hill, New South Wales, confronted by a similar problem, had been actively engaged upon working it out, and finally proved the feasibility of concentration by tabling after a preliminary fine grinding, which attracted attention to that new method of concentration. In 1896 a new table was invented and introduced by A. R. Wilfley, of Denver, Colo., which was a great improvement over anything previously in use, and furnished new and efficient means for the washing of fine material. This led to the building of a new type of mill at Leadville, but they were still only for the extraction of galena, there being not yet any market for the blende. The latter developed in 1899 as elsewhere described.

New Jersey too had its problem of a difficult mixed ore in the franklinite-willemite-zinkite of Stirling Hill and Franklin Furnace. The long years of effort in the treatment of this ore have been referred to in other chapters of this work. Its utilization as raw material for the manufacture of zinc oxide had been accomplished in 1866, but this did not advance its availability as a source of spelter, except in so far as spelter was produced from certain of the by-products of oxide manufacture. No real step in the latter direction was achieved until Mr. George G. Convers made his successful experiments at South Bethlehem. Mr. Convers, who was then superintendent of the works of the Lehigh Zinc Co., turned his attention to magnetic separation and installed in 1892 an experimental plant of Wenström separators. The ore, which consisted of 51.92% franklinite, 31.58% willemite, 12.67% calcite, 0.52% zinkite, and 3.31% tephroite and other silicates, was first crushed to pass a 10-mesh sieve, and was then mixed with 20% of its weight of anthracite coal (buckwheat size) and passed through a brick-lined revolving cylinder, heated by gas from a Taylor producer. The heat of the furnace was regulated so that the ore issued from it at a bright red. The hot ore was conveyed into a revolving cooler, around the surface of which cold water was sprayed. After cooling, it was sifted to remove unburned coal (which was used subsequently on the grates of the zinc oxide furnaces, whereby the small quantity of zinc retained by it was recovered), while the ore itself was collected in bins, whence it was led to three Wenström magnetic separators, arranged in series. These machines were run so as to make a clean non-magnetic product of willemite, zinkite, calcite, and silicates, and a magnetic product consisting chiefly of franklinite. The latter was sent directly to the oxide furnaces; the former to jigs and tables by which the calcite and silicates were removed. The final products were: (I) *magnetic,* franklinite and willemite, assaying about 29.66% ZnO, 37.20% Fe, and 9.34% Mn; (II), *non-magnetic, heavy minerals,* chiefly willemite, assaying from 46.38% Zn, 3.76% Fe, and 6.68% Mn. to 48% Zn, 2% Fe, and 7% Mn.; and (III) *non-magnetic, light minerals,* chiefly calcite and silicates. The process gave good results; but the cost of the roasting and the uncertainty of producing a uniformly magnetic product led to further experiments, from which a direct separation of the minerals, without previous roasting, was developed by Mr. J. P. Wetherill, the consulting engineer of the company.

It had been shown by Faraday, Plücker, Wiedemann and others that magnetism is an inherent property of all substances; which are either attracted or repelled by the poles of a magnet, though in most substances the manifestation of that property is exceedingly feeble. Those substances which are attracted are said to be paramagnetic; those which are repelled are diamagnetic. The paramagnetics show a wide variation in magnetic intensity; the diamagnetics show but slight difference in intensity as compared with air, which is the neutral substance. Taking air as unity, the diamagnetic intensity of bismuth is only 0.99982 and bismuth is the most diamagnetic substance known; on the other hand, among the paramagnetics, if the attractability of steel be assumed as 100,000, that of magnetite is as high as 65,000. Mr. Wetherill conceived that advantage might be taken in the slight variations in the magnetic attractability of feebly magnetic substances, which up to that time had been commonly regarded as quite non-magnetic, to effect a separation of them if he employed magnetic fields in which the lines of force were greatly condensed. This was accomplished by tapering the pole pieces, and with such magnets it proved possible by suitable adjustments to effect mineral separations of great delicacy.

The first Wetherill patent was dated March 3, 1896. This claimed broadly the art of separating feebly magnetic material from non-magnetic material, together with the particular form of separator described, the essential feature of which was the electro-magnet with tapering pole-pieces. As to the originality and nature of this great invention, it is best to quote from the decision rendered in respect to it in a suit before the Imperial German Patent Office, brought by the Mechernicher Bergwerks-Aktien-Verein (owner of the Mechernich separator) against the Metallurgische Gesellschaft (owner of the Wetherill separator) to test the validity of the Wetherill patents. The decision of the German patent office was summarized as follows in the *Engineering and Mining Journal* of Nov. 17, 1900:

"Claim 1 of the patent No. 92,212, covering the process of separating the so-called weakly magnetic substances by direct magnetization, is upheld; the wording of claims 2 and 3 it was found necessary to change so as to preclude a possible misinterpretation, the new context to express without ambiguity that the constructions covered by either of the two claims are patented only in so far as they serve for carrying out the process as defined by claim 1.

"For the consideration of the question, whether the process characterized by claim 1 was new and patentable at the time of the application, it is immaterial that long before the date of application the existence of weakly magnetic and non-magnetic minerals was known, besides the strongly magnetic ores; likewise the classification given by M. Faraday 60 years ago dividing all substances into two classes, paramagnetic and diamagnetic, since constituting a common acquisition of scientific and technical knowledge, is by no means prejudicial to the patent.

"The Application Department knowing these premises has allowed the first claim on the well-justified ground that Wetherill was the first to recognize the applicability of these known facts to the magnetic separation of weakly magnetic substances, without first transforming them into the strongly magnetic state and to demonstrate their separation from non-magnetic substances upon a commercial scale.

"Magnetic concentration up to the time of Wetherill was developed only to a very small extent and still more limited in its practical application. It was principally applied to the dry concentration of iron ore which by roasting was convertible into ferroso-ferric oxide — FeO, Fe_2O_3 — this being considered the only iron compound corresponding in its magnetic properties to the native magnetite and separable by means of the magnet.

"In Germany only a few works have attempted to concentrate by this method the spathic iron — $FeCO_3$ — interspersed with zinc blende.

"This process involved the difficult task of converting the spathic iron by roasting into ferroso-ferric oxide (artificial magnetite).

"It would be of no consequence to investigate here the difficulties connected with this operation and their chemical causes; may it suffice to mention that in many cases it was a complete failure, in most other instances it proved unsatisfactory in spite of great expense. The news that Wetherill's process required nothing more than the ordinary crushing before separation, avoiding the extremely difficult roasting process, created great satisfaction among experts.

"Before Wetherill the efforts of specialists in this branch were guided on the one hand by the sole aim to improve the construction of the magnetic apparatus, utilizing the achievements of physical and electrical sciences; the progress made in metallurgy relating to the chemical nature of the roasting process, on the other hand, stimulated efforts toward converting iron compounds, thought to be practically non-magnetic, into artificial magnetite.

"This problem was simplified to a remarkable extent also from an economic point of view when Wetherill demonstrated the possibility of direct separation of the weakly magnetic substances.

"The statement of the complainant relating to the alleged prior use of methods similar to the patented process, producing essentially the same effects, is incorrect. Complainant has not given evidence in support of such statement. Referring especially to the old Buchanan separator the argument of the defendant has not been invalidated that the Buchanan separator before Wetherill's application for the patent had never been applied to the separation of weakly magnetic substances from non-magnetic admixtures.

"Complainant moreover adduced a laboratory method for separating feebly magnetic substances from non-magnetic ones, which in some respects bears slight resemblance to the context of claim 1 of the disputed patent. This method, described by Mann in Neues Jahrbuch für Mineralogie, Geologie and Paleontologie, 1884, II, 161, in its entirety, however, would not justify the annulment of claim 1 of the defendant's patent.

"In the first place, the publication of Mann has no reference to concentrating complex ores for technical or industrial purposes, but serves merely for solving an interesting mineralogical problem by analyzing the constituents of certain minerals, it being understood that no further utilization or technical application of the products was contemplated. A conclusion as to the practicability of Mann's method for dry magnetic concentration of ores was by no means evident.

"Furthermore magnetic concentration has to deal with entirely different substances, with other classes of minerals than those which Mann experimented upon in connection with his research work.

"Finally the method itself is in a number of points essentially different from the Wetherill process."

The right to the use of the Wetherill separator was the most valuable asset which the Lehigh Zinc Co. put into the New Jersey Zinc Co., when the latter was formed in 1896. It was quickly put into application at Franklin Furnace. With its aid it became possible to produce a willemite-zinkite concentrate, assaying about 48% zinc, 5% manganese, and 2 to 3% iron, which was a highly desirable ore for spelter manufacture, and a franklinite concentrate, which was of excellent character for the manufacture of zinc oxide and spiegeleisen. By this separation the value of the average ore of the Franklin mine, which without the process was only about $2 per ton, was increased to $5 per ton, and it became profitable to extract the whole of the great ore deposit of the mine (estimated at 8,000,000 tons) or such proportion of it as the methods of mining should permit, whenever the market required. The production of the willemite-zinkite concentrate led to an increased production of high-grade spelter, and the surplus of this ore was exported on a large scale to Europe.

The importance of the Wetherill invention in connection with the Franklin mine was thus of a wonderful character, but perhaps its moral importance in connection with the zinc industry at large was even greater. The fact that one of the great metallurgical problems of the nineteenth century had been solved in so brilliant a way by so simple means directed renewed attention to the great class of mixed sulphide ores which had so long baffled ingenuity. It was found that the powerful Wetherill magnets could separate blende from many mixed sulphide ores, especially the blende that contained more or less combined iron. The application of this process proved successful in the case of the Leadville ore. In other cases it was found that a suitable roasting enabled pyrites to be picked out, either by the Wetherill separator or by separators of low magnetic intensity, the design and construction of which was greatly improved in view of the new and large demand for them. The key to their application was found to be in roasting the ore in just the right way — a discovery which, like many others, appeared simple after it had been made. In this way brilliant success was achieved in producing a high grade of zinc concentrate from the mixed blende-marcasite of Wisconsin.

The success of these processes led to investigation and experiment on other lines, resulting in the invention of the ingenious electrostatic separator, which is due to Prof. Lucien I. Blake and Lawrence Morscher the Sutton-Steele pneumatic table; and the flotation process, which was invented by C. V. Potter, of Australia, and as modified by Delprat, up to this date has proved the best method of separating the mixed sulphides of Broken Hill, N. S. W. In the United States the flotation process has not yet found any extensive application, but an ingenious modification of it by W. M. Sanders has recently enabled a separation to be made of the blende of Marion, Ky., from the fluorspar with which it is associated, that previously had been an unsolved problem.

In concluding this review of the advance in the art of dressing zinky ores, it may be stated that at the end of 1907 there are few kinds of ore in which the association of minerals is not so intimate that crushing to pass a 40-mesh screen fails to release them from each other, which cannot be enriched to a grade of 40% Zn, while in many cases they can be raised to 60% zinc, or upward. Some ores are amenable to one process; others to a different process; others still, and these are the majority, to a combination of processes. But if the proper process be applied, most ores containing zinc can be made to yield a commercial zinc product. Previous to 1896 the ores of this class were practically worthless. In no other branch of the zinc industry has there been so marvelous an advance in so brief a time. The result has been an immense increase in the available supply of raw material, not only in the United States, but also throughout the world, of gigantic magnitude and supreme industrial importance.

XXII

ZINC SMELTING

THE art of zinc smelting is simple in principle, but complicated in practice. It depends upon the reducibility of zinc oxide by carbon, or carbon monoxide, or both. Consequently zinc sulphide — blende — must first be roasted to obtain the oxide. Zinc silicate (ZnO, SiO_2) is reducible directly by carbon.

Zinc oxide begins to be reduced by carbon at 1125° C., but at that temperature the reaction takes place only so long as the presence of carbon dioxide in the gas is kept below 0.2%. As the percentage of CO_2 increases, the reduction temperature also increases, being 1500° C. when 0.76% of CO_2 is present. This is one of the limitations of the zinc-smelting process. However, as commonly carried out, there is no difficulty in keeping the carbon dioxide below 0.2%.[1]

The boiling point of zinc is 925° C. Consequently, even if reduced at 1125° C., the zinc is produced in the form of vapor. If the reduction be performed in a retort the tension of the gases developed therein forces them out of the retort, and by causing them to pass through a tube, cooled to 415°–550° C., the zinc vapor is condensed to liquid form. Zinc smelting is, therefore, a process of distillation. Under certain conditions, among others the condensation of too dilute a gas or the too rapid cooling of the gas to below 415° C., the zinc may condense in solid form, as a finely divided powder, known as zinc dust or blue powder, which is objectionable. Even in the best regulated zinc-smelting process there is a certain formation of blue powder, and in smelting in the electric furnace, on a large scale, the product is chiefly blue powder. The reason for this is yet unknown. It is possible that the ability to condense liquid spelter from the comparatively small retorts of the ordinary furnace, and the present inability to do so from the electric furnace, are due to reactions in the former, not duplicated in the latter, as to the nature of which we do not know. Our knowledge of the physico-chemistry of zinc reduction is very recent and is still far from complete.

Although zinc oxide begins to reduce, under certain conditions, at 1125° C., the speed of the reaction is greatly increased by increase of temperature, and it being for technical considerations important in prac-

[1] G. Bodländer, *Zeitschrift für Elektrochemie,* VIII, xliv, 833 to 843.

tice to complete the working of a charge in 24 hours, it is essential in practical smelting to conduct the operation at a considerably higher temperature. Given a certain time for the distillation, which is commonly about 18 hours, the remaining six hours being occupied in discharging and recharging the retorts, the higher the temperature, the more complete will be the extraction of the zinc. But here enter other complications. The singulo-silicates of iron, lime, etc., begin to form at about 1200° C., and as the temperature rises further more infusible slags can form, and the gangue of the ore containing these elements may give rise to slags which quickly corrode and destroy the retorts in which the distillation of the zinc is being conducted, to such an extent indeed as to make the process impracticable. Moreover, with increase of temperature, other metals, especially lead, distil over with the zinc, necessitating a further refining of the latter in order to produce a marketable quality of metal. An ordinary temperature of distillation is 1250° to 1350° C. The performance of the process at 1200°C. is known as "slow driving," while 1400° to 1450° C. is "hard driving."

Good practice tends strongly to hard driving, because the extraction of metal is greatly increased, without corresponding increase in the consumption of coal, as compared with "slow driving." The ability to smelt at high temperature is secured by strong construction of the furnace, built of highly refractory brick; the use of dense retorts, made by hydraulic pressure of the most suitable refractory material; the proper compounding of the charge, so that the slag that may form will be of the minimum corrosive character, and so that the least possible matte will form; the use of a great surplus of reduction material to absorb the slag like a sponge; and the design of furnace that will ensure the most equable temperature.

The various details which enter into the practice of zinc smelting are so many and so complicated that bulky treatises are devoted to them without by any means exhausting the subject. The reader is referred to Metallurgy of Zinc and Cadmium, by W. R. Ingalls, and Métallurgie du Zinc, by A. Lodin. There were originally four different methods of smelting, viz., the English, in which the distillation was effected in comparatively large pots; the Carinthian, in which it was performed in small, vertical retorts; the Silesian, in which it was done in comparatively large inclined retorts; and the Belgian, in which small inclined retorts were used. The English and Carinthian systems never had any general application and are no longer in use. In recent years a new system, known as the Rhenish, which is a combination of the Belgian and Silesian, has been developed, and is now the favorite in the best practice.

In a century of practice the art of zinc smelting has undergone many improvements in details, but has remained unchanged in its essentials.

It has been found impossible to conduct the distillation successfully in a retort holding more than 167 kg. of ore (exclusive of the reduction material) and for a satisfactory treatment of high-grade ore it has been found in practice that the Rhenish retort, holding about 34 kg. of ore, is the maximum that ought to be used. The necessity for the employment of such small retorts implies a large requirement of manual labor per ton of ore treated, and it has been sought to reduce it by smelting the ore in large quantity in a blast furnace, or in an electric furnace, but so far all efforts in those directions have failed. Nor has the effort to charge the small retorts of the ordinary furnace by mechanical means yet proved a commercial success, although mechanically it has been achieved.

There are three systems of zinc smelting now in use, namely, the Belgian, the Silesian, and the Rhenish, which are based on the same general principles, but differ in the types of retorts employed, the furnaces designed to receive them, the grade and character of the ore than can be treated, and the manner of manipulation. The primary difference among the three processes is the use of comparatively small cylindrical retorts arranged in several tiers, each with a slight inclination, in the Belgian process; and comparatively large muffle-shape retorts (commonly called muffles) set in one tier in the Silesian process. The Rhenish is a combination of the Belgian and Silesian and is used chiefly in Rheinland and Westphalia, and to some extent in Belgium and elsewhere.[1] The Belgian process as used in Wales is sometimes called the Welsh-Belgian, although it presents few or no distinctive differences.

Until a few years ago the Silesian process was the only one employed in Upper Silesia and Poland, but recently, owing to the increasing use of blende and the consequently richer ore-charge, the Rhenish process has found extensive application in Upper Silesia. The smelters of the United States use chiefly the Belgian process, but of late a modified Rhenish process has been adopted at two works. Some of the English and Welsh smelters employ the Belgian and some the Silesian process; in some instances furnaces of each type are to be found in the same works. The Rhenish furnace is adopted generally by the smelters of Rhenish Prussia and Westphalia. In Belgium, the characteristic furnace of that country is still the most commonly in use. The Silesian process was

[1] In consulting the old hand-books some confusion will be found as to the classification of zinc-smelting processes. The old Silesian process, which is now everywhere abandoned, was modified by the introduction of certain features of the Belgian process and the combination is referred to as the Belgian-Silesian by some of the older writers (*vide* Kerl, Grundriss der Metallhüttenkunde). This is the process now commonly employed in Upper Silesia, which I designate simply as the Silesian. On the other hand, some writers call the Silesian modification of the Belgian process, used in Rheinland, Belgian-Silesian. This is now best known as the Rhenish process.

applied at an early date at two of the works of the Société Anonyme de la Vieille Montagne (Valentin-Cocq and Flône), but was eventually modified into the Rhenish type; similar furnaces are used at Viviez, France, but with gas firing, while at Valentin-Cocq and Flône direct firing is still adhered to. During recent years there has been a marked tendency on the part of the Belgian smelters toward a form of Siemens furnace, which in some of its features approximates to the Rhenish type.

The practice in the metallurgy of zinc has undergone many changes during the 100 years that the industry has been in existence, but the changes have been generally the result of gradual development and never by the introduction of a radical innovation. So gradual has been the evolution that many methods and types of furnaces have remained quite unchanged through long periods of years. Thus, both in Belgium and Kansas there are furnaces in use at the present time which in design date back more than 30 years. For the successful distillation of zinc ore we appear to be limited to comparatively small retorts; all attempts to effect the distillation in blast furnaces or otherwise on a large scale, save for the production of zinc oxide, have been failures.

The chief changes and improvements which have occurred in the metallurgy of zinc during the last 40 years have been the following:

1. Replacement of calamine by blende as the most important ore of zinc.

2. Successful introduction of mechanically raked furnaces for blende roasting, this being especially a feature of modern American practice.

3. Utilization of the sulphurous gas evolved in blende roasting for the manufacture of sulphuric acid, which is done to a large extent in Germany and Belgium, to a less extent in the United States and France, and recently has been undertaken in Great Britain.

4. Introduction of gas firing, with or without heat recuperation, especially in connection with the distillation furnaces, leading to economy of fuel and better extraction of zinc and permitting the construction of larger furnaces.

5. Manufacture of improved retorts by means of hydraulic pressure, leading to an increased extraction of zinc and ability to smelt more corrosive mixtures of ore.

6. Improvement in the sanitary condition of the furnacemen by proper control of the fumes, etc., originating from the furnaces; this is a matter which has received a good deal of attention in Belgium, Germany, and Great Britain, and little or none in the United States.

7. Introduction of labor-saving devices for the handling of material.

8. Utilization of natural gas as fuel in the United States.

The most important recent development in the metallurgy of zinc has taken place in America, and has been not the result of technical study.

and experience, but the taking advantage of the natural-gas resources of Kansas.

The smelting of zinc ore for zinc oxide is analogous to smelting for spelter, but the operation is conducted with an excess of air (which must be carefully excluded from the spelter retort) and the zinc reduced and distilled is immediately burned to oxide. The gas containing the oxide, which escapes from the furnace, is purified from dust by allowing the latter to settle, and after cooling is passed through cotton cloth, which strains out the oxide. The operation has certain difficulties of its own, but is free from most of those which are troublesome in the production of spelter.

We have seen already, in the previous chapter, how zinc was produced experimentally in the United States as early as 1838, at which time the industry was only just becoming established on a sure footing in Europe. In 1840 the total production of spelter in Europe was only a little more than 17,000 tons; in 1830 it had been less than 5000 tons. Between 1841 and 1850 various attempts to smelt zinc in the United States were made, but the only ore then available was the red oxide of New Jersey, which was mixed with willemite and franklinite in such a way that a clean separation could not be economically effected. The only thing that could be done was to separate the ore by hand-sorting as well as possible, but apparently it was impossible to effect a clean separation in that way.

The regular manufacture of zinc was first undertaken in 1850 at Newark, N. J., by Richard Jones, the ore being charged into Belgian retorts just as it came from the mine. The experiment proved a failure owing to excessive breakage of the retorts due to the high tenor of the ore in iron and manganese. Attention was then directed to recovery of the zinc as oxide, and a furnace constructed of fire-brick with a large clay muffle was designed, which withstood the corrosion better than the Belgian retorts. A row of these was erected in connection with a muslin bag apparatus (invented by Samuel T. Jones) to collect the fume, and the regular manufacture of zinc oxide was begun. In 1851 Samuel Wetherill, of Philadelphia, invented the process, since known as the Wetherill process, by which the extraneously heated muffle was done away with. The ore mixed with anthracite coal was thrown in a layer 3 to 4 in. thick upon a hearth composed of perforated cast-iron plates, 1 in. thick; the door was closed and cold air blown under the grate, which passing through the charge raised the temperature to such a point that the ore in contact with the carbon was reduced to metallic zinc, vaporized and oxidized, passing off as a white smoke to the collecting apparatus, where the products of combustion strained through the muslin, leaving the oxide inside the bags. This process proved so successful that it was introduced immediately and has remained in use without essential change up to the present time. It was one of the few important contributions that America has made to the metallurgy of zinc. Works for the manufacture of zinc oxide were put in operation at Jersey City in 1854, this being known as the Passaic Zinc Works.

Attempts to produce spelter were not given up. In 1856 the Lehigh Zinc Co. of South Bethlehem, Pennsylvania, caused to be erected a spelter furnace of the Silesian type at its mine near Friedensville, four miles south of Bethlehem. This furnace failed to yield any zinc. Neither the anthracite coal nor the retort clay seemed to be adapted to the purpose, while the ferruginous-calcareous character of the ore obtained at Friedensville was a continual source of trouble. It was not yet known in America how to smelt such ore.

In 1857, F. W. Matthiessen and E. C. Hegeler, who had just come to the United States from the school of mines at Freiberg, Saxony, obtained permission from the company to experiment on their own account at the abandoned plant. They did it on a small scale, using one muffle placed in a kiln altered for the purpose. They demonstrated that anthracite, as well as New Jersey clay, could be used, and made some spelter in this experimental way, but failed to come to an agreement with the owners of the property for building works, largely on account of the financial crisis prevailing at that time. They then turned their attention to the West, where they studied the zinc deposits of Wisconsin, and late in 1858 began the erection of the present works at Lasalle. Lasalle was selected as the point where the Illinois coal field approached nearest to the Wisconsin zinc mines. The Joplin mines were unknown at that time. The works at Lasalle went into operation in 1860, and have continued without interruption to the present time.

In the meanwhile experiments were still carried on in New Jersey and Pennsylvania by Samuel Wetherill, Joseph Wharton, and others, who tried furnaces of various types. Samuel Wetherill, the inventor of the furnace for the manufacture of zinc oxide, which was then in successful use, produced some metallic zinc at South Bethlehem as early as 1858, but, although he persevered for about two years, and made in all about 50 tons of excellent spelter, the cost of production was too high and his enterprise was abandoned. The first sheet zinc made in the United States was rolled by Alan Wood & Sons, of Philadelphia, from an ingot of Mr. Wetherill's spelter. In 1859 Joseph Wharton built for the Lehigh Zinc Co., with which he had been associated since 1851 as stockholder and afterward as manager, a Belgian spelter furnace of about 45 retorts, which he operated with the aid of several workmen imported for the purpose. The fuel employed was Pennsylvania anthracite; the retorts and condensers were made mainly from the fire clay of Perth

Amboy, N. J.; the ore was obtained from the Lehigh Zinc Co.'s mine near Friedensville. The entire cost of this experiment, including the importation of workmen, construction of furnace, tools, and all collateral expenses, was $3,795.89. The quantity of spelter produced was 34,063 lb. This successful experiment of Mr. Wharton was the beginning of the manufacture of metallic zinc in this country on a commercial basis. Immediately afterward Mr. Wharton built at the works of the Lehigh Zinc Co. a complete spelter plant of 16 Belgian furnaces, which he operated for his own account under lease from the company with unbroken success until 1863, when he retired from the business. After that date works were built at Newark, Jersey City, and Bergenpoint, N. J., and at Friedensville, Penn., most of these Eastern furnaces being in connection with plants for the manufacture of zinc oxide.

In the West, the second works to be installed was a small plant at Potosi, Washington County, Mo., erected by George Hesselmeyer in 1867, which ran only for a short time. Then followed, in 1869, several works at St. Louis, among which the Glendale (now owned by the Edgar Zinc Co., a subsidiary of the U. S. Steel Corporation) has continued in regular operation up to the present time. The Illinois Zinc Co. built at Peru, Ill., in 1870. The works in Illinois obtained their ore supply from Wisconsin; those in Missouri were supplied with calamine mined in the southeastern part of that State. When the Joplin ore came into the market, in 1873, the smelters of both Missouri and Illinois were endowed with a new and bountiful supply of ore, which put them on a strong footing. A little later works were built at Weir, Kansas, by Robert Lanyon, who had previously been engaged in zinc smelting at Lasalle, Ill., whither he had removed from Mineral Point, Wis.

The zinc industry in the United States has been characterized by rapid development in respect to production. The technical and economical development has been slow on the other hand, and up to a few years ago the same type of distillation furnace was in use as at the time of the inception of the industry in this country. The Wetherill process for the manufacture of zinc oxide directly from ores is the most important contribution that has been made by American engineers to the metallurgy of zinc. Apart from that the most distinctive feature in American practice has been the successful application of mechanical roasting furnaces to the desulphurization of blende. About 1895 the discovery of natural gas at Iola, Kan., and the building of zinc smelteries at that point began a change in the American zinc industry, which became a radical one. In New Jersey the successful development of the Wetherill process for the magnetic separation of franklinite and willemite proved of great importance, and by directing attention to means, magnetic or otherwise, for the separation of the mixed sulphides of the West was an innovation in the metallurgy of zinc of far-reaching results. It is noteworthy that the two great contributions of America to this art have both been associated with the name of Wetherill.

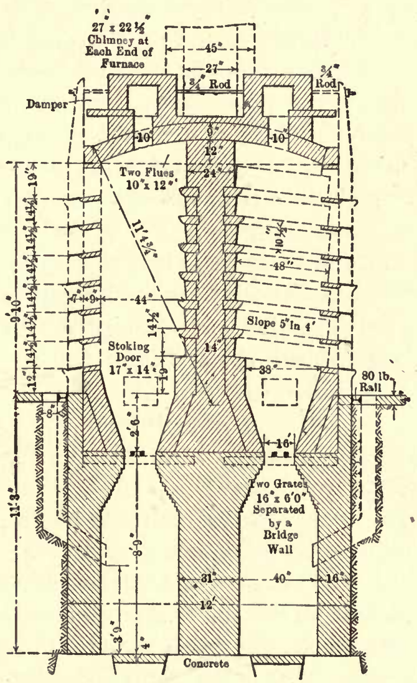
We have seen how the early attempts at zinc smelting in the United States were defeated by the difficult character of the only ore that was available and how for that reason the manufacture of zinc oxide directly from the ore — an entirely new process — became a commercial success before the manufacture of spelter. The ore of New Jersey was ferruginous, manganiferous, and calcareous — about the worst combination that can be conceived. That of Friedensville was only a little less difficult, being ferruginous and calcareous. About 1860 the Lehigh Zinc Co. succeeded in smelting the Friedensville ore, but the manufacture of spelter from the New Jersey ore, up to the introduction of a successful process of magnetic separation in 1892, was confined to the working up of by-products from the zinc oxide and spiegeleisen departments together with such little clean ore as could be obtained by hand-sorting. Considerable ore supplies also were brought from Virginia to the works in New Jersey after the mines of that State had been opened. The Wisconsin ore which became available at Lasalle and Peru was of easily-smelting character, and the industry established there developed without any special drawback. The Joplin ore, which soon came into the market, was almost the ideal ore for zinc smelting.

Something of the early history of zinc oxide manufacture has been related in the chapter on zinc mining. Originally it was thought that only the red oxide ore was adaptable to that process. It was known that franklinite also was reducible, but it was believed that the willemite (anhydrous zinc silicate) associated with the franklinite was irreducible, and in attempting to use that class of ore failure was experienced. Of course it is now well known that zinc silicate is directly reducible by carbon — and perhaps it was even then known in Europe — if the temperature be sufficiently high, and doubtless the failure in the New Jersey oxide furnaces was due to the inability to attain the proper temperature.

In the course of time the red oxide ore became so scarce that it cost the New Jersey Zinc Co. $27 a ton, while franklinite-willemite ore was available in large quantity for the mere cost of mining, $1 or $2 per ton. In 1866, according to testimony in one of the many lawsuits over the New Jersey mines, it was found that the zinc silicate of the franklinite-willemite ore could be successfully reduced in the oxide furnace by the addition of a small proportion of lime. Thereafter, this class of ore became the great source of zinc oxide. The process was originally made a success by the filtering bags invented by Samuel T. Jones and the furnace with perforated cast-iron grate and under-grate blast invented by

Samuel Wetherill. Even up to the present time there has been no essential modification of the original process, except the use of lime in 1866, and the introduction of mechanical means for handling the ore and material, improved machinery (engines, fans, etc.), and an improved design of bag house.

The first spelter furnaces employed in the United States were of the old direct-fired Belgian type, such as were extensively used in Belgium at the same time. Up to a few years ago, possibly even now, furnaces of the same type only slightly improved were in use in Belgium, and as late as 1899 I saw in the United States furnaces dating from 1869 (of



Belgian Furnace, used in Kansas, 1873–1908.

course with many rebuildings) which preserved the old lines, including the nine rows of retorts and the arch in the front wall (to support the roof arch, for which the charge was mixed by hand on the floor in front of the furnace in the primitive way. As late as 1899 also I saw retorts made by hand in the United States. These instances show the conservatism that has existed in the zinc industry, both in Europe and the United States. It has been more pronounced in the latter, because until recently there were comparatively few trained metallurgical engineers, and most of the smelters were content to follow blindly the lead of those who had gone before. Consequently there was little or no progress. E. C. Hegeler was practically the only one of the early zinc metallurgists who displayed noteworthy originality. Some of his innovations have been of questionable value, but in the history of zinc smelting in America his name certainly stands with that of Wetherill.

For roasting the blende, the Freiberg furnace and a form of shelf burner with five or more hearths, both types being raked by hand, were commonly used. Calamine — which in Missouri is chiefly zinc silicate — was calcined in brick shaft-kilns. At Bethlehem, Penn., lump blende was burned in grate-kilns, and at one time also in heaps, the finishing roast being done in a reverberatory furnace. Retorts were made by hand. The furnace charge was mixed on the floor in front of each furnace, and all the work about the latter was done by hand. In New Jersey and Pennsylvania the furnaces set right on the ground and had no cellars. Two charges per 24 hours were worked, especially in the East. On the whole the New Jersey-Pennsylvania practice was decidedly better than the Kansas-Missouri until only a few years ago. The only remarkable progress was in Illinois. Up to 1901 the general practice in smelting in Kansas was little less than shocking.

Previous to 1896 all of the smelters of Kansas and western Missouri employed the same methods that were adopted when the zinc-smelting industry was first established there during the decade 1870–1880. A description of their conditions, written by F. L. Clerc in Mineral Resources of the United States for 1882 is so accurate an account of the conditions at most of the works at Pittsburg, Kan., and vicinity in 1900 that it is here reproduced (slightly condensed):

"The furnaces are built with the ash-pits above the ground, with a sloping bank of earth or cinder leading up to the furnace floor. The buildings are scarcely more than sheds, and are huddled together with little regard to their mutual relation. The first cost of the buildings is inconsiderable. In the smelting process the cheapness of the fuel renders economy in this direction unimportant, and the cheapness of living makes labor obtainable at wages as low as anywhere in the country. The works are usually owned by partners, who do the work of salaried employees, and consider as profit what would be only the interest on their money and their wages at some other occupation. The furnaces roughly constructed of inferior material will not long sustain the heat required to exhaust the zinc from the cinder, and it is the accepted opinion that there is no economy in "butchering" the furnace for the sake of a small additional percentage of metal; it is preferred to increase the production of the furnace and to reduce the cost of labor and fuel by increasing the charge of ore — in other words to butcher the ore and save the furnace. At the same time the personal supervision of the proprietors and their intimate knowledge of the business makes possible results that could not be expected by a company operating on a larger scale."

Since Mr. Clerc wrote as above there were of course some improvements in the older Kansas and Missouri works, and during the decade 1890–1900 most of them passed out of the hands of individual proprietors into those of joint stock companies, but the smelting practice continued to be very backward in many respects. Nevertheless many of these plants earned fortunes for their owners. This is further explained by Mr. Clerc, as follows:

"But the most secure advantage these works have over those at a distance comes directly from the manner of buying the ore. It has been seen that ores are not sold on their contents of metal, and that the miners are absolutely ignorant of their value; ores differing 5 or 6% are often held at the same price. A personal knowledge of the ores of particular diggings, and their behavior and yield in the furnace, often enables these smelters, by a slight advance in price, to pick up desirable lots of ore, and at the same time raise the price of all the ore held in the neighborhood. The smelters at a distance, buying in very much larger quantities through agents who are ignorant of other branches of the business, are placed at an evident disadvantage. This system of personal supervision of all branches of the business by the owners of the works is clearly applicable only to very small works; while labor-saving machinery and facilities for handling the ore can only attain the maximum economy when large amounts of material are to be handled — consequently when the works are large, and the machinery is constantly kept employed. On the other hand, under these favorable circumstances, in every prosperous owner of a mining lot and in every enterprising furnace brigadier is to be seen the possible proprietor of a new smelting works. It is from lack of sufficient capital and knowledge of the commercial part of the business to market their product advantageously that the weakness of such companies mainly arises. The accumulation of a few months' metal is sufficient to tie up all their capital and exhaust their available credit. Sales are made through commission men, with orders to sell the metal for what it will bring. Large consumers, knowing the condition of affairs, are careful to get the lowest bids before making purchases. Large metal houses, who might otherwise dispose of the whole product, are not disposed to have much to do with it; for no price above actual cost is safe to buy the metal at in order to sell it again. Occasional good sales, or cheap lots of ore, give uncertain profits; and a slight rise in the price of metal is sufficient to "fire in" new furnaces. Under such circumstances no real advances in the metallurgy of zinc are to be expected.

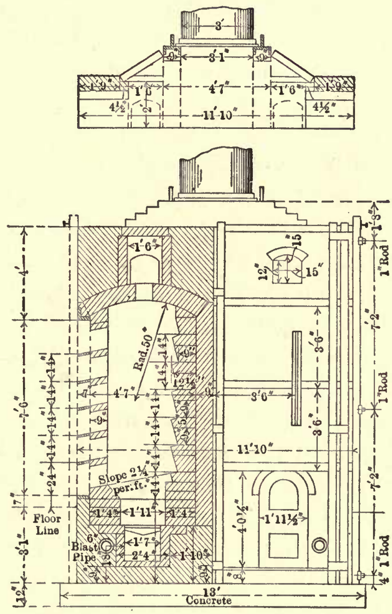
"Two companies controlling large bodies of mineral land — the Southwestern Lead and Zinc Co. and the Granby Mining and Smelting Co. —

have been driven to undertake the smelting, in part at least, of their own ores, in the hope of obtaining a certain sale for their ore product, which will enable them to pursue some definite policy in the management of their mines. The undertaking is not without its difficulties in the present state of the zinc industries. The strength of their position lies in their ability to supply their works with ore, without the risk of carrying a large stock on hand, and at the same time to develop their mines and increase the amount of their royalties and their profits from lead smelting."

The two mining companies above referred to entered the smelting business, the Granby company erecting a works at Pittsburg, Kan., and the Southwestern company building at Rich Hill, Mo. Both showed a desire to improve the commonly existing smelting practice and installed Siemens furnaces of the same type as used at Peru. However, these furnaces did not prove entirely successful either at Pittsburg or at Rich Hill, and consequently the other smelters of the district could not see any inducement to adopt them, and gas firing received a setback from which it did not recover. The failure of the Siemens furnace in Kansas and Missouri appears to have been due chiefly to ignorance as to the proper management of it and its accessory gas producers. The latter were of the original Siemens form, which is now recognized to have been seriously defective. The same producers were installed in the beginning at Peru, Ill., but in course of time were abandoned in favor of more modern and efficient forms.

Aside from the matter of the furnaces these attempts of mining companies to engage in the smelting business did not prove commercially successful and after some years were abandoned; the Granby works were dismantled early in the nineties, but the Rich Hill works have been operated rather steadily by lessees, who have used, however, direct-fired Belgian furnaces erected near the old Siemens furnace. The conditions of ore production in the Joplin district have never been favorable to company operations on a large scale. The mining company controls only the ore which it mines from its own land. In the case of ore mined in leased land, or ore mined by sub-lessees, other persons have a contractual interest in the production, and it has been found almost impossible to reconcile the various interests in agreement upon a broad policy having the future in view rather than the immediate present. It is only since 1901 that there has been any material change in this respect and a tendency among the mining companies to reënter the smelting business, in which the Granby company, purchasing a smeltery at Neodesha, Kan., in 1901, was again the leader. Since then its lead has been followed by the United Zinc Companies, and the American Zinc, Lead and Smelting Co., two of the most substantial of the Boston companies, which became interested in the Joplin district in 1899.

In New Jersey and Pennsylvania the practice in zinc smelting remained as backward as in the West. The only essential difference was a somewhat better construction of the furnaces. The latter were direct-fired Belgians, but were characterized by absence of cellars into which ashes and residues could be dropped for easy removal. The furnaces were built up simply from the floor, with only a shallow ash-pit under the grate, and the residues were raked out of the retorts to fall on the floor in front of the furnace, whence they had to be removed by shoveling. The furnaces were designed for the use of small sizes of anthracite, which was burned with an under-grate blast. They were divided by a longi-



Distillation Furnace used in New Jersey, 1901.

tudinal wall and a transverse wall into four sections (as were also some of the Western furnaces), but after a while the transverse walls were omitted. The retorts were cylindrical, but were only 6½ to 7 in. in internal diameter, instead of the 8 in. common in the West. The lower row of retorts was protected from the radiated heat of the fire by a row of thick tubes, called cannons, about the same size as the retorts, but open at both ends. There were commonly seven rows of retorts, 224 retorts per furnace massive, or "block." The retorts were charged twice per 24 hours and prolongs were used. In other respects the works were of simple construction. The ore to be smelted being of oxidized character, roasting furnaces were not required except at Friedensville and Bethlehem. The works built at Pulaski, Va., in 1879, was unique in the installation of furnaces with only one range of retorts, instead of two, and the employment of retorts of larger diameter than commonly.

While the smelters of Missouri-Kansas and New Jersey-Pennsylvania remained for many years at a standstill in their smelting practice, those of Illinois, especially Matthiessen & Hegeler were making noteworthy advances. Mr. Edward C. Hegeler early directed his attention to gas firing and showed that it practically eliminated the restrictions as to height of a distillation furnace; only since it would have been inconvenient to build and operate a furnace so high as his system of firing permitted he built a very long furnace and turned the gas in at one end, which came to substantially the same thing as if he had built a furnace of equal height and turned the gas in at the bottom. This was accomplished by introducing the quantity of gas required to heat the whole furnace and burning it gradually by the introduction of air at intervals.

Hegeler's first large furnace, which was erected in 1872, had a long, high-arched combustion chamber, 40 ft. long, containing 408 retorts (204 per side), arranged in five rows. In connection with this furnace there were many peculiarities, which were abandoned in later constructions, but the general principle has remained unchanged and the length of the furnace was increased finally to 1008 retorts, but that was found to be too long for satisfactory working and the number was reduced to 864. As to whether these excessively long furnaces are good or bad practice is more properly the discussion of a metallurgical treatise than an historical. It is sufficient to remark that their use has been confined to Lasalle, Ill., and to works in the natural gas field of Kansas, where, however, the tendency has recently been somewhat against them. However, the long Hegeler furnace certainly had the important result of leading to the introduction of labor-saving devices for charging and discharging the retorts, which subsequently became a distinctive feature in American zinc-smelting practice in general. The method of preparing the charge by means of a mechanical mixer and bringing it to the furnace in a large car, moving on a track in front of the furnace, from which it could be shoveled directly into the retorts; the tapping of the spelter from the condensers into a kettle carried by a truck, with a shield to protect the men from the heat of the furnace; and the drawing of the residues from the retorts with the aid of a car, having a protecting shield and rollers to support the heavy rabbles which are put into the retorts; these were all in regular use at Lasalle previous to 1882. Also in use at that time were the augur machine for making retorts and a plunger machine for making condensers.

Another event of much historical interest was the invention of the Hegeler roasting furnace, in 1881, and with its aid the beginning of sulphuric acid manufacture as a by-product of blende roasting in the same year. Mechanical roasting furnaces had previously been used in Europe, but had not found much favor and to this day are regarded somewhat askance even for simple roasting, not to speak of roasting for sulphuric acid manufacture. Yet the Hegeler furnace has been in regular and successful use since 1881. However, these anomalies are so many in the practice of zinc smelting that it is needless to express surprise at any disregard of successful precedents which appears in history.

Indeed, the greatest anomaly of all is the disregard in the United States of the technical methods of Matthiessen & Hegeler, who were well known to be the most successful — commercially — of all who were engaged in the zinc industry in the West. In 1882 their works had a capacity of 28 to 30 tons of metal per day, and were the largest in the United States. They were making not only spelter, but also sulphuric acid and sheet zinc. In the sheet zinc market they had for many years (since 1868) enjoyed a highly profitable monopoly, the price obtained for sheet being about 2 c. per lb. higher than the price for spelter. Regardless of all this, the other smelters, with one or two exceptions, were still following the careless, slovenly methods described by Mr. Clerc, and continued to do so for 15 years later. It is to be explained that many of the furnaces and machines of Matthiessen & Hegeler were patented, but there were no generic patents among them, and it displays a poverty of invention that others were not able to design non-infringing devices to accomplish the same purposes.

The shining exception among the other zinc smelters was the Illinois Zinc Co., of Peru, across the river from Lasalle, which in 1882 had the second largest works in the United States (capacity 18 to 20 tons per day) and at that time had three Siemens-Belgian furnaces in operation, the first of these having been erected in 1877. Alongside of these, however, were old direct-fired Belgian furnaces, some of which were still in operation as late as 1900, but were abandoned shortly after that. The Siemens furnaces at Peru were of a peculiar construction, and probably not of the best design, but they have given satisfactory results and have been in constant use with only slight modifications in design. The plant of the Mineral Point Zinc Co. at Depue ~~Peru~~, Ill., completed in 1906, has been equipped with the same type of furnace. The Illinois Zinc Co. followed closely the footsteps of Matthiessen & Hegeler. In 1882 it erected a rolling mill. A few years later it put up a sulphuric acid factory, using hand-raked muffle furnaces for roasting the blende. Later, when the basic patents on the Hegeler roasting furnace expired, it adopted that type.

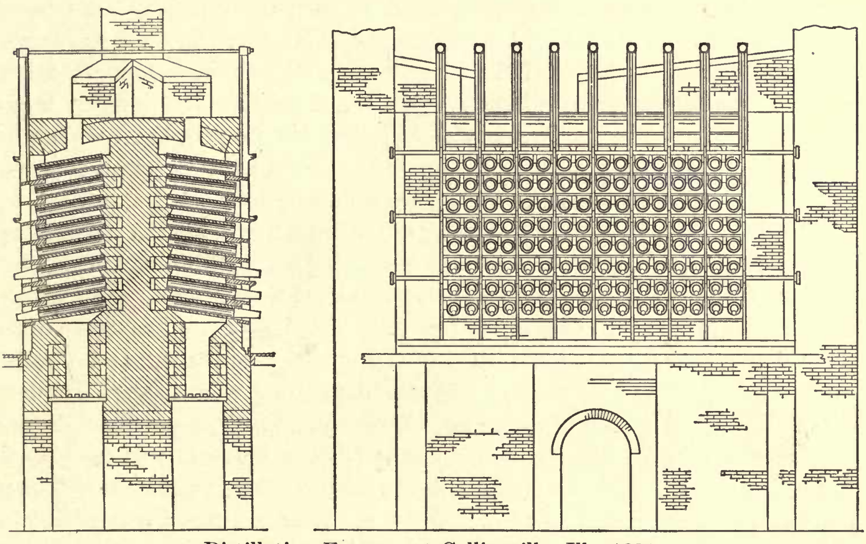
Among the other smelters, the improvements between 1882 and 1896 were comparatively few and related chiefly to details. The augur machine for making the retorts came into general use. The old practice of distilling two charges per 24 hours was abandoned in favor of the modern practice of one charge per 24 hours, which rests on sound metallurgical principles. In the West the furnaces with eight and nine rows of retorts were gradually abandoned, seven rows high (16 in a row, giving 224 retorts per double furnace) becoming the standard. In the East the furnaces were reduced to seven rows high, and even to only four; six and seven being the common arrangements. Also, in the East the cylindrical retort was abandoned in favor of the elliptical, but the latter has never been employed in the West, except in connection with the Siemens furnaces at Peru, Pittsburg, and Rich Hill, which had large Rhenish retorts, and the Rhenish furnaces which have lately been built at Pueblo, Colo., and Iola, Kan. The use of prolongs was continued in the East, but was abandoned in the West on the ground that the extra saving of zinc by them did not compensate for the extra labor entailed by them.

Between 1891 and 1900 various improvements began to be introduced, but still these were mostly in details and in so far as they related to the essentials of zinc smelting they were approached in a half-hearted way. Thus one of the keys to successful zinc smelting is the manufacture of the densest and most refractory retort that is possible. European smelters had already accomplished this by the Dor press, whereby the retorts are molded by great hydraulic pressure. As early as 1893 these presses were introduced in New Jersey and Pennsylvania, but apparently it failed to be recognized how important an instrument they were.[1] Experiments in gas firing with a Rhenish recuperative furnace were made at South Bethlehem in 1894, but not until the Palmerton works were erected in 1899–1901 did either this form of furnace or the system of firing come into use on a large scale. H. C. Meister at Collinsville, Ill., had exemplified the proper construction of a distillation furnace house, the whole furnace being erected above the ground level, with an upper working floor, the inconvenient, unsanitary, and uneconomical cellars and tunnels of the ordinary Western construction being thereby dispensed with, but he found no imitators until the Palmerton works were constructed. Except at Lasalle and Peru gas firing, *i.e.*, with producers, found no application whatever until after 1900. Another of the keys to successful zinc smelting is the proper mixture of the charge. Matthiessen & Hegeler had shown in the eighties how best to do this, but the lesson passed unlearned. About the only improvement that the Kansas smelters originated was the blowing out of the residues from the retorts by the injection of steam. The hot steam pipe being disagreeable to handle,

[1] These presses, invented by E. Dor, a Belgian engineer, were used at the Asturienne works, at Auby, France, as early as 1877, and in 1893 were employed at almost all of the works in France, Belgium, and Rhenish Prussia.

this was superseded by the questionable practice of introducing water, the explosion of which ejects the residues.

The great innovation in the early nineties was the introduction of the mechanical roasting furnace. The Brown horseshoe furnace had been successfully employed for the roasting of copper ore. H. C. Meister, of the Collinsville Zinc Co., conceived that it could equally well be used for the roasting of blende, and in 1893 erected one at Collinsville. About the same time S. C. Edgar put one in at the Glendale works, at St. Louis. The experiment was entirely successful, and after that had been proved by a few years of operation, no zinc smelter thought of employing anything but a mechanical furnace if it were possible to do so. It is true



Distillation Furnace at Collinsville, Ill., 1891.

that the Hegeler furnace had been in successful use for more than 10 years before the Brown furnace was introduced, but although it was a mechanical furnace, nevertheless it required a comparatively large amount of labor in attention and was of comparatively high first cost, which were of relatively insignificant considerations in connection with sulphuric acid manufacture, but not so for simple roasting. Moreover, the Hegeler furnace was closely covered by patents.

The Brown furnace also was patented and the Collinsville Zinc Co. and S. C. Edgar secured the rights to use it in the States of Indiana, Illinois, Missouri, Kansas, and Arkansas. They aimed to retain for themselves the advantage in smelting which it conferred. This advantage was a large one. The cost of labor in roasting per ton of ore in the old kilns and reverberatories was about $1.25; with the Brown furnace it was only about $0.45. Naturally, the other smelters were on the alert to put themselves on an equal footing in respect to this great economy. Unable to use the Brown furnace, they tried the Pearce, Wethey, Ropp and Zellweger, it being about 1898 when general attention was turned in this direction. The Pearce and Wethey furnaces did not prove so successful, but the Ropp furnace, which was introduced by the Lanyons at Iola, Kan., did fully as good work as the Brown. The owner of the Brown patents, together with the Collinsville Zinc Co. and Edgar Zinc Co., then brought suit against the Lanyon Zinc Co., claiming that the Ropp furnace was an infringement of the Brown. There resulted a litigation which ranks among the most costly and most hard fought over a metallurgical patent. In court after court the Brown patents were sustained and the Ropp held to be an infringement. Then Mr. Joseph Cappeau, general manager of the Lanyon Zinc Co., devised a modification of the Ropp furnace, according to which the Ropp furnaces already built could easily be altered. This was done. The Brown people immediately brought suit against the Lanyon Zinc Co., claiming the Cappeau furnace to be an infringement. In this they were defeated.

However, the litigation left the best furnaces still in the control of patent owners, or rather the furnaces which had been demonstrated in practice to be successful, and the other smelters were slow to experiment with different forms. Consequently, only the Zellweger has come into general use, and hand-worked kilns of the old type continued to be built, up to two or three years ago, although in roasting with natural gas the cost is about 85 c. per ton, against only about 35 c. in mechanical furnaces. The Brown furnace was a distinct invention. It was developed from the old O'Harra furnace. In the latter great practical difficulty had been experienced in keeping in order the rails and running mechanism of the stirring carriage. Brown overcame this difficulty by putting those parts in recessed chambers at each side of the roasting hearth, the frame of the stirring carriage passing through a continuous slot at each side of the hearth. Ropp put a tunnel under the hearth, with a slot in the center of the latter. The courts held that this tunnel was a recessed chamber adjacent to the hearth and consequently infringed the Brown patent. Cappeau removed the side walls of the Ropp furnace below the hearth, and supported the latter on legs. The court held that this was not an infringement, because the furnace being entirely open under the hearth, there was nothing there resembling a chamber.

Economically the great advance in the metallurgy of zinc in the United States has been the result, not of technical improvement, but of a wonderful bounty of nature. This is the occurrence of natural gas in comparatively close proximity to the zinc mines of the Joplin district. By the utilization of this the zinc smelters were able to acquire many of the advantages of producer-gas firing, together with some others of great importance, and practically none of the disadvantages. At first the use of natural gas was a case of fuel obtained at practically no cost, with no handling involved and no ashes to be removed. Such an industrial gift is almost without parallel in the economic history of the world.

Natural gas was first used for zinc smelting in the United States in Indiana, where several small works were erected about 1892. The reason for the establishment of the industry was simply that gas existed there. Ore was available from Wisconsin and from Missouri; also in small quantities from Kentucky and Tennessee. In many respects the inauguration of zinc smelting in this district was well considered. The district commanded several ore supplies; the chief market for spelter was further to the east; in general it is economical to transport zinc ore rather than spelter so long as it be going in the direction of the final consumption of the spelter. However, the management of the Indiana smelters was not broadly and vigorously conducted. The business was not developed to the extent which would have commanded from the railways an equality in freight rates with Lasalle and Peru and consequently remained at a disadvantage in that respect. The natural gas supply had from the beginning a cost which did not give it any great advantage over coal, and it soon waned and increased so much in cost that the industry was abandoned. By 1900 it was practically dead, although one works at Marion continued to run in a fitful way for two or three years longer.

The Indiana smelters were quite rational in their adoption of furnaces. The best of them simply erected the standard Belgian furnace and turned in gas at the bottom, which burned instead of coal on a grate. On the whole their works were crude, the furnaces being built without ash-pits or cellars (like those of New Jersey), wherefore the labor in connection with them was comparatively high, and except for the method of heating the furnaces there was nothing new in their practice.

It is unnecessary for present purposes to go into the early history of natural gas in Kansas. It is sufficient to remark that by 1895 the developments at Iola were decided by Robert Lanyon and brother to warrant the risk of erecting a smeltery there. They had previously been engaged in smelting at Pittsburg, Kan. They deserve much credit for their boldness in venturing a large amount of money in works dependent upon a new and uncertain supply of fuel, but further than that they displayed little originality and indeed their misconception of the problem before them was subsequently to prove of decidedly bad effect on the zinc-smelting practice in general. The Lanyon family has been for 40 years prominently identified with zinc smelting in the United States. Commercially it has been highly successful, but this has been due to its intimate knowledge of the market conditions, especially its shrewdness in buying ore, and its close supervision of all the details of the business. Technically it has made few contributions to smelting practice, and indeed has been, through its inattention to the metallurgical principles and failure to appreciate their importance, a retarding influence rather than a progressive one. In the case of the Iola furnace its influence was not merely retarding, but also was misleading.

Instead of imitating the practice in Indiana, where zinc smelting was already being done successfully with natural gas, the Lanyons decided to imitate the Hegeler furnace, used with producer gas at Lasalle. Consequently they erected a long furnace, five rows of retorts in height, with 60 in the row, the furnace massive having 600 retorts. It was attempted to turn in the gas at one end and introduce the air at intervals along the front, just as at Lasalle, but it was omitted from consideration that at Lasalle the fuel was hot, comparatively weak, producer gas, while at Iola it was practically pure methane (CH_4). The result was simply what ought to have been expected.

At the temperatures which are frequently obtained in industrial firing, especially in zinc smelting, the hydrocarbons of a fuel gas, either artificial or natural, are subject to dissociation, *i.e.*, they are split up into their elementary constituents, carbon and hydrogen. If this happens in the presence of an adequate supply of air both the hydrogen and carbon will be burned, the former to aqueous vapor and the latter to carbon dioxide. If, however, the supply of air be insufficient only the hydrogen may be burned, while the carbon will be deposited as soot. With natural gas, of which upward of 90% is hydrocarbon, more difficulty is liable to be experienced on this account than with ordinary fuel gas, which is comparatively poor in hydrocarbons. This dissociation of hydrocarbons with the accompanying deposition of soot is liable to cause trouble in metallurgical firing with natural gas unless it be prevented. The fact that natural gas is dissociated in that manner is, however, one of the attributes to which it owes its great heating power, the latter being due largely to the radiation from the incandescent particles of carbon which are set free. If they be deposited as soot the remedy is simple, consisting merely in providing a requisite supply of air and insuring its thorough mixing with the gas. This was not understood in the early day of natural gas firing at Iola, Kan., and deposits of soot were permitted to form around the retorts in the distillation furnaces, reducing the heat conductivity of the walls of the retorts and consequently the extraction of metal from the ore, the soot sometimes accumulating to the extent that the passages for the combustion products between the retorts would be completely closed and had to be opened by barring.

Other smelters who built at Iola followed blindly the lead of the Lanyons, duplicating their furnaces simply because they were the only ones they knew and their previous practice had been distinctly imitative. The Iola furnace thus having become established, efforts had to be directed toward making it work properly. Of course it soon was perceived what was the root of the trouble, and changes were made to circumvent it. Admission of the gas at one end only of the furnace was discontinued, and pipes were laid on to introduce it through small jets at intervals along the front. The jets were reduced in size and the pressure was greatly reduced. These improvements were of gradual development. In 1899 there were five smelteries in operation at Iola and all were experiencing trouble. The cost of smelting as compared with the cost at Pittsburg, Weir, and the other points in the coal field was largely in favor of the gas smelters, but their extraction of metal was so much lower in percentage that the net result was to keep the two methods of smelting on substantially an equal footing. Even so late as the summer of 1899 many of the coal smelters did not realize that there was going to be any advantage in natural gas smelting. However, it was only a matter of a year or two more before the gas smelters surmounted the difficulties of securing a proper combustion in an unfortunate type of furnace and increased their percentage of metal extraction to as high a point as had ever been reached by the coal smelters.

In erecting its works at Cherryvale, Kan., the Edgar Zinc Co. installed furnaces after the Indiana type, but greatly improved, and never experienced any of the trouble that the Iola smelters went through and effected a high percentage of metal extraction from the beginning. In their later practice the Iola smelters to a considerable extent abandoned the long furnaces, erecting new ones of only half the length, it being perceived that the labor-saving devices introduced also from Lasalle were not dependent upon a continuous long furnace, but could be used just as well with two shorter furnaces in line. The same thing had been perceived several years earlier at Cherryvale, where three short furnaces were arranged in line. It is now generally recognized that there is no advantage in building a zinc distillation furnace of excessive dimensions, while there are several disadvantages. A further improvement in the Iola furnace was the reduction in height from five rows of retorts to four rows, which made it considerably easier for the men in charging and discharging.

Up to the utilization of natural gas in Kansas there had been little change in the general cost of smelting for many years. The smelters at Pittsburg and vicinity had available a large supply of slack coal, which was available so cheaply that in spite of their extravagant use of it the total fuel cost in smelting was low as compared with European conditions. In 1882 slack cost about 50 c. per ton and run of mine \$1 to \$1.50.

About the same figures prevailed in 1899. The wage for common labor was $1.50 per 10 hours, and for all the men employed in the works the average was probably about $2 per day. Substantially the same conditions existed in 1899. The cost of smelting in 1899 was $10 to $12 per ton of ore in the majority of works and probably had been in the neighborhood of those figures for 20 years previously. Such improvement as there had been in the practice was chiefly in the increased extraction of metal. In the treatment of Joplin ore in 1899 the extraction in the best managed works was about 82% of the zinc. What it was in former times no one knows. It was not until 1898 or 1899 that any company in this field regularly employed a chemist to sample and assay the ore smelted. No further comment on the backwardness and carelessness of the practice is required. It is fair to suppose that as experience was gained in the art by the rule of thumb methods practiced, and as little improvements were made, there was some advance in the metallurgical result, but as to how much there is uncertainty. It is to be borne in mind that the Joplin ore was, and still is, almost the ideal ore for successful zinc smelting. The smelters required it to be almost pure blende and of ridiculously low content in iron and lead. Ore containing more than 2% iron and 1% lead, or less than 55% zinc, was purchased only at a heavy discount. When the first Colorado ore (from Creede) was smelted in 1899 the result was utterly disastrous. Yet the same ore became regarded inside of five years as something exceptionally desirable.

The smelters of Illinois and the St. Louis district had all along a decidedly better metallurgical practice than those of Kansas, but they labored under certain disadvantages, and except at the large works in Illinois, where gas firing was employed, the cost of smelting was not much different from what it was in Kansas. The works at Lasalle and Peru made sulphuric acid as a by-product, wherefrom there was a profit corresponding to $4 per ton of ore, and they made a further large profit out of rolling their spelter into sheet zinc, in which business they had for many years, and practically still have, a monopoly.

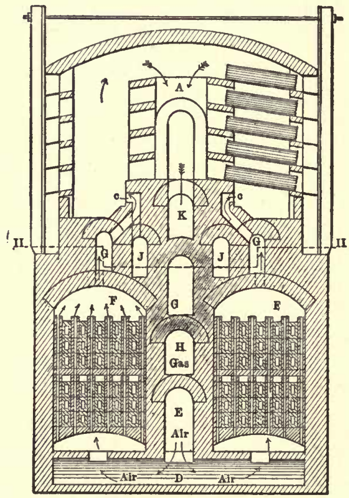
The smelters of New Jersey, Pennsylvania, and Virginia operated for a little less per ton of ore than the Kansas, and made a metal extraction of about 82%, but they used a considerably lower grade of ore and the latter was of decidedly more difficult smelting character, wherefore their results were the more creditable.

The inauguration of smelting with natural gas in Kansas led almost immediately to a reduction of the smelting cost to $7 per ton of ore, corresponding to an economy of 0.3 c. to 0.5 c. per lb. of spelter, inasmuch as 2000 lb of the Joplin ore of the usual grade yielded about 1000 lb. of spelter. This great economy was due partly to the almost complete elimination of the fuel cost;[1] partly to the saving in labor, there being no fuel or ashes to handle; and partly to a greater sub-division of general expense, the works being larger. Whereas formerly a works with six blocks of furnaces, smelting 12,000 tons of ore per year, was a large plant, the works in the gas field, with their larger furnaces, were never begun with less than three furnaces, giving a capacity for smelting 15,000 tons per year, and every time a new furnace was added it increased the capacity by 5000 tons. As soon as the gas smelters raised their extraction of metal to the same percentage as the coal smelters they naturally put the latter out of business. This happened in 1901.

However, the gas smelters reckoned incorrectly that their gas supply was costless. The Iola pool was exceptionally favorably situated, being more or less in the shape of an elongated ellipse with a line of railway running through it on the major axis. The smelters were able, therefore, to build their works right alongside the railway and obtain gas by drilling in the immediate vicinity, sometimes in their own yards. Certain of them ran their works for three or four years from two gas wells costing $1500 each and 1200 ft., or so, of 4-inch pipe line, costing about $600, and in such cases the cost of the gas was an insignificant fraction of a cent per 1000 cu. ft.; but other smelters made expensive investments in gas land, well-drilling and pipe lines, and in their cases the gas really came to a considerable figure when they reckoned up the cost with the realization that they had not been making an investment on capital account but had merely been anticipating their fuel bill for several years ahead. Moreover, the time came in a few years when the gas pressure diminished largely under the heavy and constant drain, and more wells had to be drilled and larger pipe lines put down to secure and convey the requisite supply of gas at the lower pressure. Finally it developed that the supply of gas at Iola was no longer sufficient to justify the erection of more works at that place, and the projectors of new works had to look to Neodesha, Altoona, Chanute, Caney, Deering, Coffeyville, and other places in the Kansas gas field, but at none of them was there a large gas pool underlying a town with good railway connections and other necessary facilities as at Iola, and it was a case from the outset of locating the works at the railway, and near the town, and reaching out for the gas with pipe lines of considerable length; also the value of gas land had increased greatly in the meanwhile; consequently, the immediate investments, together with the maintenance charges, put a cost of 1 c. to 2.5 c. per 1000 cu. ft. on the gas. By 1903 this, and some increase in the wages of smelter men, had raised the cost of smelting to $8 or $8.50 per ton. Even by

[1] In referring to fuel, the zinc smelter means only the coal or gas required to heat his furnaces. The coal of special character which is mixed with the ore is "flux," or more properly, "reduction material."

that time it was apparent that the natural gas field would soon lose its prestige, because of the probability that a modern works of good engineering design and construction, with sulphuric acid chambers for recovery of that by-product, in the coal field of Illinois, or further East, would be on equal terms with the Kansas works and would have a far longer life. This forecast was borne out in 1906 when two large works were erected in Illinois and another was projected. However, building in the Kansas gas field continued, even extending into the Indian Territory, and is justified under special conditions as to local gas supply, etc., but it is obvious that the industry in that section will not become a permanent one, and will always have a perambulatory character.

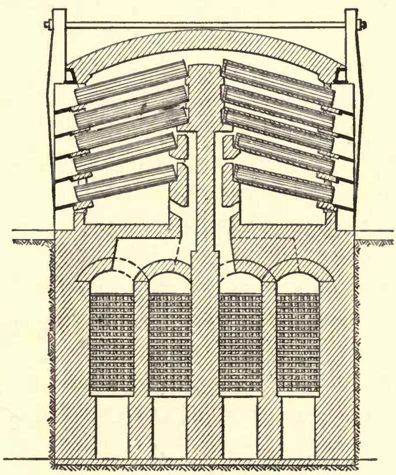


Convers & DeSaulles Furnace,
Palmerton, Penn.

Since 1901 there has been a great advance in American zinc-smelting practice; more perhaps than in the entire previous history of the industry. The Kansas and Missouri smelters have learned to treat the base ores of Colorado and elsewhere in the Rocky Mountains, at first only with poor extraction of metal, but soon with greatly improved results. The outcome of this advance in their art was the exclusion of the European smelters from the American market and the importation of large quantities of ore from British Columbia and Mexico. The marvelous utilization of these new sources of ore supply is marked by the fact that out of 190,000 tons of Western spelter produced in 1905, about 54,000 tons was derived from ore mined west of the Rocky Mountains, including British Columbia and Mexico.

In 1901 zinc smelting was inaugurated in Colorado, at Pueblo, by the

United States Zinc Co., a subsidiary of the American Smelting and Refining Co. This company erected a large and costly plant, a duplicate of one of the most modern plants in Belgium. This led to the introduction in the United States of the Belgian practice of resmelting the residues remaining from the distillation of zinc in blast furnaces for recovery of their gold, silver, and lead contents. The same practice was subsequently attempted by the Cherokee-Lanyon Spelter Co. in the Iola district, Kansas, but under the conditions there it proved a failure. The Pueblo works were equipped with gas-fired Siemens furnaces of the Overpelt type. The great works of the New Jersey Zinc Co. at Palmerton, Penn., were also equipped with gas-fired recuperative furnaces, but the tendency



Neureuther-Siemens Furnace, Peru, Ill.

there has been strongly toward the counter-current system of heat recuperation. At the works of the Mineral Point Zinc Co. at Depue, Ill., the Neureuther-Siemens furnace, which is used at Peru, was adopted. These new works mark the progress in gas-firing and regenerative furnaces in the United States. As illustrative of their economy, it may be remarked that in 1906 the direct-fired Belgian furnaces at South Bethlehem, Penn., required 2.75 to 3.30 tons of anthracite, rice size, per ton of ore, while the regenerative furnaces at Palmerton used only two tons, and even the latter figure would not normally be considered good practice in zinc smelting.

In extraction of metal from the ore there was a great advance, and economically this was the most important of all, inasmuch as each percentage of additional extraction corresponds roughly to 50 c. per ton of ore smelted. In the East the average extraction of 82% in 1895 had become 86% in 1905. In Kansas and Missouri the average extraction in 1899 was about 80%; in 1905 it was about 85 to 86% in the case of the docile Joplin ore, which only was smelted in 1899; in the case of the baser, more difficultly smelted Rocky Mountain ore the extraction was not quite so high. A large part of the increased extraction of metal was due to the more general use of the hydraulic press for molding the retorts; a large part was due to a better knowledge of the principles of zinc smelting and scientific control of the work. In 1898 only a few works employed a chemist; in 1905 there were few which did not, and many employed also metallurgists and engineers.

Another noteworthy development of these five years was the introduction of the practice of keeping separate the first draw of metal from the condensers for sale as special spelter. The first part of the distillation being conducted at the lowest temperature, the metal coming over then is lowest in lead, and on that account is salable at a premium of \$2 to \$3 per ton over "ordinary prime Western," while the metal of the second and third draws is still sufficiently low in lead to serve for galvanizing and some other purposes. Obviously this classification was of material advantage to the smelters.

In the manufacture of zinc oxide, the recent improvements were largely of a mechanical character. The great plant of the New Jersey Zinc Co. is a wonderful example of modern construction in this respect. For many years the New Jersey Zinc Co. and its subsidiary companies had a monopoly of the manufacture of zinc oxide, but a few years ago the Ozark Smelting and Mining Co. entered the business, building a works first at Joplin, Mo., and then a second works at Coffeyville, Kan., and the success of these showed that there was no secret in the manufacture of zinc oxide and directed attention to that industry which promises to have important commercial results. For many years the United States Smelting Co. at Cañon City, Colo., had been making a zinc-lead pigment and the Picher Lead Co. had been making sublimed white lead. The ready sale of those products induced the Ozark Smelting and Mining Co. in 1906 to undertake the manufacture of zinc-lead white, using mixed sulphide ore from New Mexico. This proved entirely successful and opened a new use for that class of ore, which only 15 years previous was utterly valueless.

In summing up the status of American zinc smelting at the end of 1907, it is no longer to be said that as compared with European practice it is characterized by backwardness. It is rather to be said that while the European practice excels in some respects, the American excels in others. In most matters of mechanical handling, and in roasting blende ore, the American is decidedly ahead. In the construction of the distillation furnaces and in distillation practice, including the recovery of by-products, the European leads. The cost of smelting is about the same in the two Continents. The cheaper labor of Europe is offset by its dearer fuel. In percentage of metal extraction, the European smelters on the whole have the advantage, but it is not a large one. In conclusion, it may be said that the American zinc-smelting practice, capable as it is of further great improvement, is no longer a branch of metallurgical industry to be ashamed of.

XXIII

COMMERCIAL CONDITIONS

THE commercial history of the zinc industry in the United States is concisely reflected in the statistics, which are available with completeness, in so far as production, imports and exports, and consumption are concerned, back to 1873. These statistics are summarized in the following tables:

PRODUCTION OF SPELTER BY STATES [1]

(In tons of 2000 lb.)

Year	New Jersey and Pennsylvania	Virginia and Tennessee	Total East	Indiana and Colorado	Illinois	Kansas and Oklahoma	Missouri	Total West	Grand Total
1882	5,698		5,698	....	18,201	7,366	2,500	28,067	33,765
1883	5,340		5,340	....	16,792	9,010	5,730	31,532	36,872
1884	7,861		7,861	....	17,594	7,859	5,230	30,683	38,544
1885	8,082		8,082	....	19,427	8,502	4,677	32,606	40,688
1886	6,762		6,762	....	21,077	8,932	5,870	35,879	42,641
1887	7,446		7,446	....	22,279	11,955	8,660	42,894	50,340
1888	9,561		9,561	....	22,445	10,432	13,465	46,342	55,903
1889	10,265		10,265	....	23,860	13,658	11,077	48,595	58,860
1890	9,114		9,114	....	26,243	15,199	13,127	54,569	63,683
1891	8,945	4,217	13,162	....	28,711	22,747	16,253	67,711	80,873
1892	9,582	4,913	14,495	....	*a* 31,383	24,715	16,667	72,765	75,328
1893	8,802	3,882	12,684	....	*a* 29,596	22,815	13,737	66,148	89,686
1894	7,400	1,376	8,776	2,173	26,799	25,588	11,992	66,552	81,499
1895	9,484	3,697	13,181	3,736	31,996	25,775	14,998	76,505	99,980
1896	8,139	2,427	10,566	1,595	34,578	20,759	14,001	70,933	74,399
1897	7,218	3,365	10,583	1,506	36,370	33,396	18,125	89,397	99,980
1898	8,631		8,631	2,654	44,449	40,132	19,533	106,768	115,399
1899	8,805		8,805	4,020	46,098	52,021	18,107	120,246	129,051
1900	8,259		8,259	....	*a* 38,750	62,136	78,806	115,627	123,886
1901	8,603		8,603	....	*a* 44,896	74,240	13,083	132,219	*b* 140,822
1902	12,180		12,180	....	*a* 47,096	86,564	11,087	144,747	*c* 156,927
1903	12,301		12,301	877	*a* 47,659	88,388	9,994	146,918	*d* 159,219
1904	14,893		14,893	4,871	*e* 47,740	107,048	12,150	171,809	*f* 186,702
1905	*e* 23,044		23,044	6,599	45,357	114,948	11,800	178,704	201,748
1906	30,167		30,167	6,260	48,238	129,741	11,088	195,327	225,494
1907	38,060		38,060	5,200	56,103	138,655	11,594	211,552	249,612

[1] Up to 1900, inclusive, the statistics in this table are from Ingalls, Production and Properties of Zinc; 1901–1904, from Mineral Resources of the United States; 1905–

CONSUMPTION OF ZINC IN THE UNITED STATES

(In tons of 2000 lb.)

Year	Production	Imports			Supply	Exports	Consumption
		Spelter	Sheet	Total			
1873..	7,343	3,420	5,561	8,981	16,324	37	16,287
1874..	10,000	1,797	3,008	4,805	14,805	22	14,783
1875..	15,833	1,017	3,660	4,677	20,510	19	20,491
1876..	16,000	474	2,306	2,780	18,780	67	18,713
1877..	17,500	633	671	1,304	18,804	720	18,084
1878..	19,000	635	628	1,263	20,263	1,273	18,890
1879..	21,000	710	556	1,266	22,266	1,066	21,200
1880..	23,239	4,046	2,035	6,081	29,320	684	28,636
1881..	30,000	1,430	1,364	2,794	32,794	746	32,048
1882..	33,765	9,204	2,207	11,411	45,176	745	44,431
1883..	36,872	8,534	1,655	10,189	47,061	426	46,635
1884..	38,544	2,935	476	3,411	41,955	63	41,892
1885..	40,688	1,758	920	2,678	43,366	51	43,315
1886..	42,641	2,150	546	2,696	45,337	459	44,878
1887..	50,340	4,194	463	4,657	54,997	68	54,929
1888..	55,903	1,913	148	2,061	57,964	31	57,933
1889..	58,860	1,026	507	1,533	60,393	440	59,953
1890..	67,342	1,000	391	1,391	68,733	1,648	67,085
1891..	80,262	404	11	415	80,677	2,147	78,530
1892..	84,082	149	14	163	84,245	6,247	77,998
1893..	76,255	213	14	227	76,482	3,723	72,759
1894..	74,004	194	20	214	74,218	1,804	72,414
1895..	87,591	372	21	393	87,984	1,530	86,454
1896..	81,878	520	14	534	82,412	10,130	72,282
1897..	100,387	1,453	8	1,461	101,848	14,245	87,603
1898..	114,104	1,371	....	1,371	115,475	10,500	104,975
1899..	129,675	1,493	....	1,493	131,168	6,755	124,413
1900..	123,231	1,007	....	1,007	124,238	22,410	101,828
1901..	140,822	388	....	388	141,210	3,390	137,820
1902..	158,237	619	....	619	158,856	3,237	155,619
1903..	158,502	364	....	364	158,866	1,521	157,345
1904..	181,803	467	....	467	182,270	10,073	172,197
1905..	201,748	521	....	521	202,269	5,516	196,753
1906..	225,494	2,204	....	2,204	227,698	4,670	223,028
1907..	249,612	1,778	....	1,778	251,390	563	250,827

In the above table, consumption has been computed without taking into account the difference in stocks of metal on hand at the beginning

1907, from The Mineral Industry. The statistics in the fourth column are the production of Indiana up to 1899; of Colorado from 1903 onward. (*a*) Including Indiana. (*b*) Including 2716 tons of dross spelter. (*c*) Including 2675 tons of dross spelter. (*d*) Including 3302 tons of dross spelter. (*e*) Including West Virginia, whose spelter is produced from Joplin ore. (*f*) Including 3300 tons of dross spelter.

and end of each year, statistics for which are unavailable over the whole period covered by the table.

PRODUCTION OF ZINC OXIDE IN THE UNITED STATES

Year	Quantity		Value, f.o.b. Works		Tenor in Zinc at 80%	
	Short Tons	Metric Tons	Total	Per Short Ton	Short Tons	Metric Tons
1880..	10,107	9,172	763,738	$75.38	8,086	7,338
1881..	10,000	9,083	700,000	70.00	8,000	7,266
1882..	10,000	9,083	700,000	70.00	8,000	7,266
1883..	12,000	10,899	840,000	70.00	9,600	8,719
1884..	13,000	11,797	910,000	70.00	10,400	9,438
1885..	15,000	13,625	1,050,000	70.00	12,000	10,900
1886..	18,000	16,344	1,440,000	80.00	14,400	13,075
1887..	18,000	16,344	1,440,000	80.00	14,400	13,075
1888..	20,000	18,149	1,600,000	80.00	16,000	14,519
1889..	16,970	15,390	1,357,600	80.00	13,576	12,312
1890..	*20,000	*18,140	1,600,000	*80.00	*16,000	*14,512
1891..	23,700	21,496	1,600,000	67.51	18,960	17,197
1892..	27,500	24,946	2,200,000	80.00	22,000	19,957
1893..	25,000	22,678	1,875,000	75.00	20,000	18,142
1894..	22,814	20,697	1,711,275	75.00	18,251	16,554
1895..	22,690	20,498	1,588,300	70.00	18,152	16,398
1896..	15,863	14,391	1,189,725	75.00	12,690	11,513
1897..	26,262	23,825	1,686,020	64.20	21,010	19,060
1898..	32,747	29,708	2,226,796	68.00	26,198	23,766
1899..	39,663	35,982	3,331,692	84.00	31,730	28,786
1900..	47,151	42,775	3,772,080	80.00	37,721	34,220
1901..	46,500	42,266	3,720,000	80.00	37,200	33,813
1902..	52,730	46,929	4,023,299	76.30	42,184	37,543
1903..	59,562	54,034	5,005,394	83.69	47,650	43,227
1904..	59,613	54,081	4,523,414	75.88	47,690	43,265
1905..	65,403	59,349	5,232,240	80.00	52,322	47,479
1906..	77,800	70,573	6,257,361	80.43	....	....
1907..	85,390	77,449	7,731,100	90.54	....	....

The statistics of production and price in the above table from 1880 to 1892, both years inclusive, are from the reports of the U. S. Geological Survey. Apparently the figures for 1881–1888 are approximate estimates rather than totals based on reports from the producers. The statistics from 1893 to 1906, both years inclusive, are as reported by The Mineral Industry. The figures marked with an asterisk are estimated.

The production for 1906 and 1907 includes zinc-lead pigments, and consequently is not strictly comparable with the figures for the previous years.

The production of zinc oxide in the United States, with the exception of an insignificant quantity, is made directly from ore, whereas the oxide produced in Europe is obtained by the combustion of spelter, its manufacture in that way constituting one of the important channels of European spelter consumption. In considering the relative importance of the United States as a zinc-producing country, therefore, its production of zinc oxide, reduced to the basis of its tenor in metallic zinc, should be added to the production of spelter.

Consumption of Zinc White in the United States

(In tons of 2000 lb.)

Year	Production	Imports	Supply	Exports	Consumption	Tenor in Zinc at 80%	
						Short tons	Metric tons
1894..	22,814	1,686	24,500	nil	24,500	19,600	17,777
1895..	22,690	2,273	24,963	24	24,939	19,951	18,096
1896..	15,863	2,286	18,149	2,324	15,825	12,660	11,483
1897..	26,262	2,782	29,044	1,859	27,185	21,748	19,725
1898..	32,747	1,671	34,418	3,925	30,493	24,394	22,125
1899..	39,663	1,506	41,169	5,343	35,826	28,661	25,995
1900..	47,151	1,309	48,460	5,656	42,804	34,243	31,060
1901..	46,500	1,600	48,100	4,561	43,539	34,831	31,607
1902..	52,730	1,636	54,366	5,358	49,008	39,206	35,577
1903..	59,562	1,743	61,305	7,215	54,090	43,272	39,267
1904..	59,613	1,293	60,906	8,157	52,749	42,199	38,293
1905..	65,403	1,718	67,121	11,280	55,841	44,673	40,538
1906..	77,800	2,100	79,900	15,578	64,322	....	....
1907..	85,390	2,656	88,046	13,256	74,790	....	....

Previous to 1886 the only available statistics of American imports and exports of zinc white are for fiscal years ending June 30, which are of course useless for comparison with the production reported for calendar years.

The imports entered in the above table represent only dry zinc oxide, besides which a small quantity of zinc oxide ground in oil is brought into the United States.

Previous to 1897 the exports reported above include zinc ores, corresponding to "oxide and ore" of the U. S. Bureau of Statistics enumeration. There was, however, but little ore exported before 1897, when large shipments from New Jersey first began to be made.

The imports of zinc white into the United States and the supply from 1885 to 1894 were as follows (in tons of 2000 lb.):

Year	1886	1887	1888	1889	1890	1891	1892	1893
Production	18,000	18,000	20,000	16,970	20,000	23,700	27,500	25,000
Imports	1,763	2,481	701	1,343	1,316	1,410	1,221	1,950
Supply	19,763	20,481	20,701	18,313	21,316	25,120	28,721	26,950

Production of Zinc Ore in the United States

There are no complete statistics of the production of zinc ore in the United States, but the output of the most important districts, namely, New Jersey and Kansas-Missouri, is reported satisfactorily, the former by the New Jersey Geological Survey and the latter by the local journals, the reports of which are summarized regularly by The Mineral Industry. The statistics of the production of those two districts are presented in the following table:

Production of Zinc Ore in the Most Important Districts of the United States

(In tons of 2000 and 2240 lb.)

Year	*a.* New Jersey	*b.* Kansas Missouri	Year	*a.* New Jersey	*b.* Kansas Missouri	Year	*a.* New Jersey	*b.* Kansas Missouri	Year	*a.* New Jersey	*b.* Kansas Missouri
1881	49,178	58,200	1888	46,377	102,350	1895	c	144,487	1902	209,386	262,545
1882	40,138	60,300	1889	56,154	106,750	1896	78,080	155,333	1903	279,419	234,873
1883	56,085	63,700	1890	49,618	122,850	1897	76,973	177,976	1904	250,025	267,240
1884	40,094	74,300	1891	76,032	145,550	1898	99,419	234,455	1905	323,062	252,435
1885	38,526	74,000	1892	77,298	154,800	1899	154,447	255,088	1906	361,330	280,062
1886	43,877	85,400	1893	55,852	139,770	1900	194,881	248,446	1907	329,205	286,589
1887	50,220	98,300	1894	59,382	147,310	1901	191,221	258,306	..	....	....

(*a*) tons of 2240 lb. (*b*) production of Joplin district only, tons of 2000 lb.; in addition to the production in the Joplin district there is a small output in southeastern Missouri.

The only statistics of zinc ore production in other parts of the United States, which are available, are very incomplete. According to The Mineral Industry, vol. II, the production of zinc ore in Virginia and Tennessee was 8420 tons in 1887, 11,500 in 1888, 12,906 in 1889, 14,969 in 1890, 20,287 in 1891, 20,295 in 1892, and 21,000 in 1893. According to recent volumes of The Mineral Industry there was a production of 3799 tons of blende in Tennessee in 1899, and 3968 in 1900. The production of zinc ore in Wisconsin, chiefly blende, was reported to have been 15,000 tons in 1900. Since 1898 there has been a large and increasing production of zinc ore in Colorado. The output of that State in 1900 was reported by H. A. Lee, State Commissioner of Mines, as having amounted to 77,984 tons of ore, averaging 42% Zn. That total undoubtedly includes, however, the ore that was consumed for the manufacture of zinc-lead pigment at Cañon City, Colo., and for the manufacture of zinc white at Mineral Point, Wis.

Exports of Zinc Ore from the United States

Year	Short Tons	Total Value	Value per Ton	Metric Tons
1897........	9,251	211,350	$22.85	8,391
1898........	11,782	299,870	25.54	10,686
1899........	28,221	725,944	25.72	25,602
1900........	42,062	1,133,570	26.95	38,150
1901........	44,146	1,167,684	26.45	40,040
1902........	55,733	1,449,104	26.00	50,550
1903........	39,411	987,000	25.04	35,746
1904........	35,911	905,782	25.22	32,571
1905........	30,946	848,451	27.41	28,068
1906........	27,720	733,300	26.45	25,142
1907........	20,351	579,490	28.47	18,462

There were occasional exports of zinc ore from the United States previous to 1897, but they were not reported separately in the official statistics. The quantity was not large in any year.

Statistics of Price

The chief markets of the world, wherein the prices which govern the zinc industry are established, are New York, St. Louis, London, and Breslau. The price made in London practically governs the industry in Europe, although the business in Upper Silesia is transacted on the basis of the price at Breslau; the latter generally preserves, however, a certain relation to the London price. In the United States the business is transacted chiefly on the basis of the price of spelter at St. Louis. The New York price corresponds with the St. Louis price, plus the difference in the cost of transportation to the two points. That difference is not merely the freight rate from St. Louis to New York, but is the variation between the rates from Kansas smelting points to New York and St. Louis respectively. The difference between the New York and St. Louis prices at present is $0.15 per 100 lb. The difference between the New York and St. Louis price varies consequently from time to time according to the freight rates, but for many years it has been quite steadily $0.15.

Although the importation of spelter into the United States from Europe is practically prohibited by the tariff of 1.5 c. per lb., and the American price of spelter is consequently to a considerable extent independent of the European price, there is nevertheless at many times an intimate relation between the prices of the two Continents, because of the ability of American producers to export zinc at a profit under certain conditions. The freight rate on spelter from Kansas smelting points to Liverpool ranges from $0.25 to $0.40 per 100 lb. (it has been as low as $0.22 per 100 lb.). Consequently, if at any time the price of spelter at London rises materially above the price at New York, the exportation of spelter from Kansas to Europe tends to reduce the European price to the American level, or vice versa to cause the American price to rise to the European level.

The average monthly price of spelter at New York and the average annual price at London and in the principal markets of Germany, for a long period of years, are give in the subjoined tables. The New York prices are as given in The Mineral Industry; the authorities for the English and German prices are stated in each case.

AVERAGE MONTHLY PRICE OF PRIME WESTERN SPELTER AT NEW YORK

(In cents per lb.)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1875.	6.56	6.46	6.35	6.75	7.20	7.20	7.30	7.175	7.175	7.275	7.275	7.275	7.00
1876.	7.50	7.625	7.685	7.80	7.875	7.625	7.185	7.125	6.96	6.685	6.495	6.435	7.25
1877.	6.375	6.56	6.435	3.31	6.125	5.995	5.745	5.85	5.81	5.80	5.745	5.625	6.03
1878.	5.625	5 435	5.435	5.125	4.81	4.435	4.625	4.685	4.81	4.66	4.625	4.31	4.88
1879.	4.375	4.51	4.495	4.50	4.375	4.245	4.56	5.21	5.81	6.185	6.06	6.125	5.036
1880.	6.185	6.56	6.625	6.31	5.81	5.31	4.935	5.06	4.935	4.935	4.775	4.70	5.51
1881.	5.06	5.185	4.935	4.935	5.935	4.875	4.875	5.06	5.215	5.31	5.685	5.935	5.243
1882.	5.875	5.685	5.495	5.375	5.435	5.31	5.245	5.31	5.245	5.245	4.995	4.685	5.325
1883.	4.56	4.56	4.685	4.675	4.625	4.495	4.40	4.35	4.45	4.40	4.385	4.36	4.495
1884.	4.285	4.325	4.50	4.575	4.525	4.455	4.50	4.57	4.56	4.475	4.35	4.125	4.443
1885.	4.31	4.275	4.21	4.21	4.175	4.05	4.25	4.50	4.56	4.56	4.525	4.525	4.345
1886.	4.40	4.455	4.55	4.55	4.50	4.375	4.35	4.35	4.325	4.275	4.275	4.425	4.40
1887.	4.55	4.55	4.475	4.45	4.55	4.55	4.575	4.55	4.50	4.525	4.775	5.40	4.625
1888.	5.425	5.35	5.10	4.85	4.65	4.55	4.55	4.75	4.975	5.05	4.90	4.875	4.91
1889.	5.00	4.95	4.75	4.675	4.75	4.975	5.10	5.20	5.175	5.10	5.20	5.40	5.023
1890.	5.41	5.28	5.187	5.085	5.35	5.575	5.55	5.275	5.06	6.012	6.122	6.106	5.55
1891.	5.55	5.025	5.125	5.00	4.85	5.083	5.063	5.01	4.958	5.02	4.83	4.75	5.02
1892.	4.69	4.62	4.89	4.68	4.79	4.71	4.78	4.69	4.53	4.41	4.47	4.40	4.63
1893.	4.39	4.33	4.28	4.38	4.41	4.27	4.13	3.89	3.69	3.68	3.65	3.80	4.075
1894.	3.56	3.85	3.89	3.62	3.47	3.40	3.43	3.38	3.44	3.45	3.36	3.43	3.52
1895.	3.28	3.20	3.23	3.30	3.50	3.65	3.75	4.15	4.30	4.10	3.55	3.49	3.63
1896.	3.75	4.03	4.20	4.09	3.98	4.10	3.97	3.76	3.60	3.72	3.99	4.14	3.94
1897.	3.91	4.02	4.12	4.13	4.21	4.21	4.32	4.26	4.18	4.17	4.03	3.89	4.12
1898.	3.96	4.04	4.25	4.26	4.27	4.77	4.66	4.58	4.67	4.98	5.29	5.10	4.57
1899.	5.34	6.28	6.31	6.67	6.88	5.98	5.82	5.65	5.50	5.32	4.64	4.66	5.75
1900.	4.65	4.64	4.60	4.71	4.53	4.29	4.28	4.17	4.11	4.15	4.29	4.25	4.39
1901.	4.13	4.01	3.91	3.98	4.04	3.99	3.95	3.99	4.08	4.23	4.29	4.31	4.08
1902.	4.27	4.15	4.28	4.37	4.47	4.96	5.27	5.44	5.49	5.38	5.18	4.78	4.84
1903.	4.87	5.04	5.35	5.55	5.63	5.70	5.66	5.73	5.69	5.51	5.39	4.73	5.40
1904.	4.863	4.916	5.057	5.219	5.031	4.760	4.873	4.866	5.046	5.181	5.513	5.872	5.100
1905.	6.190	6.139	6.067	5.817	5.434	5.190	5.396	5.706	5.887	6.087	6.145	6.522	5.882
1906.	6.487	6.075	6.209	6.087	5.997	6.096	6.006	6.027	6.216	6.222	6.375	6.593	6.198
1907.	6.732	6.814	6.837	6.685	6.441	6.419	6.072	5.701	5.236	5.430	4.925	4.254	5.962

The price of spelter has been subject to wide fluctuations, especially in the United States, where the range has been from 7.875 c. (the average for May, 1876) to 3.20 c. (the average for February, 1895).[1] The maximum price was attained at a time when the market was controlled by a combination of producers which was organized for the purpose of enhancing the value of spelter and was temporarily successful in doing so. The minimum price was quoted during the period of depression which followed the panic of 1893.

The decline in the price of spelter which began in 1874 and continued, with only two checks, until 1885 is attributable chiefly to the new supply of rich ore that in 1870 began to be offered in the form of blende. At about the same time the United States began to be an important producer of zinc, its importations from abroad dwindled down, and this outlet for European spelter gradually became closed. Simultaneously there was a heavy increase in the world's production. Up to 1870 the spelter product of Europe was derived almost exclusively from calamine. Blende had been mined and smelted in Belgium as early as 1845, but the output of that Kingdom never attained much magnitude. The Belgian production of calamine had been on the wane since 1856. In 1870 the Scharley and Marie mines, which had previously been the most important producers in Upper Silesia, came to the end of their resources, but in the same year the blende of the district began to be utilized, although its production did not assume large proportions until nearly 10 years later.

The abnormally high prices for spelter in the United States in 1875 and 1876 were to a large extent artificial, being due to the manipulations of a combination of the Western producers, which was formed in the spring of 1875. In April, 1876, it succeeded in raising the nominal price of spelter to 8 c., New York, but production had been stimulated, consumption restricted and stocks accumulated, so that in June, 1876, the combination was practically disrupted, this being followed by a rapid decline in the price. In 1879 and 1882 syndicates to control production and price were organized in Europe, but their efforts were of only temporary effect on the market, which continued to sag under the weight of the heavy production. During the decade 1881–1890 the exports of spelter from Europe to the United States again became of considerable importance, attaining a maximum of 11,411 short tons in 1882 (in which year the American production was 33,765 tons), but since 1887 foreign spelter has ceased to be of any consequence in the American market. In 1888 there was formed in Europe a combination of the French, German, and British producers to restrict production, which went into effect in 1889 and continued to the end of 1894. This was probably the best-sustained effort to regulate the price of spelter, but although it had a

[1] In February, 1895, spelter at one time touched 2.90 c. at St. Louis.

temporary influence on the market it could not prevent production by new concerns, who were led into the business by the attraction of high prices and large profits, and its ends were thus defeated.

Since 1890 the predominant features in the zinc market have been the sagging of prices under increasing production in the early part of the decade; the enormously increasing production in the United States and the beginning (in 1896) of large exports to Europe; the decrease in the cost of smelting in the United States because of the utilization of the natural gas resources of Kansas and improvements in the metallurgical practice; and the increase in the cost of smelting in Europe because of the rise in the value of coal, especially toward the end of the decade. There was a period of industrial depression in both Europe and America in 1893 to 1895; and a recovery, which culminated in a boom in 1899 and the early part of 1900; followed by a depression in Europe, which caused a great decline in the price of spelter there, and sympathetically a corresponding decline in the price in the United States, although the period of general industrial prosperity continued here, save for a temporary setback in 1901 and 1903. It will be observed, from the accompanying table how since 1890 the American price for spelter has preserved a rather constant relation to the European price, although spelter in Europe can no longer, under normal conditions, enter the American market. Beginning in 1905, and continuing up to the early part of 1907, there was another period of great industrial activity, creating increased demand for spelter, which again carried prices to a high level.

AVERAGE ANNUAL PRICE OF SPELTER IN NEW YORK AND LONDON, REDUCED TO CENTS PER POUND

Year	New York	London	Year	New York	London
1871........	....	4.008	1889	5.023	4.299
1872........	....	4.881	1890	5.550	5.048
1873........	....	5.691	1891	5.020	5.049
1874........	....	4.973	1892	4.630	4.527
1875........	7.000	5.232	1893	4.075	3.783
1876........	7.250	5.068	1894	3.520	3.359
1877........	6.030	4.333	1895	3.630	3.175
1878........	4.880	3.888	1896	3.940	3.608
1879........	5.036	3.609	1897	4.120	3.803
1880........	5.510	3.989	1898	4.570	4.443
1881........	5.243	3.538	1899	5.750	5.405
1882........	5.325	3.693	1900	4.390	4.407
1883........	4.495	3.329	1901	4.070	3.702
1884........	4.443	3.140	1902	4.840	4.321
1885........	4.345	3.043	1903	5.400	4.560
1886........	4.400	3.097	1904	5.100	4.913
1887........	4.625	3.302	1905	5.882	5.529
1888........	4.910	3.932	1906	6.198	5.869

AVERAGE MONTHLY PRICE OF ZINC BLENDE ORE AT JOPLIN, MO.

(Price per 2000 lb. of Ore in Producers' Bins)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	12 mos.
1896...........	$24.00	$23.50	$23.00	$23.00	$21.50	$21.00	$21.50	$21.00	$20.00	$20.50	$23.50	$25.50	$22.33
1897...........	22.125	21.50	21.00	21.125	21.60	21.875	22.50	22.50	22.625	22.75	23.50	24.25	22.28
1898...........	23.00	22.50	23.00	24.62	26.50	28.50	28.00	28.37	31.00	33.70	36.25	37.00	28.44
1899...........	32.25	43.37	43.40	51.50	50.50	45.50	44.20	45.00	43.75	43.50	35.00	36.00	38.54
1900...........	30.23	29.36	28.45	28.42	26.92	25.00	24.23	25.67	24.25	24.25	24.45	25.40	26.50
1901...........	23.73	23.96	23.70	24.58	24.38	24.22	24.68	23.88	22.82	21.63	26.15	28.24	24.21
1902...........	26.75	27.00	28.00	28.85	20.23	34.10	34.37	32.50	33.58	33.58	32.10	29.25	30.73
1903...........	34.50	32.50	35.75	37.75	36.60	36.50	36.00	36.00	34.40	34.40	30.75	30.00	34.44
1904...........	32.12	34.00	36.00	36.40	34.63	32.62	35.00	37.00	40.40	40.00	44.25	46.13	37.40
1905...........	51.94	53.65	47.40	43.93	43.74	40.75	43.00	50.24	46.80	49.37	50.37	47.67	47.40
1906...........	49.33	49.25	45.60	44.00	41.50	44.20	43.88	44.38	43.20	42.50	44.43	45.55	44.82
1907...........	46.90	48.30	49.75	49.25	46.90	47.00	46.80	44.56	41.00	41.75	38.60	31.50	44.36

The statistics of the above table are taken from various volumes of The Mineral Industry with the exception of those for 1900 and 1901, for which years the values reported by the U. S. Geological Survey have been adopted. The Mineral Industry and the U. S. Geological Survey agree as to the values for the years 1896–1899, both inclusive. There are no complete statistics available for the years previous to 1896. The Mineral Industry reports the following averages: 1889, $25; 1890, $23.90; 1891, $25.90; 1892, $22.50; 1893, $19.25; 1894, $17.10. The Mineral Industry made no quotation for 1895; Prof. Erasmus Haworth, State Geologist of Kansas, gives the average for that year as $19.68. In the earlier years the figures represent the value of the average grade of ore marketed. Since 1899 they represent the average value of ore assaying 60% zinc.

In the early part of the decade 1890–1900 the average grade of the ore produced in the district was probably between 56% and 58% Zn; certainly not more than 58%. About 1900 the average was probably very close to 60%, which is rated as the "standard" ore of the district. A good deal of ore assaying 62% to 63% Zn is produced, and occasionally lots assaying as high as 64.5%. During the last four or five years the average grade has been about 58% zinc, which is representative of the present production.

The zinc mining and smelting industry of the United States has experienced many consolidations, but nothing approaching the organization of a trust, although such has several times been attempted. The ownership of the producing mines is so widely scattered that anything like securing control of the ore supply has been out of the question, and that being the case it has been too easy a matter to build new and competing smelting works to make the purchase of the existing works, at the high prices demanded for many of them, a safe venture, which has been perceived even by the most reckless capitalists.

In 1896 many of the smelteries of Kansas and Missouri were consolidated by the Cherokee-Lanyon Spelter Co., but a new lot of works immediately sprang up, and in 1901 the competition of smelters in the gas field, into which the Cherokee-Lanyon company had been slow to enter, practically put the latter out of business after a brief, unsuccessful career, with a lot of worthless old works on its hands. In 1896 also was organized the New Jersey Zinc Co., which has elsewhere been referred to. This company is often called the "zinc trust," but it is not a trust, being simply a very big, very rich, and very successful corporation. However, it is a trust in so far as it controls the production of zinc oxide, which is done through technical experience and trade prestige, and in the Eastern market only by control of the ore supply. Also the New Jersey Zinc Co. has control of the production of high-grade spelter, a comparatively small business, which is also by possession of the sole ore supply. In 1899 another group of Kansas smelters was consolidated by the Lanyon Zinc Co., and in 1902 still another group was purchased by the Prime Western Spelter Co., a subsidiary of the New Jersey Zinc Co., but as fast as works were bought up others sprang up and the only result was to introduce these large companies into the business and to some extent effect concentrations of interest, which on the whole was probably to the general advantage of the zinc industry.

Previous to 1876 the domestic production of spelter was far from adequate to supply the demand. In that year the imports, both of spelter and sheet, dwindled into insignificance. In 1880–1883 there were again rather large imports, which were due to the offerings of European smelters at low prices. Since 1883 American smelters have had control of the home market, the importations having been of no particular consequence in any year. Since 1890 there has been a steady exportation of a small quantity of high-grade Virginia and New Jersey spelter. Early in the nineties the Western smelters also began to export their surplus metal at times of depression in the home market, and thus served back the Europeans precisely as they had formerly operated in the American market.

The position of zinc in the tariff laws has been as follows:

In the Act of May 2, 1792, lapis calaminaris — calamine — was put on the free list. It continued on the free list until the Act of Aug. 30, 1842, when through an oversight (probably) it was unenumerated and therefore fell under the "catch-all" clause which fixed a duty of 20% ad valorem. In the same Act, "teuteneque" (spelter) was specifically made free of duty, wherefore it could hardly have been intended to make calamine dutiable. However, in the Act of July 30, 1846, calamine, under that name, was made dutiable at 20% ad valorem, which was peculiar, inasmuch as in the same act the rate on spelter was only 5%. The Act of March 3, 1857, reduced the duty to 15%. The Act of March 2, 1861, put calamine on the free list, where it has remained in every subsequent tariff.

Nowhere in any tariff law is zinc ore mentioned except as calamine. For 100 years the matter was of no consequence. There were occasional small importations of calamine, but they were of utter insignificance. Then a hot contest arose over the position of zinc ore under the terms of the Dingley tariff. This originated with the importation of a considerable quantity of blende from British Columbia in 1902, which increased in following years. The purchasers entered this as silver ore, free of duty, or as lead ore, paying duty on the small lead content. In 1905 the smelters of Kansas began to make large imports of calamine from Mexico. The producers of zinc ore in Missouri becoming alarmed at this foreign competition sought to put a stop to it. They first induced the Treasury department to order that blende be assessed at 20% ad valorem, under the clause in the tariff, covering metallic mineral substances, not elsewhere specified, which was effectual in excluding the Canadian ore, and then secured another order defining calamine as hydrous silicate of zinc only, which would have excluded much of the Mexican ore, the latter being chiefly carbonate. At this the smelters entered a protest, the supply of Mexican ore being abundant and especially desirable. The outcome of the matter is well summed up in the following paragraphs from an editorial in the *Engineering and Mining Journal* of Feb. 16, 1907:

"In the matter of the protests of various smelters against an order fixing a duty on zinc ore a decision was made, February 5, by the Board of General Appraisers. By an order of the Secretary of the Treasury, Feb. 10, 1906, it was held that the term 'calamine' in the Dingley Tariff referred only to the hydrous silicate of zinc, and that sulphide and carbonate ores were dutiable at the rate of 20% ad valorem. The Board of General Appraisers has completely reversed the Treasury interpretation of the law, its conclusion being that the carbonates and silicates of zinc are included within the meaning of the term calamine, as used in the Dingley Act, and consequently are free of duty, while the sulphide of zinc is also free under paragraph 614 as a crude mineral not advanced in value by any process of manufacture, subject to the qualification that any lead contents of these ores are dutiable at the rate of 1.5 c. per lb., as prescribed in paragraph 181.

"The decision as to calamine was a foregone conclusion, inasmuch as anything different would have violated the accepted commercial and metallurgical practice of a century, as was done ignorantly in the Treasury order of Feb. 10, 1906. The fact that mineralogists had a more recent and more restricted meaning for this term, or rather some mineralogists, because among mineralogists there were confusion and difference over the matter, could not rationally be allowed to supersede the preëmption of the term by metallurgists, who had never abandoned it from their common usage or lost their understanding of it. The surprising thing is that the Government should have considered it had any ground for contest on this point.

"Commercially this is the more important part of the recent decision, inasmuch as the bulk of the importations heretofore have been of calamine, but the more remarkable part is that which relates to blende. It is to be admitted that when the Dingley Law was enacted no one thought that in a few years the United States would be importing zinc blende, and when such importations were begun there was ground for the belief that blende fell under the 'catch-all' paragraph, providing that 'metallic mineral substances' in a crude state, not elsewhere specified, should be dutiable at 20% ad valorem, as the Secretary of the Treasury ordered. Now the Board of General Appraisers, guided by a decision of the Circuit Court of Appeals in what is considered to be a parallel case, holds that the phrase, 'metallic mineral substances' applies only to that class of mineral substances in which metal appears in a free state, such as the ores of gold, silver, and copper. Inasmuch as the only ores of the above character which are of commercial importance are those of gold, silver, and copper, and they are specifically on the free list, this clause in the Dingley Act under the recent decision becomes meaningless."

The producers of zinc ore carried the case to the U. S. Circuit Court, which on April 22, 1908, upheld the decision of the Board of General Appraisers.

The first mention of metallic zinc is in the tariff act of April 27, 1816, wherein "zinc, teutenague or spelter" is admitted free of duty. It continued on the free list until the Act of July 30, 1846, when spelter was made dutiable at the rate of 5% ad valorem, and sheet zinc at 15%. The Act of March 3, 1857, reduced the duty on spelter to 4% and that on sheet zinc to 12%. Four years later, by the Act of March 2, 1861, the duty on spelter was fixed at 1 c. per lb. and that on sheet at 1.5 c. per lb. It is to be observed that this increase in the rate was practically coincident with the beginning of spelter production in the United States. In the Act of July 14, 1862, the rate on spelter was 1.25 c. per lb.; on sheet zinc, 2 c. per lb. The Act of June 30, 1864, further raised the rates to 1.5 c. and 2.25 c. respectively. These rates were reduced 10% by the Act of June 6, 1872, but the reduction was repealed in the Act of March 3, 1875. The rates of 1.5 c. on spelter and 2.25 c. on sheet zinc were continued in the Act of March 3, 1883, but in the McKinley tariff, Act of Oct. 1, 1890, they were raised to 1.75 c. and 2.5 c. per lb. respectively, and were then reduced to 1 c. and 1.25 c. respectively by the Act of Aug. 27, 1894. Finally, the Dingley Act, July 24, 1897, raised the rate on spelter to 1.5 c. and that on sheet zinc to 2 c. per lb.

In the zinc industry of the United States, the labor question has been destitute of striking features. The zinc mining and smelting districts have been remarkably free from strikes and disturbances. The only embarrassing factor in this particular has been the strikes in the coal mines of Kansas, which frequently cut off the fuel supply of the smelters and thereby checked spelter production and created market disturbances. The transfer of the smelting industry to the natural gas field eliminated this source of trouble. Both in the mining and smelting districts the conditions of living have been very favorable and the supply of labor has been abundant and comparatively cheap. For many years the average wage in the smelting works was about $2 per day, while miners in the Joplin district received $2 per day, and common labor all around was paid $1.50 per ten hours. Since 1903 the increased demand for labor has materially increased the rates of wages, both at mines and smelters, but particularly at the former.

As illustrative of the increase in wages in southwestern Missouri the following data from the records of the Granby Mining and Smelting Co., which I owe to the courtesy of Mr. Elias S. Gatch, are interesting. Previous to 1893 the wages paid to miners at Granby were $0.75 to $1.25 per day. From 1895 to 1898, they were $1.25 to $1.75. In 1899–1903 they had risen to $1.75 to $2; and in 1903–1906 to $2 to $2.50. The rate of wages at Granby is usually 25 to 50 c. per day lower than at Joplin.

INDEX